The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

POST OCCUPANCY EVALUATION OF HOMES IN THE UNITED KINGDOM TO DEVELOP AN AFFORDABLE P.O. METHODOLOGY FOR HOMES IN CHILE

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Abstract

A key objective of this research was to carry out a Post Occupancy Evaluation on a sustainable home recently built in the United Kingdom (UK) (code level 4, UK-CSH) through first person research in order to produce evidence that shows that the assessment process and the certification obtained are not enough to secure targets, given that the inclusion of occupants and its complexity have not been fully considered. Furthermore, the research reveals that the occupants of sustainable homes are not fully aware of the lifestyle implications of such homes.

The inhabitants' experience of living and the performance in the experimental sustainable home produced qualitative data that was integrated with the quantitative data generated and collected by several different tools to measure them. Among the tools the main one was the 48-sensors monitoring system installed in the house, the other tools were a tracking device system to analyse individual used of energy and room permanence, diary of home events, walk through, observations and photographs for architecture analysis, extended and short length questionnaires and face to face interviews were applied. The techniques to process and analyse the obtained data ranged from simple Excel spreadsheets to the use of software packages, such as SPSS (Statistical Package for the Social Sciences) and NVivo (for verbatim interviews). And, one of the main differences between this POE study and those usually undertaken is the fact that this was a first-person research.

'Hands on' experience makes it possible to identify, select and verify real and direct problems that affect the expected performance of a sustainable home. So, when the research process is re-applied to a similar condition, it facilitates the procedure and techniques, potentially avoiding the production of excessive data and over-sophisticated measuring systems and reducing the time taken to obtain robust results. This procedure should especially be applied to social housing which is industrialised and has similar specifications.

In the drive to make homes sustainable, energy efficiency measures are moving at a pace far in excess of the preparedness of home users and their culture. The results of this research provide evidence of the importance of this issue and the lesson learned from the first person research, as a tool for post occupancy evaluation, is that certain problems can easily be solved while others require more profound revision. Instead of just being a new home for exhibition purposes, demonstration homes present an opportunity for implementing a **First Home Occupant POE** procedure, especially on new massive sustainable "social housing" developments, as they can be built quickly and inhabited by any prospective tenant willing to contribute to sustainable living, before other new owners or tenants move in.

Publications to date resulting from this PhD thesis period

7-9/11/2012. PLEA 2012, Opportunities, Limits and Needs, Lima, Peru. “Energy Meters, Energy Matters. The Upton Homes Project.” Authors N. Hormazábal, M. Gillott, J. Jackson. For oral presentation.

2-3/09/2009. CISBAT 2009, Renewables in Changing Climate: From Nano to Urban Scale, Lausanne, Switzerland. “Occupancy Evaluation of Sustainable Energy Homes that are Targeting the UK Zero Carbon Era: The BASF House.” Authors N. Hormazábal, M. Gillott. For oral presentation.

21-24/06/2009. PLEA 2009, Architecture, Energy and the Human Perspective, Quebec, Canada. “The Effect of Technological User Control Systems on Occupants of Sustainable Energy Homes. The BASF house, Nottingham, UK”. Authors N. Hormazábal, M. Gillott, G. Revell. For poster presentation.

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During the course of this study, my love passed away.

I dedicate this thesis to my beloved husband Olivier R. Espinosa Aldunate, 1961-2010.

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Executive Summary

There is no doubt about the role the building sector plays in the emission of greenhouse gases, so its contribution towards mitigating climate change could be very significant and beneficial for all societies. For authorities is therefore crucial to cover three main aspects of this major issue: **policy measures** for which political determination and will are needed; **finance**, for which attractive and novel investment tools need to be created; and **training and education**, for which the awareness and knowledge of the general public have to be developed. Within this scenario, architects and academics could contribute particularly towards the third key factor; the proposal of this thesis is a step in that direction.

This study aided to identify through direct experience, as a first home occupant (FHO) of a sustainable home, some of the issues on occupied new sustainable homes and the need to study systematically homes in-use. For the author, 1. the experience of living in an UK Level 4 sustainable home, 2. to survey and interview other occupants of UK sustainable homes built under the Code for Sustainable Homes (CSH), and 3. to survey the general public perception on sustainable homes in the UK, which involved more than three years exclusively to try to understand and address the issue of sustainability in homes, provided the foundation to establish the need to work with people, from homebuilders to homeowners, from providers and end-users, from the whole chain of players related to the home industry.

A Proposal for the First Home Occupant FHO POE + The Chilean case as an application scenery

The performance of a sustainable home should fulfil expectations, it should reflect what the certification declares it to be; theory and practice should be very close, if not the same. Political and economic changes related to the energy performance of buildings are taking place at a very fast pace, which does not leave enough time for testing, learning from experience or educating the public. Throughout this study, major and minor discrepancies between the design of a residential development (a home) and the performance of that home once it is occupied and in-use have been recognised. Considering this fact, some new initiatives have been developed and proposed. In November 2010, Technology Strategy Board (TSB) launched the programme "Building Performance Evaluation, Domestic Buildings". This programme is very coherent with the approaches and work of other institutions, such as Zero Carbon Hub and the Energy Saving Trust. The focus of this programme was targeted at either of the two late phases in the home production line, when the home is handed to its occupant:

- Phase 1: Post construction and early occupation, or
- Phase 2: In-use and post occupancy

The FHO POE proposal acknowledges the unavoidable discrepancies between the predicted and actual performance of a home once it is occupied. It is therefore suggested as an addition to current and incipient feedback processes for new sustainable homes, with the main objective being:

- To close the loop within the feedback process for new sustainable homes, to have a holistic assessment process of which the end-users, the home occupants, can be part

The secondary objectives are:

- To reduce the high costs of POE processes and make them more accessible to each housing development.
- To promote environmental education and culture among the general public, using the bottom-up approach for education.
- To thoroughly evaluate the building process of new sustainable homes
- To learn from practice
- To count on a good bank of robust information for all the entities involved in the housing sector

The FHO POE includes all the accepted standards and can adopt any convenient monitoring protocols to determine the three typical aspects defined by Hamilton in 2010 in relationship to energy savings:

- The thermal performance of fabric after construction
- The performance of installations, all the devices and systems that use and generate energy
- The psycho-physiological experience of occupants, taking into account the facilities, comfort, control and convenience (TSB, 2010)

The main proposal of a First Home Occupant POE originated from this study is to add a new stage to the existing assessment process and certification for new homes to close the loop, considering that the recommendations to be developed and applied will differ between the UK and Chile, the author’s context. Thus, if a proposal like this is to be implemented, the author is more familiar with the Chilean context than in the UK, especially with regard to legislation and the possibilities of converting it into a stage of the process. In addition to this, the regulations related to energy performance in buildings in Chile are at a different stage and it is expected that in 2013, the first certification process for energy performance in homes will begin to be applied to new homes, initially on a voluntary basis. However, in both cases, there is a great opportunity for developing a proposal like this one, given that the housing industry is projected to continue producing homes in both countries for the coming decades and that the trend toward decarbonisation in homes is going in the same direction.

The First Home Occupant (FHO) Post Occupancy Evaluation (POE) proposal is based on transforming a fact into an opportunity for a new post occupancy evaluation, given that the majority of housing developments, both private and public, normally include a demonstration home for exhibition purposes and visits by prospective occupants. In the UK, the author had the opportunity to visit some of the demonstration homes in Upton, described in appendix 17. The Upton code required for the different contractors to make a percentage of their developments into "demonstration homes". The RuralZED in Upton homes project, was a demonstration project by the Metropolitan Housing Partnership (MHP), to show homes complying with Level 6 of the Code for Sustainable Homes (CSH). One of these homes was fully implemented with a monitoring system to be tested, measured and evaluated in regard to energy performance; the study has not taken place yet (2012), however this idea of considering some homes to be demonstrative of good practice in sustainable home design seems to the author as an opportunity for the application of a PHO POE. As in RuralZED the monitoring system can be installed in the last stage of construction and that home with its prospective occupants could be part of a real life in use home study. In Chile, demonstration homes, known as 'pilotos', are more common in private home developments. When it comes to social housing, homes are allocated more than a year before they are occupied and future families begin visiting their future homes when they wish, as long as it is safe for them, while the construction process is taking place. This process favours neighbourhood organisations.

The legislative framework regarding building performance is currently at different stages of development in different countries. In Chile, the process of improving standards in homes began just fifteen years ago and these improvements were focussed on improving thermal performance and energy efficiency in building construction, putting the emphasis on new homes. In 1996, the Ministry of Housing (MINVU) along with the Building Construction Institute (Instituto de la Construcción, IC), a not-for-profit organisation, along with other government institutions and NGOs started the new code to improve the U-Value of roofs, determining specific U-Values for the 7 different climate zones of Chile. In 2001, Article 4.1.10 was added to the Building Code, whereby all new residential buildings were required to comply with these standards. Later on, in 2007, the requirements for the rest of the building envelope were decreed and made a requirement. It was planned that in 2009, a compulsory certification process would begin, where the requirements started with a minimum standard based on the Chilean climates, as well as international codes. Only recently has the certification package been adapted and fine-tuned ready to begin application in 2013. It was conceived based on and adapted from the Spanish assessment standard. The main objective was to have it as a decision tool for the housing industry. It establishes maximum values for energy demand based on reference cases that complied with the Chilean Building Code, Article 4.1.10. The Housing Ministry provided a dynamic simulation package called CCTE_CL v.2, which allows home energy demand to be calculated and compared to the reference building. The result of a study led into a more simplified package by the addition of a static calculation plus the provision of an Energy Certification Manual and a procedure guide specifically designed for new homes. During 2012, several training sessions were offered prepare people to become the first Energy Assessors for New Homes (Calificadores Energéticos de Viviendas Nuevas).

Besides the local certification package, it is important to mention that LEED has developed many local institutions in Latin America, which offer courses and training workshops to individuals so they can become LEED-certified, LEED is very influential in many developing and third world nations. The application of these standards is very expensive, especially for third world and developing nations and sometimes they do not necessarily respond to local circumstances and even less to the local culture. As an example of this, in Chile there is only one building which has been assessed in accordance with the PassivHaus standard, but none of these buildings has yet been awarded a “Platinum” label. These standards are far removed from the Chilean energy code (Reglamentación Térmica) and the prices are only affordable for big enterprises and international companies. Homes are not considered within certifications such PassivHaus or LEED.

The First Home Occupant (FHO) Post Occupancy Evaluation (POE) has to be further developed and adapted to the context where it is to be applied. For the Chilean case, this is particularly a good moment, since many of the new improvements have been taking place recently and many additions will follow. The image in figure 1 shows the model for this proposal, in which the main product is the development of a package for **FHO POE**.

Figure 1 Proposal Model for a First Home Occupant Post Occupancy Evaluation (FHO POE) The legislative aspect of the FHO POE

It is proposed to begin by adding a new part or article to the current legislation, whereby the assessment process includes the new requirements for evaluating a home after the first resident has occupied it. This requirement is proposed as part of the whole home delivery procedure; so house builders would have to consider it as part of the whole home building process. Construction companies would have to have specialised professionals, such as POE architects, POE surveyors and sociologists. To organise a POE, they would need to select the most typical home unit for the most typical family as the demonstration home. Key stakeholders among prospective residents would need to be selected and offered the possibility of being the FHO, receiving incentives and training, because these occupants would then become "home monitors". Any member of the family could be allowed to do this, subject to employment regulations, as this an educational opportunity starting at a family level and to be extended across a community, being a process that relies on the social educational model that uses the bottom-up approach. Beginning at home could be the seed for sowing cultural change regarding inhabiting a sustainable home and leading a more sustainable life.

The construction and demonstration period of the FHO POE

When the construction period begins, the FHO POE demonstration home requires to be built before the rest, which is normally done in housing projects in Chile to begin selling "in green" as it is called in Chile, this allow people from the public to visit and see "the piloto" of what could be their future home, in cases depending on the development, sometimes two different homes are showcasing, and normally some clients by this "pilotos", in privates developments especially. This demonstration home must be finished, furnished and fully implemented with a monitoring system to measure performance and it must be ready to be monitored for at least a month during the extreme seasons. The time for the FHO to be trained on site must be borne in mind. Along with the home monitor training period, the planning for the demonstration home visits needs to be developed taking account of family life and the numerical measurement periods. The home monitor must be prepared to periodically show his/her home as part of his/her job. This is particularly interesting in the context of Chilean social housing, because it is common amongst the occupants of new homes of this type for people to organise themselves ahead of time and to elect representatives. Indeed homes are often the basis for the community organisation's operations.

The monitoring period and its outcomes of the FHO POE

Based on an existing methodology, the Building Use Studies (BUS) provides a very appropriate method for adaptation to situations like the social housing development in Chile, given its open-ended format. Succinctly described in chapter three and based on the brief called "BUS Occupant Survey Method: Details for Licensees" written by Adrian Leaman, published by Usable Buildings, London and last updated in April 2009, this is clearly one of the most practical and cost-effective approaches for assessing buildings. It began life with the Office Environment Survey, a study of sick building syndrome carried out in the 1980s, was developed through the POE for offices in the 1990s until it evolved into the more recent versions of a quick, complete and complex approach to obtain professional-level feedback data on in use building performance assessed by analysing the responses by building occupants to the BUS questionnaires. There is a not BUS version for South America yet, the governmental policies in Chile in regard to energy efficiency in buildings are going through many changes that started in 2000, placing a good opportunity for know-how transfer.

After the FHO POE pilot experience

The essence of evaluation springs from the need to constantly retro feed, upgrade, learn from experience and make things better. Information and education are also key aspects in achieving sustainability in homes, so they need to be accessible to everybody within the built environment. Homes are fundamental in the lives of a great part of the population, so it is crucial to include people within the building process of housing. It is vital to make things simple for everybody - the implementation of new standards in a home cannot mean that it is more difficult for people to live in it.

> "I think they *(the government)* need trying to do something, push more literature, make us aware of it rather just sitting a device… so literature, information needs to pass out to us" (User 1, Upton Homes, 2010),

It seems that political interest is paramount – currently it is almost unthinkable that a government could not have an environmental agenda. It is convenient and fashionable for public and private institutions to wave the "green flag"; indeed it is even becoming profitable. A green building is perceived as more attractive and having added value. This could be seen as a positive symptom, given the synchronisation of many players in society pushing in the same direction. However the materialisation of this is full of contradictions. At a lecture in March 2010 in London, Bill Bordass spoke about the credibility gap:

> "we couldn't deliver low energy and carbon performance reliably in the 1990's. We are still finding it difficult" (Bordass, 2010)

Consistency between higher goals in regard to climate and energy savings is essential and one way of contributing towards this is education, by gaining participation from all levels of society. A proposal like the FHO POE could be adapted to existing home developments that need to be urgently refurbished to address the energy saving and consequent decarbonisation targets in the latest climate goals. And this FHO POE type is based on peer education. However, for the green agenda the situation should be looked at more carefully; if sustainable energy technologies (SET) is expensive for developed nations, the price is even higher for developing ones.

Chapter 1. Introduction

1.1. Buildings that make people sick

Concerning the health of building occupants, in 1984 the World Health Organization (WHO) Committee stated that more than 30% of new and rehabilitated buildings are “pathogens” and this causes discomfort to 10-30% of their occupants (Murphy, 2006). The Minister of Work and Social Affairs of Spain considers that a building is sick if at least 20% of its occupants suffer from discomfort as a result of poor air quality and indoor conditions. Those affected show symptoms such as headaches, migraines, respiratory problems, throat inflammation or ocular irritation, dry throats and dry and itchy eyes, stress and/or depression, provoked by diverse factors related to the performance and conditions of the specific space or types of technology of a building where they undertake their activity (MTASE, 1991).

It is well known that concern regarding the need to save energy in buildings has its origins in the petroleum crisis of the seventies, which, because of their greater energy-dependence, had a more direct effect on developed nations than on developing nations. At that time, almost 75% of the world’s energy was being consumed by people from developed nations, who represented a third of the world’s population (Pimentel, 1998, p 4). However, the percentage distribution between developed and developing nations is now rapidly inverting. So it was in the 1970s that energy efficiency began to be introduced in building initiatives and the first energy conservation legislation was seen. Architects, builders and professionals related to the built environment and building design, under the pressure of policies to reduce energy consumption while still maintaining interior air quality for users, opted for more hermetic solutions for buildings which depended much more on mechanical HVAC systems to acclimatise the interior environments. A collateral effect of this strategy is sick building syndrome (SBS), as defined by the WHO. Sick building syndrome is ascribed to a building when its occupants experience negative health effects or discomfort linked to the length of time they remain in the spaces of the building. In these cases, it is difficult to identify the actual, specific types and causes of the sickness; although such discomfort tends to disappear when the people affected leave the specific indoor spaces. In developed nations, SBS was more common in commercial buildings than residential ones. SBS studies appeared as the first assessment related to in-use building, where the Post Occupancy Evaluation (POE) became a crucial procedure in determining if the occupant’s wellbeing and health was or was not directly related to the building and its quality.

Figure 2 Building in Santiago, Chile with air conditioning systems added after construction (Author source, 2011)

The problems experienced by the occupants of commercial buildings are not exclusively due to their poor ventilation and airtight buildings, although this might also become a problem in residential use, given the changes in regulations regarding air leakage. Many buildings with other uses - residential, educational, leisure, sports etc. - provoke problems for people's comfort, health and productivity, which are not necessarily just derived from the interior air quality (IAQ). For example, a building with large glass façades (see photograph in figure 3), where solar amplification produces an elevated interior temperature, may require additional acclimatisation devices. Figures 2 and 3 show two buildings which have had individual HVAC systems added after construction and suffer from dazzle and pollution due to excessive lighting. Meanwhile old buildings tend to have inefficient or deficient thermal, acoustic and lighting control and many have deteriorating building materials. Another problem which can occur is when a building has equal façades in all orientations, as seen in figure 3, and other types of indoor pollution.

Figure 3 Building in Santiago, Chile, where all façades are treated the same way (Author source, 2011)

A research project on social housing in Chile in 2004 demonstrated that building pathologies, such as mould and indoor humidity, shown in figure 4 below, caused allergies and various respiratory illnesses in occupants. The problem was produced by the poor quality of the envelope and construction – non insulated brick walls and single pane windows (Colonelli et Al, 2004).

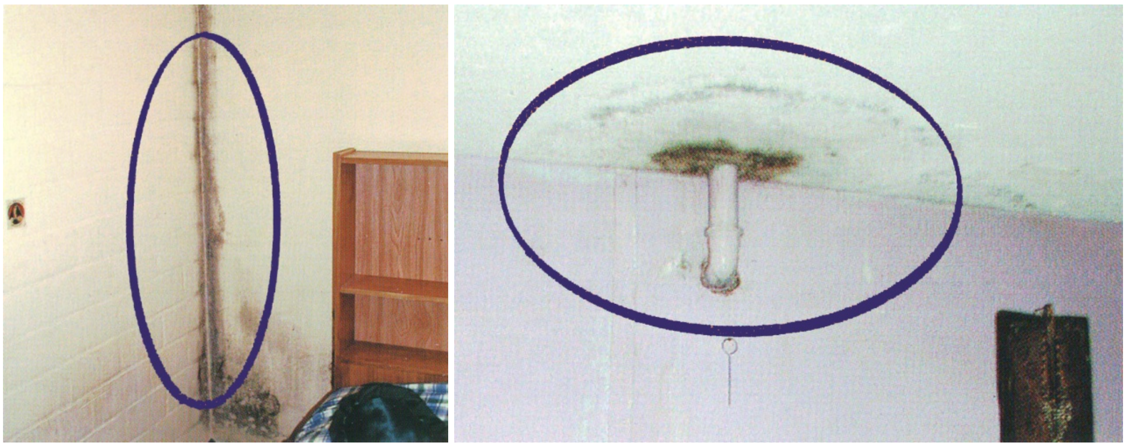


Figure 4 Two photographs from social homes in Central Chile, from year 2002, depicting indoor mould problems (Source: Colonelli et al, FONDEF D00I1039 Project – CONICYT, 2004)

In this way, the concept of a "building that makes people sick" becomes a more general and wider connotation than SBS; thus, it should be understood as a building that generates non-healthy conditions for developing indoor activities due to any combination of poor thermal, lighting and/or acoustic management within its design, poor air quality, the presence of bad odours, the abnormal deterioration of components and high energy consumption. These factors combined result in high operating costs for the building and inefficient use of energy, causing poor performance, discomfort for occupants and a general impoverishment of the quality of life of its inhabitants.

1.2. Sustainable homes and energy savings

The housing industry in a number of countries started to respond to environmental issues during the seventies in many different ways, not all of which contributed positively to the improvement of the current or predicted situation of our planet, namely global warming. Many governments however, are beginning to assume their responsibilities through regulations and agreements within and between nations in order to mitigate the disastrous predictions, which sometimes sound like prophecies (Steemers, 2003). The reality, however, is quite different for developed and developing countries, where the former are undoubtedly 20 to 30 years ahead of the latter. These differences reside in the energy consumption distribution and development rates among Organization for Economic Cooperation and Development (OECD) and non-OECD countries.

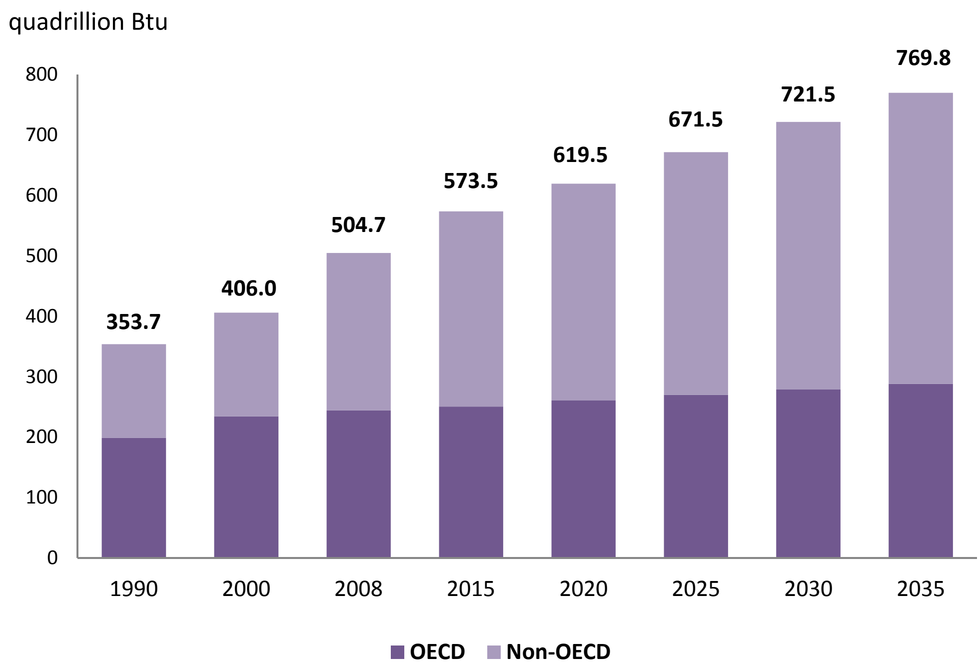


Figure 5 Energy consumption distribution from 1990 to 2035 among OECD and Non-OECD nations. Source: U.S. Energy Information Administration (EIA), (2011)

The world's energy consumption is growing quickly due to the rapidly developing economies of countries like China, India, Brazil and South Africa. As can be observed from the graph in figure 5, between 1990 and 2000, the increment was 15%, while from 2000 to 2008, it was around

25%. Where in the 1970s, OECD countries accounted for 75% of energy consumption and non-OECD countries 25%, this gap is closing and is now close to 50:50. By around 2035, it is projected that OECD countries will account for 37% of energy consumption and non-OECD countries for 63%. The relationship between energy consumption and population distribution is still very unbalanced; about two billion inhabitants in OECD countries together consume 50% of the world's energy while some five billion people share the other 50% (U.S. EIA, 2011).

As a result of the various initiatives to achieve the required energy efficiency in buildings, there are a vast number of new (and relatively new) good examples of sustainable affordable housing spread across many northern latitudes, mostly concentrated in developed nations. This provides a very good opportunity for the post occupancy evaluation (POE) of sustainable homes, because the only way to assess the many implementations is precisely through studying and evaluating them. A post occupancy evaluation is an assessment of the performance of a building after it becomes occupied. POEs have been carried out since the late sixties and today are becoming increasingly important to our understanding of occupants' behaviour in and satisfaction with sustainable homes. As the updating of codes and regulations continues, it seems that the assessment of human behaviour is a crucial procedure to develop in order to really achieve carbon emission reduction targets, while maintaining the balance between energy conservation and the comfort of the occupant.

Some of the many good reasons for carrying out POEs are:

- Validating the example and proving whether the hypotheses formed in regard to the performance of sustainable housing are true or false.
- Learning from them and sharing the findings in order to adopt their principles.
- Using them as examples of good practice and promoting them with evidence.
- Developing more efficient and appropriate types of technology.
- Contributing to the development of policies and regulations.
- Obtaining information and data.
- Promoting sustainable lifestyles among the public.
- Promoting proactive behaviour by the occupants of a home by revealing in a more transparent way how technology is contributing towards achieving sustainability in housing.

Taking into account this last point, incorporating this into the POE process is certainly a major challenge, since the information obtained will not be solely for researchers, housing authorities or the building industry but also for all type of occupants and home users, including families as a whole. In this way, the occupants themselves become an active part of the process addressing the issue of the lack of involvement on the homeowners' side. So, by involving and committing people through their own homes, their sensitivity towards environmental issues is also enhanced and those concerned become more informed about the issues (Stevenson, 2007). In this way the well-worn catchphrase "think globally, act locally" from the Rio Earth Summit in 1992, Agenda 21 (UNCED, 1992), is still very valid to encourage people to cut down their individual carbon emissions. An easy-to-apply evaluation of performance can help with finding out and understanding the needs and uses of sustainable homes. Whether these homes are new or refurbished, it is clearly important to the process of environmental learning to understand why certain technical features have been chosen and implemented in the way they have. For instance, what do they do, how do they work, and how should occupants operate them? In other words, a clearer and more direct communication between the home and its occupant needs to be achieved (Roaf, 2005).

Another good reason for "learning from our buildings" is that we maintain a direct relationship with the residential building industry. There is a tendency, particularly in the residential sector, for builders, architects and developers to not learn enough from the buildings they design and build and this is quite true for housing. Once a residential unit has been sold and has passed its warranty period, it is completely forgotten by the producer, who soon moves on to the next proposal, repeating a similar design pattern, following the regulations and market demand, but not really learning from the projects that went before (Bordass, 2007). In fact, most buildings never receive formal, continuous assessment after the users move in.

The central intention of this applied research resides in finding out the experience of the occupants of the places where they live, specifically in the case of sustainable homes. There is a vast bibliography of preceding studies around this problem - at least 40 years of examples of POEs. During the last two decades, POEs have concentrated on commercial use, because, as commercial organizations are focussed on maximising productivity, they regard the promotion of healthy and comfortable workplaces as a good investment. For the same reason, in many developed countries, POEs have also been applied to government buildings or hospitals, where the requirements are very specific. Domestic POEs have recently been re-launched. It appears that this area has been neglected mostly because of the private and particular nature of homes; whereby each owner/resident deals with their property as they wish.

1.3. Legislation in developed nations at a glance

Codes, assessments and certification of the energy efficiency of a building became ways of promoting the efficient use of energy, in response to the rapidly rising rate of consumption. When the petroleum crisis of the seventies struck, the European Union declared that the residential and tertiary sectors were responsible for 40% of total energy consumption and the majority of this energy, 25.4% corresponded to the residential sector[1].

Taking into consideration the energy crisis, many EU countries and the United States launched “incentive programmes” to reduce energy consumption. These programmes are the origins of the norms and standards designed to promote energy efficiency in many parts of the world; one of the first building codes to include energy efficiency requirements, specifically relating to fuel conservation and power provisions for dwellings was the UK in 1972, with the addition of Part F to the Building Regulation. Later, in 1985, the Guidance on Approval Document L was added including a complying incipient methodology (Figure 7). One of the first standards to include the issue was the ASHRAE. Based on Standard 90-1, ASHRAE produced Standard 90-75, Energy conservation in new building design from the United States, which was published in 1975 (Figure 6). Then, in 1978, the German regulation “EnEV” which included the energy consumption aspect of buildings (Figure 9) and Title 24, Part 6, from California's Energy Efficiency Standards for Residential and Non-residential Buildings was added to the Uniform Building Code (UBC) and the California Code of Regulations was created (Figure 9). During the late seventies, many other developed nations made energy conservation additions to their codes. Meanwhile the first legislation to appear in Latin American building regulations was in Chile in 2000 (Figure 10). This was based on the standards included in various Chilean norms related to energy conservation, calculations and materials, NCh 1079, 1977, architecture and construction, climate zones for housing in Chile and recommendations for design; NCh 1960, 1989, Insulation and the global volumetric (GV value) coefficient to calculate the energy transfer and NCh 853, 1991, thermal performance, building envelope, U and R values calculations. In countries like Argentina, Brazil and Mexico there are now many initiatives, and several institutions are working towards sustainability in buildings. However, by 2012 there

[1] http://epp.eurostat.ec.europa.eu/

had been no modifications or additions in energy conservation within their building regulations (Evans, 2012).

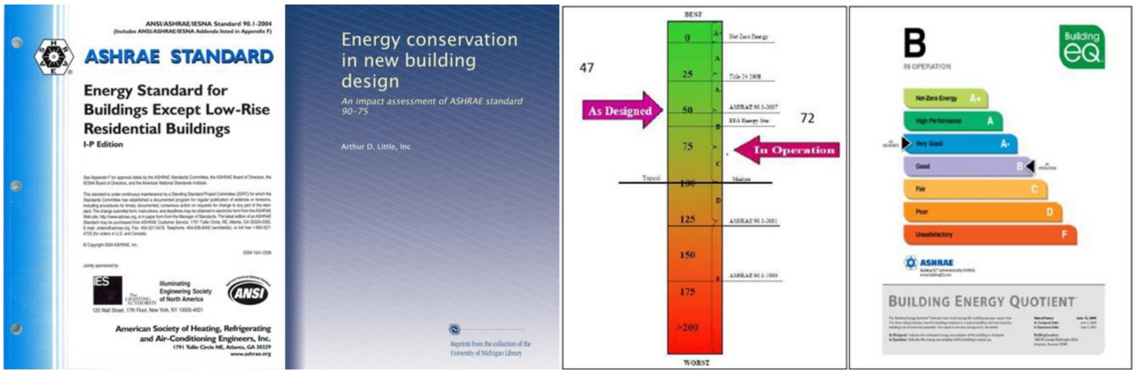


Figure 6 From left to right. A typical ASHRAE Standard, 90-1, 2004, ASHRAE Standard 90-75, Energy conservation in new building design and the ASHRAE labelling system, a "Building Energy Quotient, EQ".

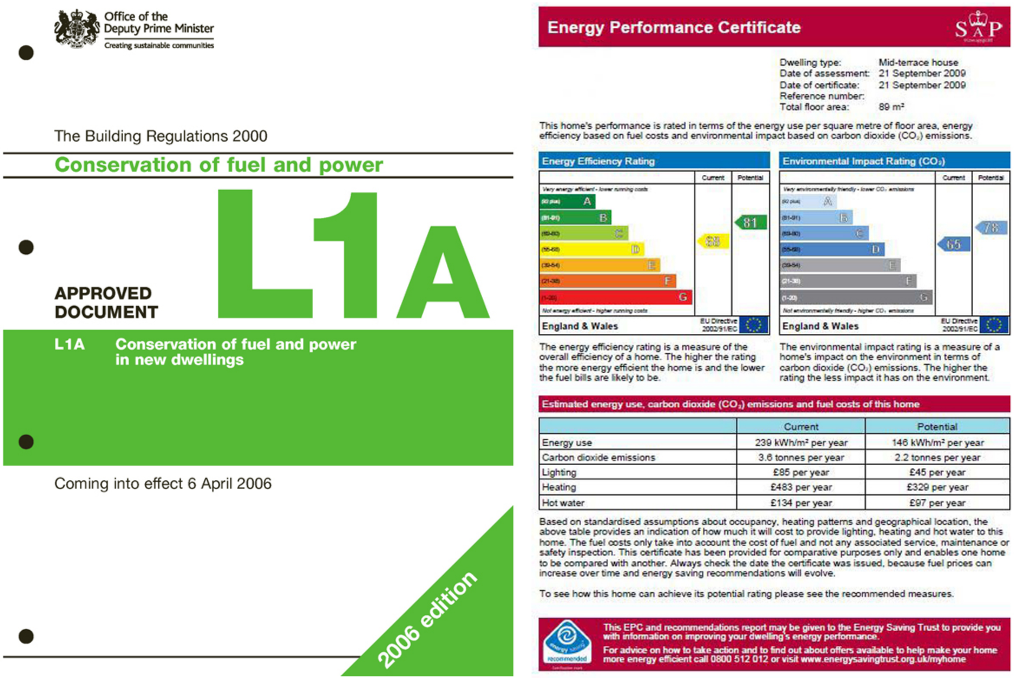


Figure 7 Left, image of the cover of Part L1A, Conservation of fuel and power in new dwellings, The UK building Regulations, 2006 edition. Right, an example of an Energy Performance Certificate, which is obtained after the application of the Standard Assessment Procedure (SAP).

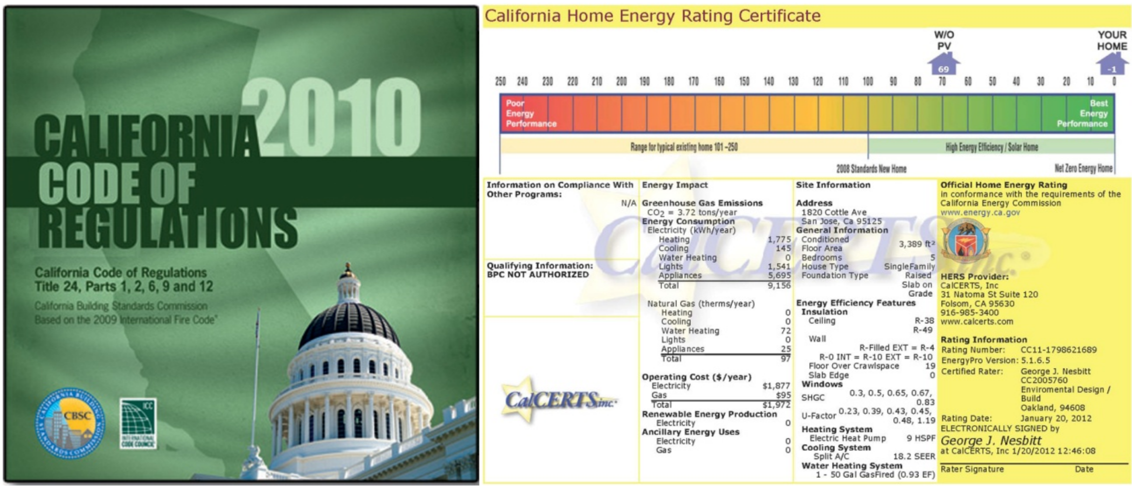


Figure 8 Left, image of the CD cover of the California Uniform Building Code, 2010 including Title 24 with its new parts. Right, an example of the California Home Energy Rating Certificate.

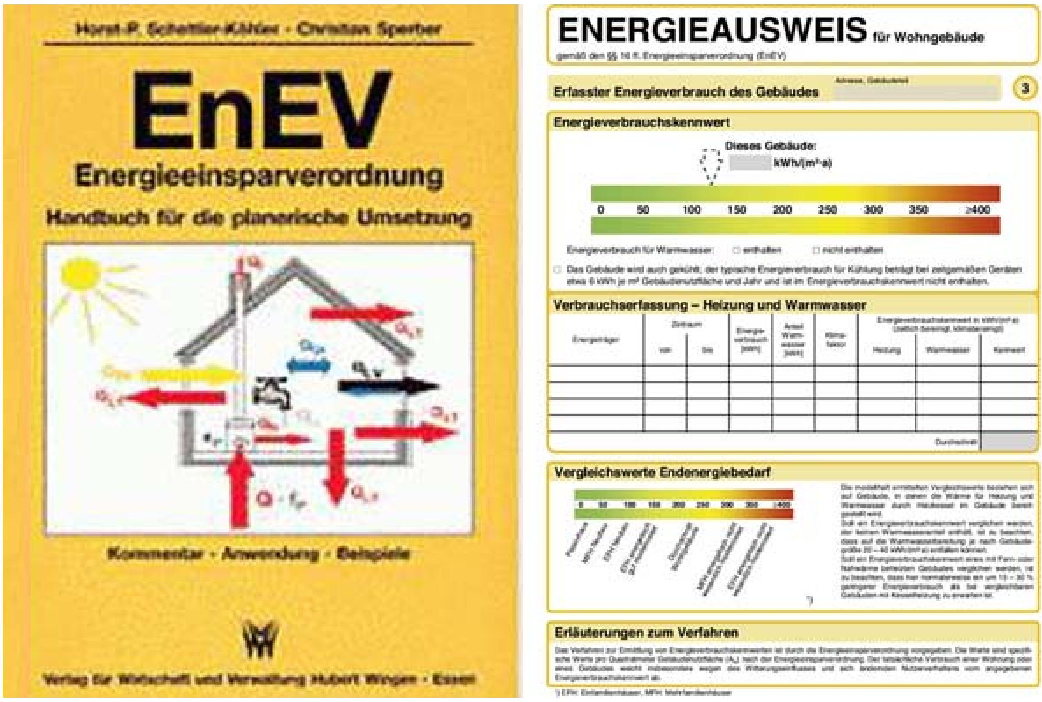


Figure 9 Left, image of the cover of the 'EnEv 2009' Energy Conservation Regulations for Buildings in Germany (Energieeinsparverordnung). Right, an example of the German Energy Certificate.

Figure 10 Left, image of the cover of the 'O.G.U.C.' The Chilean Building Regulations (Ordenanza General de Urbanismo y Cosntrucciones). Right, image of the cover of the Thermal Regulation for Housing, OGUC, Article 4.1.10, 2000.

Ten years ago, in 2002, the Directive 2002/91/EC of the European Parliament and of the Council on the Energy Performance of Building (EPB) set up some obligatory measures for the European Union. Acknowledging that the residential sector accounts for about a quarter of final energy consumption, it therefore dictated that each of its members was to comply with the Kyoto Protocol for reducing CO2 emissions. This was implemented in a series of stages: on 04/01/2006, the methodology, requirements and legal, regulative and administrative aspects were to be worked out, and on 04/01/2009 the certification of energy efficiency and the inspection of boilers and of air-conditioning systems began. For many Member States, this legislation has already been in place for some years.

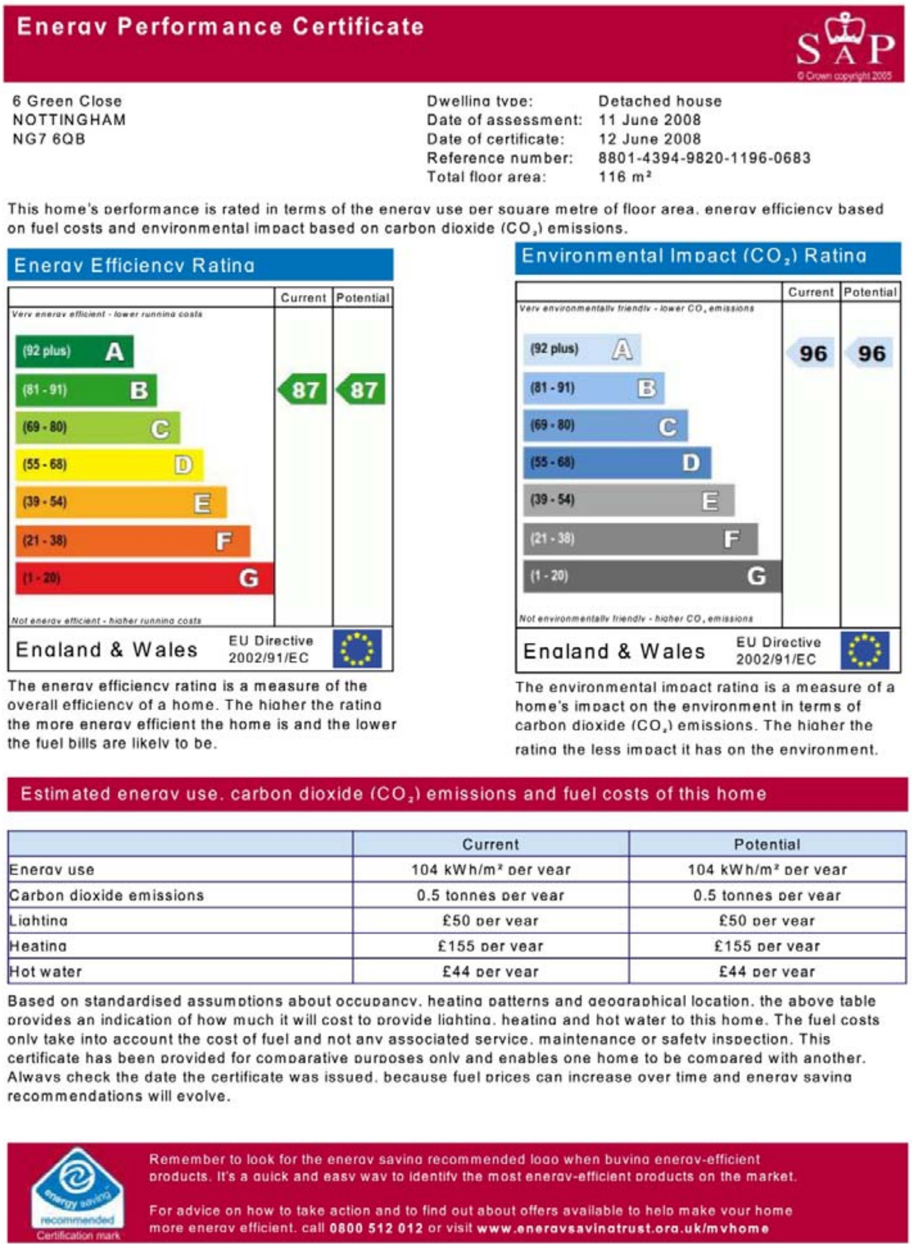
For Article 4, the most relevant requirements for energy performance are related to the typology of building, as well as differentiating between new or existing ones. Also these requirements should be reviewed at regular intervals of less than five years. Article 7 (Energy Performance Certificate – EPC (figure 11), states that:

> "Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years." [2]

Also the EPC should include:

"The reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance."[2]

The EPC should also present the predictions/simulations of the indoor climate, including the temperatures. It should include any other relevant climatic factor.


Energy Performance Certificate

6 Green Close
NOTTINGHAM
NG7 6QB

Dwelling type: Detached house
Date of assessment: 11 June 2008
Date of certificate: 12 June 2008
Reference number: 8801-4394-9820-1196-0683
Total floor area: 116 m²

This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills are likely to be.

The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy use	104 kWh/m² per year	104 kWh/m² per year
Carbon dioxide emissions	0.5 tonnes per year	0.5 tonnes per year
Lighting	£50 per year	£50 per year
Heating	£155 per year	£155 per year
Hot water	£44 per year	£44 per year

Based on standardised assumptions about occupancy, heating patterns and geographical location, the above table provides an indication of how much it will cost to provide lighting, heating and hot water to this home. The fuel costs only take into account the cost of fuel and not any associated service, maintenance or safety inspection. This certificate has been provided for comparative purposes only and enables one home to be compared with another. Always check the date the certificate was issued, because fuel prices can increase over time and energy saving recommendations will evolve.

Remember to look for the energy saving recommended logo when buying energy-efficient products. It's a quick and easy way to identify the most energy-efficient products on the market.

For advice on how to take action and to find out about offers available to help make your home more energy efficient, call **0800 512 012** or visit **www.energysavingtrust.org.uk/myhome**

Figure 11 Image of page 1 of 5, of the EPC obtained after the SAP calculation for the BASF House, also included in appendix 16

The importance of the above reference from the Directive resides in the implications it triggered for the Member States. The different countries responded at different times with modifications and further revisions to their own building regulations and codes, incorporating the energy performance certification. Among the European countries, Germany was the first to respond following the petroleum crisis. Today many of the Member States have implemented certification procedures after incorporating the changes to their codes. The cases of the UK and Germany are very interesting because both combined energy conservation in their regulations, with the incorporation of certification within their codes.

As the different regulations underwent modifications and additions were made related to the energy performance of buildings all over the world, today's certification process is the one that mandates most of the procedures towards energy efficiency and the expected carbon reduction in buildings. Many first-world countries today have quite elaborate assessment procedures to certify energy efficiency in new buildings. Their procurement packages have also been modified and improved over time. They have become a marketable service for new clients like developing nations. One of the ways in which this has been done is by convincing local governments to implement a certification process through their housing authorities; for example Chile is adapting the Spanish certification process. There are two main methodologies for the assessment processes. One of the oldest certification processes was established in Germany and was designed prior to the European Directive 2002/91/EC. Germany's energy efficiency building code, the Energieeinsparverordnung (EnEV) (Energy Conservation Regulations), is one of the most stringent codes in the world. The EnEv sets standards for insulation, fenestration, the building envelope and HVAC. The code was originally passed in 2002 and meets the requirements for the EU EPBD"[2]. This code produces two types of certificates; both consider the kWh/m² per year, equivalent to CO2 emission reductions. One is for new buildings and based on energy demand and the other one is for existing buildings, based on consumption, in which case an analysis of monthly bills needs to be taken into consideration. This implies POE and regular control.

The other methodology calculates CO2 emissions based on estimated annual energy consumption. For example, through its Standard Assessment Procedure (SAP) Calculations, the UK system determines the energy efficiency (cost of energy index) and the Carbon Index (impact on the environment index) of a new dwelling (see figure 11, the EPC for the BASF House), giving different levels which were added in 2007 to the Code for Sustainable Homes. Homes are categorised at six levels, which are subject to a defined percentage of the CO2

[2] http://bcap-ocean.org/code-information/germany-energy-conservation-regulations-buildings-enev-2009

reduction. From 2010, it became mandatory for all new housing to be Level 3 – i.e. subject to a reduction in CO2 of 25%; by 2014, they have to be Level 4 – and achieve a 44% CO2 reduction, and by 2016, all new homes have to be carbon neutral - Level 6. Both the Spanish assessment and the UK package calculate the procurement procedure based on the percentage reduction in carbon dioxide emissions per year and the estimated annual energy consumption of a proposed or finished building based on a reference building or base case (considering its geometry, building materials and orientation). They give a qualification of 1 - the building emits the same as the reference building; or 0 - the building does not emit and is therefore carbon-neutral. Currently the Spanish housing authorities are working on a more simplified way of calculating the assessments.

1.4. Energy efficiency in buildings in academic research

Parallel to the efforts and actions discussed above, energy efficiency in buildings is a latent research issue which has been taken up by many universities around the world over the last four decades or even longer. Research grants, educational programmes and many other joint efforts among the building industry, governmental institutions, and regional and local authorities in collaboration with universities have occurred in many places. The results from several works of academic applied research have been able to influence environmental policies, create new materials, develop and innovate greater efficiency among mechanical systems and so on.

Examples like the Energy Conservation in Buildings and Community Systems (ECBCS) of the International Energy Agency (IEA), Annex 53[3] in collaboration with universities and agencies from another 25 countries, are quite synchronised with Directive 2010/31/EU. For instance the mission of IEA-ECBCS, Annex 53 states that

> "The IEA (International Energy Agency) Energy Conservation in Buildings and Community Systems Programme carries out research and development (R&D) activities toward near-zero energy and carbon emissions in the built environment.[4]

Their research and development focuses on finding the best ways to integrate aspects of energy efficient and sustainable energy technologies, with the objective of designing healthy buildings and communities. They identify six factors as the most influential in building energy

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3 Annex 53 by Professor Hiroshi Yoshiro, from Tohoku University in Japan

4 http://www.ecbcs.org/annexes/annex53.htm

use, as listed and represented in figure 12. These factors are basically the same for most of the institutions involved:

1. Climate and site
2. Building envelope and form
3. Building services and energy systems
4. Building operation and maintenance
5. Occupants' activities and behaviour
6. Indoor environmental quality provided[5].

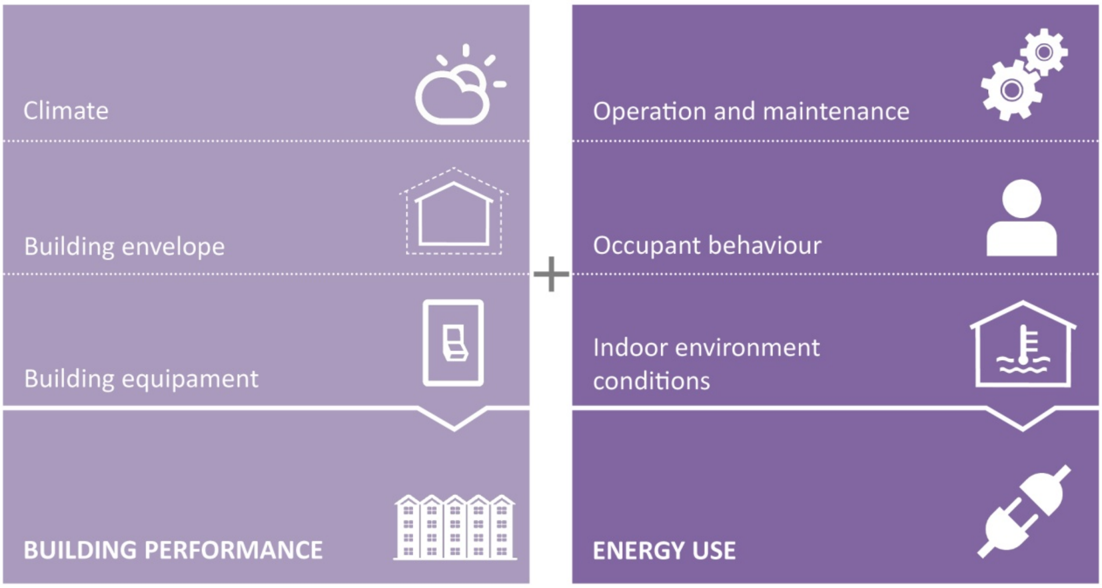

Figure 12 Graphical representation of the six factors identified by Annex 53 influencing "building performance" and "energy use" when evaluating energy efficiency in buildings

The last three factors related to human behaviour are undeniably identified as crucial in energy consumption results. The different ways of measuring and controlling them, especially for the housing industry, pose an ongoing challenge in regard to research methods and possible solutions to the problem. In the above section, the results of one of the IEA-ECBCS, Annex 53 research projects carried out in Beijing, China, were described. In addition, for the Creative Energy Homes (CEH) project, a similar situation was also identified among two social housing projects built to Level 4 of the UK Code for Sustainable Homes (CSH), which were identical in regard to specifications and family profiles. The bills for winter 2008 showed that one of the homes consumed three times more than the other.

5 http://www.ecbcs.org/docs/Annex_53_Factsheet.pdf

In March 2011, following a three-year study called “Homes of Our Times”, the Metropolitan Housing Partnership (MHP), supported by the Building and Social Housing Foundation, published a report detailing their somewhat expected findings. The research the MHP undertook focused on the impact of energy efficiency in new, retrofitted and existing homes. The MHP highlighted similar issues to the work of the IEA-ECBCS, Annex 53. The research question of this thesis is closely related to both studies. The Homes of Our Times research identified the alarming difference between the certified performances given to the design and the actual performance occupants really experience, showing that more than 50% of the households do not have any awareness of the sustainable energy technologies incorporated into their homes. Another important problem that was revealed was that of communication, where the transfer of information to occupants about their sustainable energy homes and their features was not successful. Residents did not engage in, read up on or inform themselves about how to benefit from living in a sustainable home, despite the information being available in different forms. Therefore the financial savings objective for the occupants as a result of their supposed lower energy consumption, that would also imply a reduction in their carbon emissions, was simply not reached. It was very disappointing for the MHP to discover that the Energy Performance Certificate (EPC) granted to their new homes did not have any meaning or visibility for occupants.

As a consequence, there are now several new initiatives to overcome these issues. New ways of communicating the important information about sustainable homes and their features are being developed, and the MPH has been working on a campaign called “Set it Right”. Also other UK institutions, both public and private, are going in the same direction to develop awareness and knowledge of how to experience new sustainable homes.

Therefore, the recent efforts being undertaken by different institutions and organisations to really attain energy efficiency in buildings and reduce the CO_2 emissions are very much on the right path and awareness of the problem is clear; however the solutions to it require ongoing exploration. It is a difficult task to predict, educate and control human behaviour in homes, and much more expertise and input from the social sciences is needed. It appears urgent to develop better tools and ways of educating people on energy efficiency and the consumption of energy (maintenance, operation, occupancy, etc.) The amount of initiatives, efforts and actions that are being implemented today to develop awareness among the British public about these issues is quite considerable. The next section will describe and discuss some of these efforts. One of these is the Soft Landing Framework, “for better briefing, design, handover and building performance in-use" (BSRIA BG, 2009). Developed in the UK, this is a good practice that began as a simple piece of first-person research.

1.5. Sustainable homes and the zero carbon era in the UK

During the nineties, residential energy demand in the UK kept increasing at a steady pace, as can be observed in figure 13, with only one major peak of about 560 TWh/year, until 2004, when it started to diminish at a slower pace of 2.5% per year until two new peaks occurred, one in 2008 of 540TWh/year and an estimated 560TWh/year for 2010. Both years were characterised by having extremely cold weather, which meant that homes required heating for longer periods each day (Boardman, 2012).

Boardman suggests that the increasing number of households explain the growth of total energy demand. Furthermore, the projected growth of the population and the changing nature of households mean an increase in the demand for homes, because families with fewer people per household are becoming more common and indeed it is not unusual to find many young professionals living by themselves. Boardman argues that the projection being used by the Environmental Change Institute that the number of properties will grow by 30% between 2008 and 2050 has been revised by the Committee on Climate Change (CCC), who in their 2010 Annual Report and Accounts suggest that the predicted 30% increment in housing will in fact happen by 2030. By 2030, the CCC proposes to cut UK greenhouse gas emissions by 60%, which will entail a complete reform of the UK electricity market, converting it to zero carbon, as well as an overhaul of the existing stock of poor envelope homes and the replacement of current cars for electric or plug-in hybrid ones. The ultimate goal is to legislate for the 80% cut by 2050 in the UK.

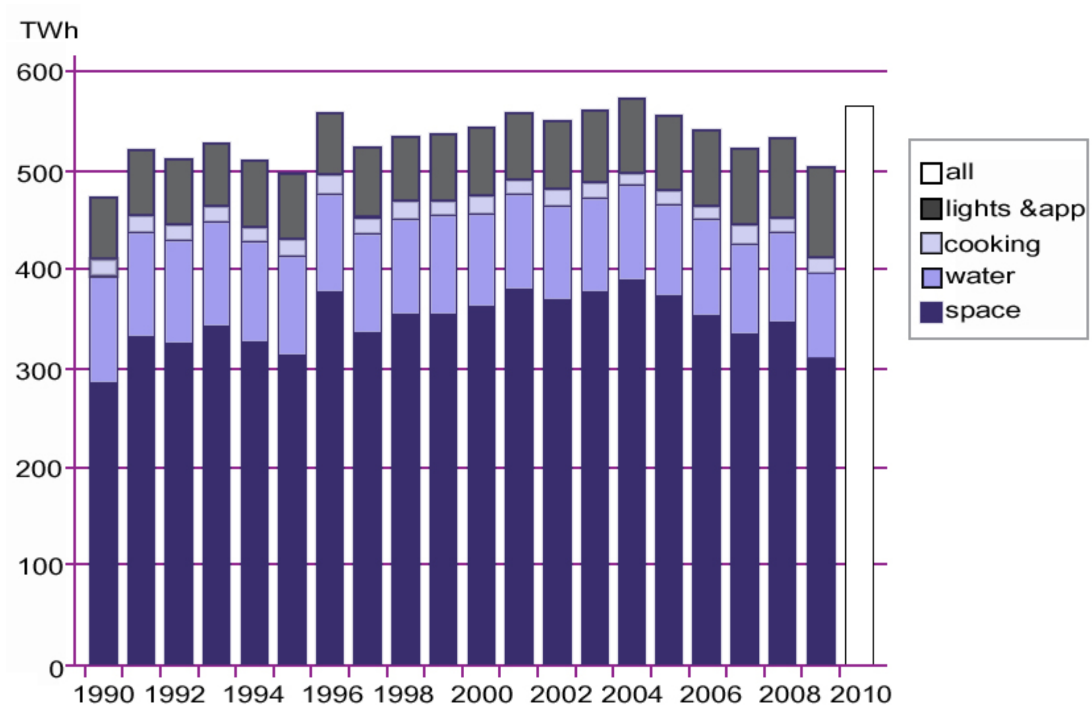

Figure 13 UK housing energy demand in TWh/year distributed by the different uses of a household, from 1990 to 2010 (Source: Boardman, 2012, p.4)

In 2003, the Environment Agency of the UK declared:

> “The construction industry plays a major role in improving the quality of the built environment, but it also impacts on the wider environment in a number of ways.” (EAUK, 2003).

The EAUK clearly states that in the UK, the agent causing 30% of industrial pollution events is the construction industry. Furthermore, 19% of the total waste generated in the UK is produced by the construction and demolition of structures. The fact that the majority of buildings in the UK today are still not energy efficient implies a misuse of limited resources such as water and energy.

> The energy used in constructing, occupying and operating buildings represents approximately 50% of greenhouse gas emissions in the UK.” (EAUK, 2003).

To reach better standards of energy efficiency in buildings it is required that the conservation and reduction of energy does not affect negatively the level of comfort for the user. The needs associated with energy in buildings are basically heating, cooling, lighting, heating water and cooking.

Therefore a building will be more energy efficient if it demands less energy to satisfy these needs in relationship to a reference. This can be achieved by improving the thermal quality of the envelope; utilising efficient systems for heating, lighting, food needs and hot water and/or adding the use of renewable energy systems, such as solar energy, to obtain hot water.

First of all a definition for 'zero carbon housing' needed to be stated in the light of the UK Agenda set for the coming years. The results of the consultation were published in July 2007 under the title "Building a Greener Future: policy statement". In this publication, the UK government's ambitious intentions for all new homes set out the following - the reduction of carbon emissions for residential use should be done progressively through the energy efficiency building regulations, setting the following targets with year deadlines:

- Year 2010 – 25% reduction (Level 3 in CSH)
- Year 2013 – 44% reduction (Level 4 in CSH)
- Year 2016 – 0 carbon emissions (Level 6 in CSH)

The most accepted definition of what the government means by 'zero carbon housing' or 'carbon neutral home' is related to the emissions produced *after* a house becomes occupied by the residents. It is measured through calculations, whereby predictions are made based on estimates which consider the physics of the building, its systems and the expected use. Thus, a zero carbon home implies that the amount of power a home needs to function with space heating, hot water, ventilation and lighting, the expected power usage from appliances and the inputs and outputs of energy from the housing scheme obtained from installations directly connected to centralised networks will result in net zero carbon emissions throughout the course of a whole year. This reduction can be achieved through appropriate design and the correct use of building materials for the latitude in which the home is going to be built. If energy demand cannot reach zero purely through the appropriate design and building materials, as may be the very likely in extreme climates in particular, the energy demand differential should be covered by the production of energy by other alternatives, such as the application of sustainable energy technologies (SET) which can transform renewable energy, such as solar radiation or wind, into power.

The governmental consultation of July 2007, which also defined 'zero carbon' for homes soon realised that it would be difficult to achieve those ambitious targets in the timescale set, while in opposition, the "Callcutt Review of Housebuilding delivery" that was published few months after, in November 2007, showed that the supply of new homes for 2016 will not be difficult due to the nature and structure of the UK housing industry, counting on its business model and supply chain, considering land, material and skills. The results of the review was symptomatic on the side of industry, nevertheless recommending that strategically the Government should insist on the measure while at the same time letting experience help develop a more precise definition of ‘zero carbon’ (Callcutt, 2007). Thus, by the end of 2008, the Government announced that the zero carbon requirements will also apply to all new non-domestic buildings from 2019. They also published a more clear definition of ‘zero carbon’ in the consultation “Definition of Zero Carbon Homes and Non-Domestic Buildings” in December 2008 (DCLG, 2008).

Nonetheless, at the beginning of 2011, the Task Group of the Zero Carbon Hub (ZCH) stated in its report for the UK government, “Carbon Compliance: What is the appropriate level for 2016?”, that the improvement proposed by the government through the CSH (Code for Sustainable Homes) which implies a 70% reduction in the 2006 level of carbon emissions from homes will not be “deliverable as a national minimum standard for all dwellings from 2016” (ZCH, 2011), because it will be derived by restricting the design of housing. It therefore proposed that the built performance emissions of new homes from 2016 should comply with, but not surpass, the following levels in regard to carbon emissions and these levels should be subjected to the home typology:

- 10 kg $CO_{2(eq)}$/m^2/year for detached homes, 60% approximately.
- 11 kg $CO_{2(eq)}$/m^2/year for other homes (semi-detached, terraced, etc.), 56% approximately.
- 14 kg $CO_{2(eq)}$/m^2/year for low-rise flat buildings, 44% approximately.

These limits will need to be reviewed and re-established when the preparations get underway to develop the assessment package for 2016 through the UK Standard Assessment Procedure (SAP) or a similar tool. The Task Group also suggested that the carbon compliance levels should be set as absolute amounts instead of percentage reductions in the carbon emissions calculated for previous standards. The “Carbon Compliance for Tomorrow’s New Homes Task Group” identifies a conceptual difference between current standards and those to come, since the recommendations they are following apply to ‘built’ performance instead of ‘designed’ performance, as is the case for 2006 regulations, although they do suggest an approximate percentage for each level of carbon emission reduction, as indicated above. Consequently, it could be expected that the targets established are not going to be met as they are too ambitious, and future adjustments to diminish the requirements are clearly already taking place.

1.6. The case studies, the BASF House and the Upton Homes

The BASF House, Nottingham

Figure 14 The BASF House on the main campus of the University of Nottingham.

The in-depth case study of this thesis, the BASF house, an experimental sustainable home built on the main campus of the University of Nottingham (figure 14) focuses on the study of the performance of this home during the winter periods of 2008-09 and 2009-10, taking the month of February for the first winter and from December to March for the second winter. February 2009 was the first full winter month with regular occupancy (three adults) in the home and reliable data for analysis were being logged; previously the monitoring system had required calibration. The monitoring and control system implemented in the house was a pioneer system, which required continuous testing and adjustment for at least a month to finally count on robust data. The quantitative data were obtained through the 48-sensor monitoring system for indoor climate and energy usage. In parallel the qualitative data, which will be presented in subsequent chapters, were obtained from questionnaires, verbatim interviews with occupants and the diary of events of the BASF House.

The Creative Energy Homes (CEH) Project of the Department of Architecture and the Built Environment, University of Nottingham (figure 15), is a research and educational showcase of six low or zero carbon houses. The BASF House, the first of the six homes built by the CEH Project, is an experimental energy home completed at the beginning of 2007. One of the most important features of this home is its thermal performance throughout the whole year to achieve comfortable occupancy and use energy efficiently. To realise these objectives the house relies on passive design features, construction materials and techniques appropriate for the latitude, and on low to zero carbon technologies. The house is projected to surpass Code Level 4 stated in the UK Code for Sustainable Homes (CSH). As the Energy Performance Certificate (EPC) indicates after the Standard Assessment Procedure (SAP) calculations confirmed through the simulations done with the software TAS, the energy use should not surpass 104 kWh/m².

Figure 15 The Creative Energy Homes on the main campus of the University of Nottingham.

Another assessment reference considered for the BASF House was the German PassivHaus standards for Europe, applying most of the design principles included in this package to potentially reach the requirement of the total energy demand for space heating and cooling of less than 15 kWh/m² per year for the treated floor area, which is proposed for buildings located within the latitudes 40º and 60º North. The other general features for building design typically required by the PassivHaus standards, which conceptually coincide with the CSH, include:

> "very good levels of insulation with minimal thermal bridges
> well thought-out utilization of solar and internal gains
> excellent level of airtightness
> good indoor air quality, provided by a whole house mechanical ventilation system with highly efficient heat recovery"[6]

The principle behind these specifications are that:

- "the heat load of the design is limited to the load that can be transported by the minimum required ventilation air".

In this way, a building that address these standards can reach comfort for users without needing a traditional heating or active cooling systems, therefore the needed heat is minimum and can rely on reduced nominal outputs for the devices in charge of space heating, hot water and ventilation, being all in one unit, counting on the many possibilities offered in the current market.

The Upton homes, Northampton

The real life case study comprised of 10 occupied homes of volunteer families from the Upton Homes project (Figure 16), a large-scale residential development located in Upton Meadows, Northampton. Since its beginnings the Upton homes project was a real remarkable one. It captures much media attention and much expectation for being one of the biggest urban "sustainable" development proposals for the time in the UK. Upton is part of the south-west district of Northampton, and is located also to the south-west of the city of Northampton. It has an area of 44 ha approximately and the Upton homes project built over 1,100 new homes on the area that was previously a green field site.

[6] PassivHaus Basic Principles (Resource: http://www.passivhaus.org.uk/)


Figure 16 The Upton homes project, a typical street.

A very remarkable milestone was the creation of the Upton Code, which first edition was published in spring on 2003, followed by a revised version in March 2005. These two versions of the Upton Code were the supplementary planning guidance for the Upton development. They included all the changes and additions that were occurring with the UK codes and Building Regulations, therefore when the Upton homes project started the construction, it was required to comply with CABE 2004 and the BREEAM standards with its three levels of approval (Ecohome, Ecohome Good and Ecohome Excellent), in 2004 the Upton homes project received the status of Ecohome Excellent. Later in 2006 the revised version of the UK code, the Code for Sustainable Homes (CSH) became the new requirements that the project needed to respond to, then the majority of the homes built in 2007 complied with the different levels of the CSH and the current legislation.

The volunteer families included in this study were obtained after a survey period previously done, 100 questionnaires were door-to-door distributed, 50 were completed and from those, 10 families responded they were willing to volunteer for this real-time energy monitor trial period. For the study it was preferred to have terraced houses instead of flats, nevertheless of the ten homes one was a flat. The specific energy and environmental requirements for these two sites are listed in the following table 1. For the 10 homes the Code for Sustainable Homes (CSH) was not mandatory, it was voluntary, five of the homes, out of the ten belonged to Metropolitan Housing Partnership and they were design to comply with CSH.

Table 1 Energy and environmental requirements established by Upton Design Code (UDC) prepared by EDAW

SITE	Nº UNIT	MANDATORY ACROSS WHOLE SITE	DEMONSTRATION PROJECTS/TECHNOLOGIES
B	3	BREEAM/EcoHomes Excellent National Home Energy Rating - NHER rating 10 Code for Sustainable Homes - CSH (2007 - voluntary) Northampton Design Code (NDC) Passive solar design Solar water heating Rainwater harvesting	Photovoltaic (PV) systems – min. 25 units Green roofs – min. 25 units
D1	7	BREEAM/EcoHomes Excellent NHER rating 10 CSH (2007 - voluntary) Northampton Design Code (NDC) ZED standards Passive solar design Solar water heating Insulation improvements High internal air quality	PV systems – min. 90 units Micro-combined heat and power (micro-CHP) – min. 60 units Rainwater harvesting – all freehold units without green roofs Green roofs (extensive) – min. 60 units

The expectations from the project were the capability to demonstrate how large-scale developments can incorporate best practice and sustainable principles of urban growth. It was also established that the design strategies contemplate conventional forms of housing to meet the expectations of homebuyers (EST, 2006) [7]. Other very important feature was that the project included a variety of ownerships depending on their socio-economical profiles, and the development should consider about a 22% of social and affordable housing; from the social perspective this feature is a very sensitive one, it prevents social segregation and it makes more inclusive and democratic communities.

The project contemplated different sizes of dwellings from 1 to 5 bedrooms, the heights of the project were also regulated depending on the area; from 2 to 2,5 storeys and 2,5 to 3,5 storeys, with maximum of 3 storeys. The density varied depending on four established character areas within the terrace aspect, going from low to high density; detached, semi detached, town, mews, flats and mix-use homes.

By October of 2007 244 homes were completed. In accordance with the project aspirations, in May 2009 "World Class Cities" published that Upton was one of the few case studies

[7] Creating a sustainable urban extension – a case study of Upton, Northampton. Energy Saving Trust, 2006 edition (need to be included in the bibliography)

constructed in the UK as an example of a successful application of sustainable urban extension principles, were Research and Development (RD) approaches brings up a tangible result. On the same year the Upton project received the 2009 Sustainable Development of the Year Award (projects under £2million) granted by the UK Green Building Council.

The master plan for the Upton project was expected to be built in eight years, it was divided on eight sites or developing areas (figure 17), most of them are completed, however during this study the project was still under construction (winter 2010). As the project continues its development, several housing developers and design firms have taken part of this sustainable urban expansion. For all the sites needed to comply with the energy and environmental requirements and regulations for new residential use. After 2007, all the new homes needed to comply with the Code for Sustainable Homes (CSH) voluntarily, except with the elements of the CSH that are included in Part L of the UK Building Regulations; some of them within the Upton project were designed to be Code Level 6.

Figure 17 Upton Masterplan by EDAW 2005. Source: Upton Design Code, Pp.75, English Partnership.

1.7. Research Questions and Hypothesis

Energy efficient considerations for achieving sustainable energy homes do not necessarily take into consideration the satisfaction and comfort of the occupants. They also typically require a great deal of effort and preparation by the occupant to achieve the performance expected. In spite of the best intentions and political concerns, the proponents of energy efficient and sustainable homes have neglected to determine if the conditions required to maintain and operate these homes are user-friendly and occupant-appropriate. Consequently, a gulf can arise between the success of sustainable energy homes and their occupants, leading to the following research questions and hypothesis:

- **Do energy efficient and sustainable homes provide the occupants with the comfort of a "standard" home and with equal ease of use?**
- **Can we actually live in sustainable energy homes?**
- **Does the inclusion of the sophisticated forms of renewable energy technology required to achieve energy efficient standards presume that the occupants have a certain level of education or that they have received adequate training in the specialised maintenance of the equipment?**

Hypothesis

The satisfaction of occupants is a key indicator of the success of energy efficiency innovations, developed in the framework of measures, strategies and legislation for achieving more sustainable homes; however current practice does not necessarily take into account environmental comfort and may even harm the occupants' psycho-physiological wellbeing.

This thesis seeks to uncover evidence that the post occupancy evaluation process should form part of a regular assessment procedure based on the reality and culture of the occupants of a domestic property, rather than this assessment being based purely on simulations and calculations of the building's performance. It does this by contrasting and comparing the results obtained from the application of qualitative techniques (textual) and quantitative tools (numerical), through the POE methodology. Therefore the proposal of this study is to set the groundwork for developing a **First Home Occupant POE** using a demonstration sustainable home in a new housing development to close the loop within the procurement process of sustainable homes.

For the case studies reviewed, which included experimental and real life cases, different measuring instruments, employing both quantitative and qualitative techniques, were applied to pursue the Post Occupancy Evaluation (POE). The POE considered indoor climate, the perception and behaviour of the occupants and in use home energy performance, allowing the results obtained through quantitative and qualitative data to be compared, combined and integrated. The main tools applied are listed below:

Continuous monitoring systems with remote access packages were installed in order to record house performance and indoor climate data at all times. A number of 48-sensors for indoor climate quality (focusing mostly on thermal aspects), water and energy consumption (power) measurements began logging data after occupants moved into the case study homes. This data was then formatted, processed and analysed through Excel data files and through the SPSS (Statistical Package for the Social Science) software.

Temporarily and experimentally, the application of a non-typical tool for POE studies was tested to understand the individual use of energy among occupants. A tracking device system was installed to understand the permanence of occupants in the different public spaces of the home (living room, dining room and kitchen). During a determined period of time, occupants agreed to use a tag while at home to track their use of devices and time of permanence within ground floor spaces. The tracking system allowed the drawing of a plan view with 3D boxes in each virtual zone related to the electrical devices and sockets located in each room. Every time an occupant entered, stayed and left, a zone was plotted. The results of this data were graphically represented on a plan view in which the density of thousand of dots indicated permanence and power usage by individuals.

Questionnaires are one of the most widely used tools as the basic part of the method to collect data from the occupants of buildings. This approach is one of the oldest and has been recognised by most POE authors as the most simple and cost effective. It is user-friendly and can be easily applied by surveyors and occupants to study in-use buildings. To add, complement, supplement and/or confirm results, face-to-face interviews and other tools, such the 'diary of home events' from occupants were utilised within the overall method applied to all the case studies involved in this thesis. BASF home occupants and visitors and Upton homes occupants were all subjected to at least couple of these tools. The data gathered from the questionnaires and ´diary of events' was formatted, processed and analysed through Excel data files and the SPSS (Statistical Package for the Social Science), while for the verbatim interviews the NVivo software was used. The database was then processed by a series of scripts to produce the results.

Field observation or walk through and architectural design analysis are typical tools for architects (such as the author) to understand buildings and the use and quality of spaces. These techniques were continuously utilised prior to and following occupancy to analyse predictions and expectations. Acute constant observation as a type of first person architectural research is extremely important in the study of buildings to learn, propose and test design recommendations and improvements. Most of the techniques can have a graphic representation and are based on computer aided design (CAD) software, schemes and photographs. Several of them were utilised in this thesis, as will be shown throughout.

The outcomes from the application of this combined methodology aided by these research tools and techniques have been integrated throughout the study. The analysis of thermal, lighting and ventilation parameters was crucial in understanding the psycho-physiological behaviour of the occupants of the sustainable energy homes. The analysis of the case studies primarily focused on the periods when the higher energy consumption occurred; i.e. wintertime in the UK.

The thesis became a collection of different types of data (numerical and textual), mainly recorded during winter periods (2009-2010), from occupied sustainable homes, where the different homes became case studies. Specific aspects of these homes were analysed with different tools for the particular studies within the broad topic of the performance and energy consumption of sustainable energy homes (recently built, i.e. after or in accordance with the UK Code for Sustainable Homes) and with the people inhabiting them.

1.8. Chapter Conclusions

Across the whole building sector, the production and functioning of the built environment demand substantial energy and materials during the different stages, scales and processes. This sector is already identified as being the one with the highest energy consumption; about 50% of total energy consumption in most developed nations goes to the building industry (Boardmann, 2012, p.iv). To take the case of Europe, buildings consume about 40% of the total final energy requirements, which makes them the largest sector in energy consumption, followed by the 33% corresponding to transport (Economidou, 2011, p20). The crisis of the seventies pushed governments and international institutions to really act in order to control the energy problem immediately and into the future. Several international meetings designed to make the world more sustainable were held and attended by many countries. Besides the total energy consumed by buildings, 25% of total carbon emissions exclusively are generated by the existing home stock in many OECD countries. This fact is receiving increasing attention from different governments, resulting in many initiatives, especially in developed nations. Nonetheless, many non-OECD countries have also given priority to climate initiatives, especially in political discourse, but they lag far behind in regard to policies and legislation.

There are many reasons for governments putting this issue on their agendas, the most powerful ones are political and economic reasons, in addition to the fundamental reasons of climate change and the urgent need to make energy savings. This last goal is vital for European countries as their energy security is being strongly affected by energy supply and sources. Although the interests and reasons for energy conservation might differ from the agreed ultimate goal, it is important to recognise that the issue is on many government agendas, which is very positive. Furthermore, it has been seen that to achieve world climate targets, large-scale decarbonisation and energy savings within the building industry will have to occur. Energy efficiency is certainly one way of reaching these goals; in fact it is the energy efficiency strategies that look to be the best way to reduce emissions at the lowest possible cost.

Within this rapidly changing, broad and complex framework, the in-depth study of many initiatives towards decarbonisation seems attractive. However this thesis will focus on people behaviour in regard to energy conservation practices in their new sustainable homes

Chapter 2. Post Occupancy Evaluation (POE)

This chapter briefly describes the POE (Post Occupancy Evaluation) process, its definition, history, evolution and the types of POE. It also reviews how this type of assessment procedure is applied to homes.

Post Occupancy Evaluations have been undertaken consistently for more than four decades (MSU, 2008), and throughout this period many definitions of Post Occupancy Evaluation (POE) have been proposed by different researchers in the field, most of them academics or institutional researchers, a few of which will be reviewed in this section. The literature on POE is quite extensive; and a vast number of guidelines, protocols and tools for POE have been developed. Which one is used depends very much on the type of buildings under assessment. During recent years there has been increasing interest in this topic. This has been highly revisited, in response to a new urgency regarding energy issues with respect to human behaviour; as reviewed above.

2.1. Definitions

Since its emergence in the early seventies, POE has been defined as an assessment process applied to buildings after they become occupied and in use, where the main objective of the process is to ensure the occupants' wellbeing. During the 1980s it was attempted to attribute the definition to Wolfgang Preiser and/or Gerald Davis. However neither of them recognised the definition as theirs. Nonetheless most definitions are grounded in the basic definition given by Preiser; as

> "[…] the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time" (Preiser, 1988, p1).

Since then, the term Post Occupancy Evaluation (POE) has been used and is known by its acronym among researchers and scholars who are dedicated to this field. Although the meaning of this term is largely accepted and used, the etymology of the meaning of each word still produces discussion. If one considers the literal meaning of the name, it could also be understood as the procurement process that proceeds 'after' a building has been occupied, 'post occupation' implying that occupants have left the facility, instead of being a process that takes place while the building is in-use, 'during occupation'. Preiser also defines three main variables that need to be considered when carrying out a POE: performance-measures; the scale of the building, from a room to big facilities; and the user-occupants, from an individual to a big group.

In 1991 the Research Steering Group of the Royal Institute of British Architects (RIBA) proposed a definition that was more specific and dedicated to the different stakeholders involved in the building process; where POE is:

> "a systematic study of buildings in use to provide architects with information about the performance of their designs and building owners and users with guidelines to achieve the best out of what they already have" (RIBA, 1991).

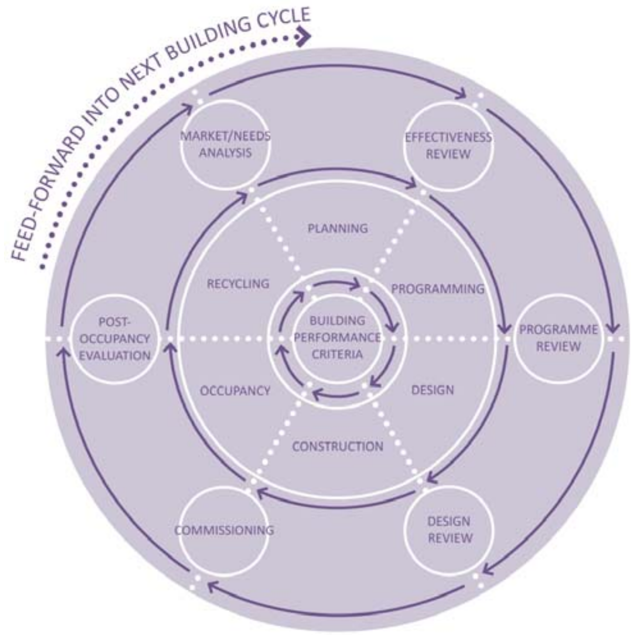

Figure 18 Post Occupancy Evaluation (POE) process model. Source: Wolfgang F.E. Preiser, 2005, p17 (Jay Yocis, University of Cincinnati.)

Ten years after the RIBA definition, the Board on Infrastructure and the Constructed Environment, of the National Research Council - Federal Facilities Council (FFC) of the United States, published a report called "Learning from our buildings", in which they established a very thorough definition. It states that the POE procedure is the one that evaluates building performance in a systematic manner and the procedure is applied once the building is completed and occupants have inhabited it for a period of time. They add that it should feed the next building cycle, as shown in the above figure 18, which effectively represents the core of the report in the sense of the need to learn from buildings. The FFC is determined to distinguish POE from other types of building assessments, because the focus is set on occupants and their requirements. As shown in figure 19, this includes such aspects as:

“[…] health, safety, security, functionality and efficiency, psychological comfort, aesthetic quality, and satisfaction. (FFC-TR No. 145, 2001, p1)

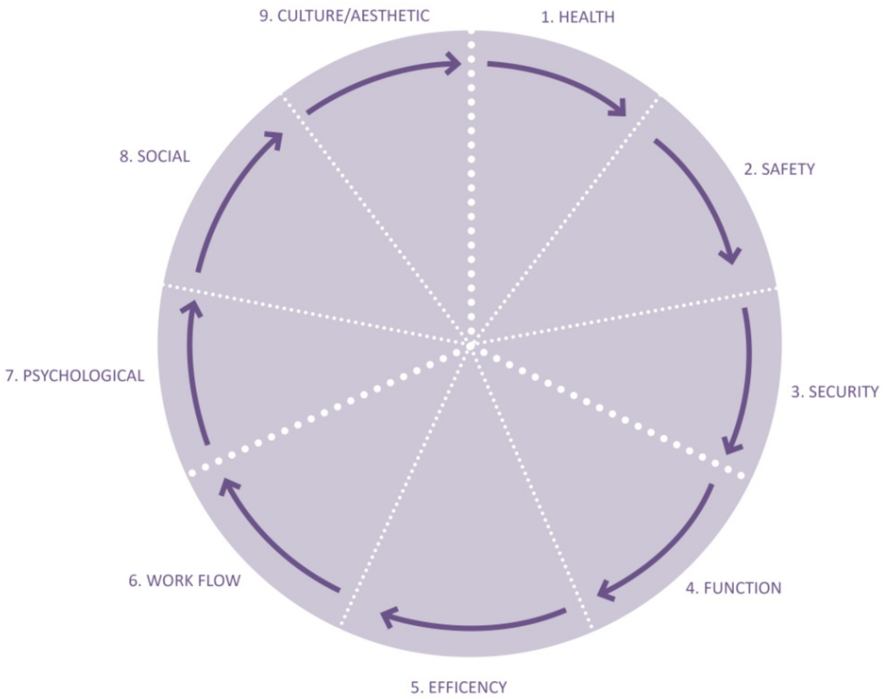

Figure 19 Levels of evolving performance Criteria. Source: Wolfgang F.E. Preiser, 2005, p6

The FFC goes further with the definition by adding to it an additional step which considers the process from an earlier stage in the life of a building, where the focus is still on the occupants of the building but it proposes to use the information learned from previous POE assessments. As well as including the early stage of the life of a building, for the FFC it is crucial that a building is evaluated within its life cycle; therefore, over and above the declared focus on determining the occupants’ comfort and satisfaction, as stated in the previously quoted reference, it adds

“[…] organizations are attempting to find ways to use the information gathered to support more informed decision-making about space and building investments during the programming, design, construction, and operation phases of a facility’s life cycle.” (FFC-TR No. 145, 2001, p1)

Vischer contributes to the definition with stating that POE is:

“[…] any and all the activities that originate out of an interest in learning how a building performs once it is built, including if and how well it has met expectations” (Vischer, 2001).

More recently the author Adrian Leaman stated in a very succinctly way that

> "Post occupancy evaluation (POE) of buildings tries to answer two broad questions: "How is a building working?" and "Is this what was intended?" POE is about real-world outcomes and their consequences ("ends") rather than design prescriptions ("means")" (Roaf, 2004, Pp. 491).

Similar to the definition given by the FCC, Leaman adds that POE

> "[…]aids learning from experience to improve the next generation of buildings – a kind of quality control writ large." (Roaf, 2004, Pp. 491).

In chapter 39 of the book *Closing the Loop* by Roaf, Horsley and Gupta, it is suggested that the indicators that are related to POE are primarily quality of life, health, thermal comfort, and noise and the tools for obtaining and measuring these indicators include sociological survey techniques, regeneration-based checklists and the Vital Signs project.

All the different authors have defined POE in a very similar way. The results obtained from the assessments should respond to the final question addressed by a POE: "how can the assessed building be improved?" To answer this, a report should be prepared and subsequent actions should be taken to conclude this assessment process despite the fact that it is "an evaluation". Another way of improving building performance with regard to the occupants' wellbeing is constructively implied when talking about learning from buildings that have been already evaluated while they are being occupied and in-use; this will help to avoid the same mistakes being made on a similar building which is due to be designed and built.

This however raises new questions: if the emphasis is on occupants - on the human beings that inhabit any particular building - and if it is assumed that any particular building could be subjected to a POE as, according to Leaman "a kind of quality control", then how many times should a POE be applied in the life cycle of a building (in use)? And how often? In his definition, Leaman metaphorically describes the Vital Signs Project8 (an educational project for architecture schools that was started in 1988 by academics from the College of Environmental Design, University of California – Berkeley) as consisting of a 'doctor's kit for the auscultation of the vital signs of a building as part of its medical diagnosis. For the author, the opportunity to use this tool as an architectural student was a remarkable experience that set the basis for understanding the importance of knowing how a building is working while it is being occupied.

Now, if one takes literally the meaning of 'vital signs' it is evident that a POE should not be a 'once in a lifetime' assessment for a building and that the learning from our buildings should

[8] http://arch.ced.berkeley.edu/vitalsigns/

be ongoing, especially with all the changes in climate that are being observed. Bearing in mind the scale of domestic dwellings, the POE could be something similar to the annual roadworthiness and emissions test to which vehicles are subject, such as the annual M.O.T. assessment of vehicles in the UK, which includes an emissions test that a car needs to pass every year to be legal for driving. Perhaps a home could therefore be assessed every five years during its use, for instance?

The POE definitions and applications, including a huge range of methods and protocols, have been applied for more than 30 years and it is possible to find an excellent library of examples and information about POEs published in different media. The majority of examples and case studies are from the Northern Hemisphere, since most of the POE research has been undertaken in developed nations; nonetheless it is possible to find research and information about POEs from other latitudes as well. All the information represents a good source of material from which is possible to learn and to develop ways of applying similar assessment processes to other places. Currently, many of the techniques applied to these procurement processes have greatly benefitted from the use of computers and social science software to aid the analysis of data.

The architect Rab Bennets, when introducing the Soft Landings Framework, challenged us to consider the role of the construction industry, stating that the world of architects is reluctant and even incapable of learning about the performance of its own creations. The result is buildings and facilities that very often do not respond to the operational expectations of the occupants, or even worse, buildings that are demolished in a short time, not even completing the normal 50-year life cycle of a building. Bennets adds that for professions outside the construction industry, it is seen as positive and normal to strive for “continuous improvement”, whereby the lessons from a previously completed project can be applied to the next project. This procedure, which seems so natural, even obvious, rarely occurs within the construction industry, where capital costs are the real source of obsession and almost the sole objective for the industry. He continues by saying:

> “Shortcomings in basic requirements such as comfort, energy consumption and adaptability are not only irritating and costly in their own right, but also undermine attempts to achieve high levels of sustainability.” (Bennets, 2009, in BSRIA, Pp….).

This statement brings to bear many important factors related to the building industry. The market is the factor with by far the greatest influence, followed by education and learning. These factors are crucial, not just for building industry professionals, but for all the occupants of buildings if changes are to take place. Therefore, a more inclusive process, where the ‘inhabitants of buildings’ regardless of their type and function become actively involved and considered might be the beginning of a more sustainable and healthy way of living. Post Occupancy Evaluation is applied in the real-world, to understand the everyday experience of the life of occupants of any building; it is not an experiment to be pursued and analysed in a laboratory.

2.2. History and Evolution of POE

Peter Manning carried out one of the first pieces of work on Building Performance Evaluations while he was doing his graduate studies at the University of Liverpool during the second half of the sixties (Manning, 1967). In 1972 the Building Performance Research Unit at the University of Strathclyde in Scotland published a paper and a book titled “Building Performance” by Markus and colleagues from the School of Architecture. According to Preiser (1997), the history of POE started with the one-off case study evaluation of a primary school in Liverpool by Manning and progressed from there.

During the 1970s and 1980s, due to the sprawl of post-World War II residential construction work, the first POEs were primarily focussed on housing in Western Europe and the United States; the need for housing and the rebuilding of urban places produced rapid growth without a real understanding of the needs of society and its inhabitants. Consequently there arose a great deal of residential social pathology thirsty for evaluation and studies (Preiser, 2004). The POE research expanded rapidly and was developed with multiple types of methods, tools and goals; as Zimring stated, the “evaluations ranged in scope from brief student projects to well-supported longitudinal studies” and people from many different fields applied the assessment, from private consultants and government workers to academic researchers (Zimring, 1980).

Later on, during the 1980s and 1990s, the POE process concentrated primarily on commercial buildings (company offices) and secondly on hospitals, public, government and educational buildings etc. POEs for office buildings were in high demand because of the relationship between a healthy work environment and productivity, which made stakeholders more aware of the need to study and improve (if deemed necessary) their working environments so as to increase production and therefore profits, so the managing of facilities is a key aspect of this type of POE. In 2005, the national cost to the economy associated with losses in productivity due to illness provoked by indoor air quality (IAQ) in commercial offices in the United States, was approximately US$64,000 billion (Presti, 2005).

In response to sick building syndrome (SBS) and within the POE methods, the Building Use Studies (BUS) appeared in the UK in the mid eighties. Sheena Wilson and Alan Hedge did the first study through the application of extended 16-page questionnaires for the occupants of offices, in their survey called 'UK – the Office Environment Survey'. After this 1985 survey, five year later the number of questions in the BUS questionnaires was reduced substantially and most of those related to health were removed. In 1997, the standardised two-page BRE/Royal Society of Health survey was implemented in place of the BUS survey. In 1995, BUS benchmarks and licensing were introduced in the UK, and Australian benchmarks were added in 2004. New Zealand and international green building benchmarks came along two years later. Further revisions of the different BUS surveys for different countries and the BUS version for residential building began to be developed in 2006. In 2008, the firm Arup adopted BUS as their method (Leaman, 2010).

The National Energy Management Institute (NEMI), a non-profit organisation located in Virginia, stated that in "healthy" buildings the general productivity of any company can be incremented by at least 1.5% when environmental conditions are enhanced, while for buildings with any type of poor performance, after refurbishment this increment is between 7% and 10%. On the other hand, the Buildings Owners and Managers Association[9] (BOMA) International claims that the average increase in productivity is about 18%. In one of their POE studies, they demonstrated that at least 50% of the office buildings in Caracas, Venezuela have inadequate indoor environmental conditions. With an increase of just 5% to 7% in productivity, these companies would realise an enormous increase in profits that they do not currently perceive. The BOMA has stated that the first reason for a company to move their offices to another place or enhance their indoor conditions is because of poor indoor environmental quality; consequently, those companies that offer a "clean" air environment obtain more loyalty from their occupants.

Currently there are many institutions (public and private) that have officially developed guidelines, tools and protocols for POE applications, where every aspect to be pursued during the evaluation is clearly indicated. An example of this is a document posted online by the Department of Human Services, State Government of Victoria, Australia, which describes the

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[9] BOMA International is one of the largest international federations in the world that started in 1907 in the United States, and which today has more than 100 local associations, of which 15 are international affiliates

whole procedure of a POE to be applied to a health facility[10]. It is notable that a year into this research, in October 2008, the author carried out a 'Google search' for POE on the Internet, which resulted in 31,400 sites that mentioned "post occupancy evaluation". When the author repeated this experiment almost two years later, there were 390,000 sites where the phrase appeared. For the search term "post occupancy evaluation guidelines", 9,070 sites were listed. The increment of sites over a period of two years shows the enormous amount of information available today on this topic and also demonstrates the increasing level of interest in the theme. This quick search was done in English; a search for the equivalent words in Spanish brought up a slightly lower number of sites. The sites vary from academic papers written by well known POE authors, and thousands of POE examples of all types to simple publications.

The academic world is currently populated with researchers and research, like this study, for example, all oriented towards making efforts to add more evidence and propose new ways of convincing the building industry of the importance of evaluating buildings by having the focus set on users and considering them and their culture. The importance of Leaman's thinking is seen in the need to provide robust evidence and a logical process for gaining leverage over emissions, where the order is first people, then energy, and last carbon. It therefore seems necessary to recalibrate what the industry does and, instead of translating facts into numbers, to put the focus on what people do. The following list from Leaman (2009) proposes a series of steps for the decarbonisation process, where the starting point is people, as can be observed from the list:

- Engage people, otherwise unintended consequences may occur
- Reduce demand, as prevention is better than cure
- Increase efficiency for the services that produce the demand in existing buildings
- Avoid waste, the starting point
- Decarbonise supplies, considering that low carbon energy is a scarce resource not to be squandered

[10] *www.capital.dhs.vic.gov.au/Assets/Files/poe_detail2010.doc*

- Obtain results in the simplest way possible, ensuring they are robust without being expensive
- Make use of opportunities, for instance when purchasing, maintaining, and refurbishing.
- The problem is not just heating and insulation

2.3. POE types and process models

During the building process of any architectural proposal, many types of evaluation are undertaken during the different stages, such as planning, programming, design, construction and occupancy. These evaluations involve different types of expertise and disciplines and they are technical evaluations, in which different aspects, mostly physical ones, are assessed (Preiser, 1988). The types of POE are grouped into three major categories (figure 20) defined by Preiser (1999) and the Federal Facilities Council (2001):

Indicative: An indicative POE indicates the major strengths and weakness of the performance of a particular building. It consists of interviews and field observations.

Investigative: This is a more in-depth investigation of the performance of a particular building. The outcomes try to comprehend the causes and effects of issues in building performance.

Diagnostic: This correlates measurements of the physical environmental aspects with the psycho-physiology of occupants. The results normally lead to new knowledge of the aspects of building performance.

There is a greater diversity of POE methods which primarily focus on assessing:

- User Satisfaction (1960 to present)
- User assessment of building comfort and functionality (1980 to present)
- User behaviour using self-reporting methods (1980 to present)
- Technical performance of building systems: costs and others (1995 to present)
- Balanced Scorecard Approach: balance of performance, building impact of the business process, growth and satisfaction of employees, impact on other stakeholders (2001 to present).

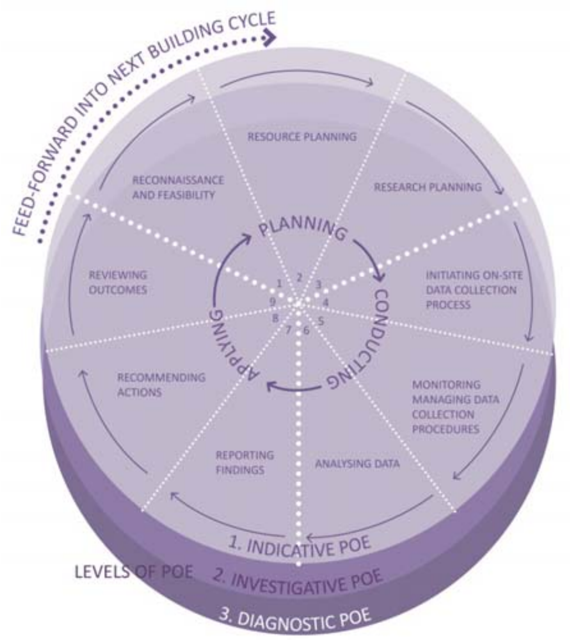

Figure 20 POE Levels of evolving performance criteria scheme. Source: J. Yocis, Univ. of Cincinnati and FCC (2001).

2.4. *Tools for POE*

The methods described above use different assessment tools - both qualitative and quantitative - and tools have also evolved over time, involving technology, especially computer programmes and software, which have also helped to enhance some of these tools, making assessments more complete, easier to process and analyse, and sometimes less time consuming. At the same time, however, they have become highly complex.

Field Observations in Sustainable Homes

Walking through the buildings, alone or in groups, recording impressions and observations, making sketches and drawings, taking photographs and specialised thermal images, carrying out a list of standard observations and small-scale plans to be used in the visit are some of the tools that could aid the process of field observations. This could also include quick quantitative measurements (for instance using a light meter, infrared or any thermometer, anemometer, hygrometer, noise meter, multifunction meter), which can help the surveyor to observe many aspects of the building that are immediately apparent; however the data will be much richer if combined with discussions, personal interviews, questionnaires, and surveys with occupants and the building manager, if possible.

Questionnaires and Surveys

Perhaps the most commonly employed technique for POEs is the structured questionnaire. This approach requires the development of a range of questions geared to measuring user responses in the required subject areas.

There exist two major types of questionnaire. One is the quantitative questionnaire, which simply involves ticking boxes rating the accuracy of statements or circling the appropriate answer, as in a multiple choice questionnaire. This is a very common tool used in a POE, so it is important that questions are clearly worded to obtain outcomes that can be interpreted statistically. The second is the qualitative questionnaire that asks for written comments which obviously tend to differ from person to person and so the process by which they are analysed is not numerical, but looks for meaning. In a way they are similar to a verbatim/e-mail interview where the main difference resides in the spontaneity of the written versus the oral answers. The first type, the quantitative questionnaire, is useful for making quick comparisons between projects and/or benchmark projects to get an overall view of the situation under investigation. The second type, the qualitative questionnaire, gives detailed and case-specific qualitative data.

A major advantage of the questionnaire approach is that it allows a large sample of users to be surveyed and therefore, if done well, can improve statistical reliability. Generally the best advice, as Bordass (2005) states, is to “keep it simple”. It is a specialist job to draw up a survey and there are experts who are dedicated to doing just this. Surveys are expensive to prepare and process. They are not just a simple collection of questions; rather they are highly structured and statistics are required for processing them. There are many pitfalls with questionnaire design. Before embarking on the cost of a major survey, it is recommended that pilot questionnaires be tested. Also it is necessary to consider carefully how the questionnaires are to be analysed.

Verbatim Interviews

Interviews can fill in the gaps where the questionnaires fall short or more in-depth observation is required. Although it has long been accepted that interviews are one of the best ways of gauging occupants’ satisfaction levels, it is also recognised that they are time-consuming and therefore more expensive. However, it seems that they have not been able to be replaced by other tools, as the personal contact for psycho-physiological and perception outcomes cannot be replaced by a set of questions on a paper, by email or any other means. Results are much more complete when a personal interview has taken place (Stevenson, GHA presentation, 2008).

Facilitated Discussions (Focus Group) or Workshops

In group discussions, delicate situations can arise and can result in understanding and then agreement or consensus (e.g. two opinions are better than one); however, the surveyor must remain in charge of the situation and needs to be experienced in leading focus groups. If this is not the case, then the validity of the results obtained by the discussion may not be fulfilled. Nonetheless, "discussions are a valuable form of feedback at any point during a project; sharing experience and insights at the start, reviewing problems in the middle, and in post project reviews at the end" (Bordass, 2005, p) but they might not by themselves constitute a POE. They could be part of it and they are an excellent way of gauging the occupants' satisfaction during the whole process, but to systematise discussion can be very complex.

Workshops are organised with key participants to gather user responses. This approach has the advantage of being a focused, short-duration technique, but feedback and results are informative of different issues related to the performance of the building in regard to the occupant's comfort. Although on their own they are not reliable enough to constitute an evaluation, they could be part of a POE and a contribution towards beginning a more in-depth assessment.

Physical Monitoring, Measurements and Analysis of Performance Statistics

Performance data, for example regarding water and energy consumption, rainwater collection, biomass boiler efficiency, solar panel efficiency, natural and artificial lighting levels, internal temperatures, air change rates, ventilation patterns, among other aspects should be taken with regularity within defined relevant periods (daily, weekly or monthly, depending on the depth of the study) for a whole year at least (although a 24-month period would be preferable) and should then be analysed and compared with benchmarks and projected and/or previously simulated performance.

While all the above are being applied, another important test that needs to be carried out, especially in office buildings and housing, due to the high demand for a reduction in energy consumption, is a pressure test to assess the air-tightness and check if expectations are being reached. The downside of this type of test is its high cost, but it is undoubtedly the best way to prove that internal gains will be maintained when needed, especially during the winter in places located in Nordic regions, such as the Scandinavian countries.

Bordass, 2005, has written extensively about POE research and methods, based on his experience of the subject. He emphasizes that POE techniques should be simple to use, applicable to a broad range of case studies, they should be robust but comprehensive, and the cost of tools should be low and accessible to everybody, which implies they also have to be quick and easy to operate. Finally all the above should be able to rapidly generate useful results. With regard to information, Bordass suggested that information on performance data obtained in benchmark-based cases should be available and easy for anybody to access where possible. He adds that in the past access to information regarding the data management of benchmark-based cases was difficult to find because funds were not available on a regular basis to carry out this type of process (Bordass, 2005).

2.5. POE for an affordable sustainable home basic requirements

The following is a general overview of how a POE might be carried out in housing. Before conducting a post occupancy study to evaluate the extent to which a building is achieving its intended use, it is important to define two things in order to ensure the acquisition of fair, honest and reliable data.

Firstly, what information is required; and what it will be used for. For example when looking at the BASF house as a prototype for new affordable mass housing, it is important to gain an understanding of how any potential resident might occupy the space, rather than focussing on the use by one particular inhabitant.

Secondly, it is important to define who the occupant is and understand their stake in the building (i.e. owner, long-term tenant, temporary tenant, relative or visitor) and their position in the family, gender, age, and other related demographic information. Every occupant will have a different interpretation in regard to his or her home, and they may all have a different way of using the many spaces in the house. Also it is important to recognise different users' needs (i.e. less able-bodied people, the elderly or those with very specific requirements).

The information gained in order to evaluate the building's performance in regard to the occupants' comfort can be either quantitative or qualitative and can be completed through a series of questionnaires, surveys and personal responses. Some quantitative data can be gathered without input from the user, such as room surfaces and volumes, number, size and orientation of windows, types and efficiency of appliances, especially boiler size, characteristics of the ventilation, number of vents, how they are operated, and so on. It is important to note that whilst quantitative responses might be easier to evaluate as they can be plotted on graphs and spreadsheets and analysed statistically, qualitative responses, especially when the focus of the study is the occupants, are sometimes more insightful, as they are about the psycho-physiological (emotional and physiological) effects the space has on the occupants, which are undoubtedly very important when discussing personal comfort.

It is also important to gauge a range of responses from different times of day and different periods in the year, as the levels of comfort are intrinsically linked to exterior climate and conditions; therefore the latitude and orientation of the building location is crucial. A climate analysis is therefore an important tool to apply prior to or during the study. Normally several periods of study will be established at the time, as extreme climatic situations tend to occur in a normal year (i.e. the hottest weeks during summer, the coldest weeks during winter, maybe close to the solstices and sometimes around the equinoxes).

Once all the information has been gathered, it is up to the surveyor to use the information to evaluate the building performance that will be part of the data analysis. But what the surveyor definitely needs to evaluate are all the aspects that affect - positively or negatively - the wellbeing of the occupants.

If the responses are wide-ranging, then the researcher must look objectively at the results. One way is to draw a standard deviation (if the results are quantitative) and focus on achieving comfort for 85% to 95% of occupants within the different parameters that are being measured. The study could also concentrate solely on one parameter, for example thermal comfort, so all the data to be collected will concentrate solely on this aspect, which at the same time will be influenced by many variables; for quantitative data for instance, surface and air temperature, relative humidity and radiation are among the factors that may prove influential, while for qualitative data, factors such as the construction and design characteristics and the routines, clothing and activities of the occupants, may be the key influential factors.

Clearly it is ideal to achieve a comfortable environment for every occupant and by introducing methods of control this may be possible. It must be noted, however, that an occupant is only likely to take control if they have a higher level of perceived ownership of the place (i.e. one-off visitors are unlikely to open windows and turn off heating whereas as someone who lives in a house would assert total control over heating, cooling, lighting, etc.) These methods of control must also be simple and easy to manage by people who might have no knowledge of the system (for example, the complicated WebBrick system installed in the BASF house might be suitable after all the inhabitants have been trained to use it, or it might be accompanied by a user manual, but it would most certainly be unsuitable for a new, untrained tenant who was to inhabit the house).

No two POEs will ever be identical, as no two responses will ever be the same, especially if the information has been obtained through qualitative tools. The preparation and carrying out of observations, questionnaires and surveys is only the first step to a successful evaluation; how the researcher uses and analyses the information is crucial. As with all research, it is important to know what you would like to get out of it before starting, but you must also be open to additional information (for example, although the research might be on thermal comfort, if the occupant, say, complains that their boiler is too noisy, this might be directly related to the space being cold, as to avoid the noise, they turn the boiler off). People react to spaces differently and require and relate to them for different purposes.

Chapter 3. Methodology

This chapter describes the methodology used in this thesis considering that all the tools and techniques are common ones used in Post Occupancy Evaluations where as mentioned in the previous chapter the subjects of study is people and their behaviours in regard to particular phenomena. It has not been an easy task to classify this thesis within a particular architectural research method, nor as a typical post occupancy evaluation either. If the author must declare a title for the methodology, it will be "from experience to theory", based on the well known Confucius' analects: "I hear and I know/I forget. I see and I remember. I do and I understand", however the use of a "mixed methodological approach" is a more appropriate classification.

3.1. From experience to theory

In line with the statement by Leaman during a lecture on POE in the Department of Architecture, University of Nottingham at the end of the first semester of the 2008-9 academic year,

> "architects prefer to learn through direct personal experience while engineers prefer principles and established rules",

Both Leaman (2009) and Fisher (1994) have drawn a comparison between the traditions of learning, teaching and practicing within medicine and architecture and building construction. Both of them concluded that, unlike medicine, the professions related to building construction have not developed a tradition of practice-based user research. In his article "Can this profession be saved?" fifteen year ago Fisher concluded that architecture could learn more from the successful teaching-learning experience in studies in fields such as medicine, diversifying the architecture profession and studies by including more research methods and POE processes while providing professional practices where the diagnosis and assessment of buildings are included.

As Leaman states (2004, in Roaf, 2004)

> "POE has taken 30 or more years to get off the ground, partly because it has not been obvious which techniques are best"

and it is recognised that it is an interdisciplinary issue. To date, most POE studies have been carried out on commercial or institutional buildings. During the last decade and following the publication of the Code for Sustainable Homes, the POEs for private residential buildings have become a focus for studies and there is still a long way to go in this area.

For this study a mixed-methods sequential explanatory design (Creswell, 2005; Tashakkori and Teddlie, 1998) that has been developed in the field of social and behavioural sciences has been applied, consisting of:

Two distinctive phases: quantitative and qualitative

- Step 1: Collection and analysis of the quantitative (numerical) data
- Step 2: Collection and analysis of the qualitative (textual) data to help explain and elaborate on the numerical data obtained in step 1.
- Step 3: Qualitative data builds on quantitative data (see appendix 1) and the first two steps try to connect in an intermediate phase.

The rationale behind this methodology is for the quantitative data and its analysis to help to understand the research problem. The qualitative data explains the numerical results in-depth, through the subjects in study, the occupants' perceptions on their sustainable homes.

For this methodology, an important issue is the relationship with the "priority or weight" which is given to each of the two phases (Ivankova et Al., 2006) and why. The weight has been given to the quantitative data obtained through the monitoring system and this has been the starting point for analysing, comparing and contrasting findings with the qualitative data. Given that this real-life research has produced an enormous amount of data from both the quantitative and qualitative phases, this data was subjected to a lengthy process of analysis, using a broad range of tools, with the final goal of connecting and integrating coherently the results from the two phases, to attain a holistic and in-depth view of the issue under study.

3.2. The research scheme

In order to respond to the objectives of the research, the scheme in figure 21 depicts the steps undertaken to pursue this study. It shows all the operations carried out to find evidence and produce the basis for a proposal for the First Home Occupant POE of a sustainable home.

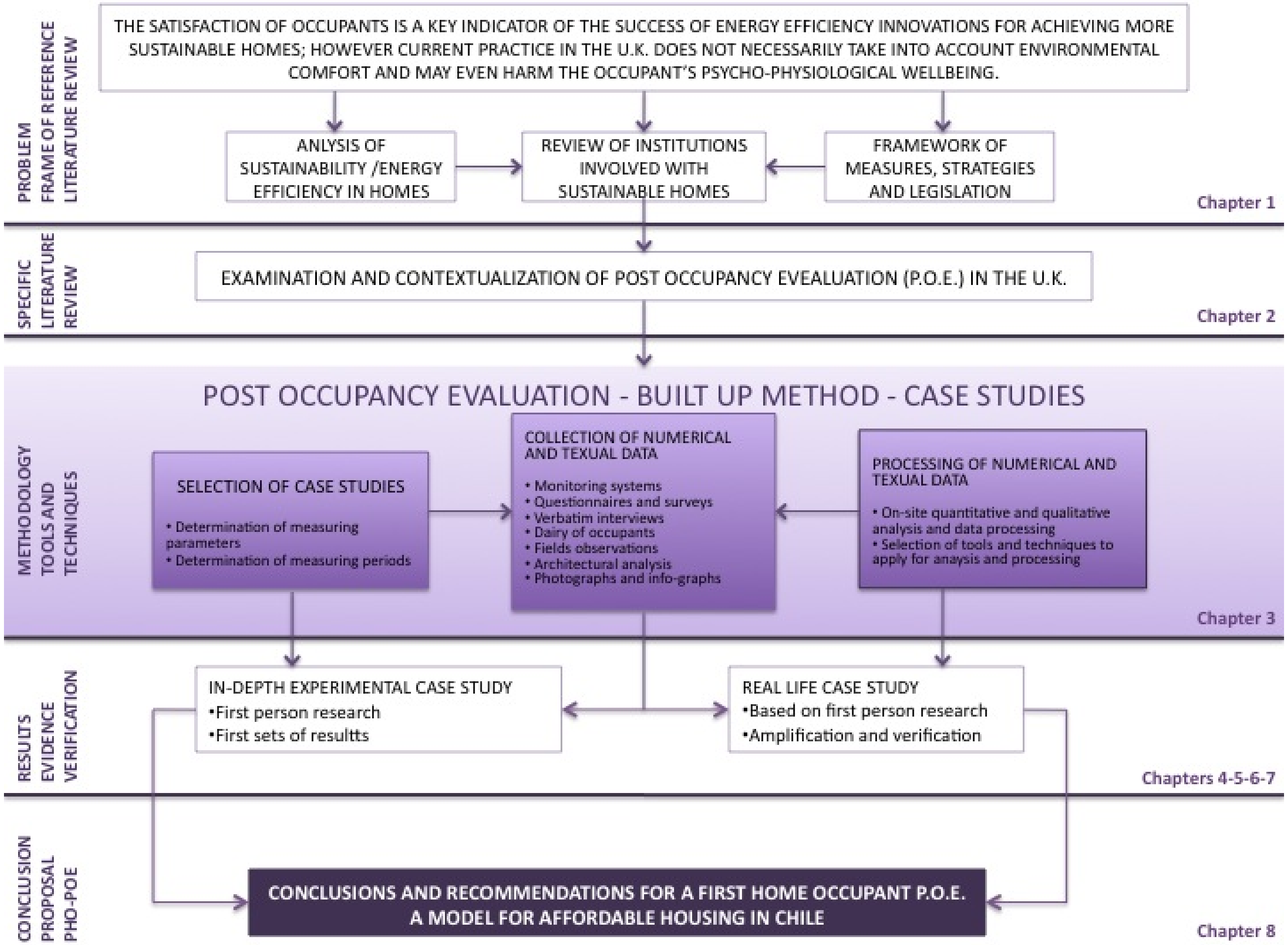

Figure 21 Scheme of research sequence, from the problem, its framework, methodology, actions to the conclusion; referencing the respective chapter

Although energy efficiency developments, strategies, legislation, and assessments aim to consider the wellbeing of our environment, the wellbeing of occupants still features as an indicator of its success.

Hypothesis

> **The occupants' satisfaction is a key indicator of the success of energy efficiency innovations, developed in the framework of measures, strategies and legislation for achieving more sustainable homes, considering that current practice does not necessarily take into account environmental comfort and may even harm the occupants' psycho-physiological wellbeing.**

Research Questions

- **Do energy efficient and sustainable homes provide the occupants with the comfort of a "standard" home and with equal ease of use?**
- **Can we actually live in sustainable energy homes?**
- **Does the inclusion of the sophisticated forms of renewable energy technology required to achieve energy efficient standards presume that the occupants have a certain level of education or that they have received adequate training in the specialised maintenance of the equipment?**

Main Objective:

To uncover evidence through qualitative techniques contrasted with the quantitative tools used within the POE methodology to confirm that a post occupancy evaluation process must be included in the regular assessment procedure and that it must be based on the reality and culture of occupants, not only on simulations and calculations of the building's performance. Therefore the proposal of this study is to establish the basis for developing a First Home Occupant POE using a demonstration sustainable home in a new housing development to close the loop within the assessment process of sustainable homes.

General Objectives:

1. To determine if the inclusion of the sophisticated types of renewable energy technology required to achieve energy efficient standards entails:

    a. the occupants having a certain level of education.
    b. a need for specialised technicians trained in the maintenance of the equipment.

2. To determine the general awareness and knowledge of people on topics related to sustainable homes

3.3. Selecting the case studies

The two **case studies** included in this research were offered to the author as part of the PhD research on post occupancy. The author did not have any involvement in the design and construction process, nor influence over the selection of the case studies and nor influence on the different monitoring tools applied to these case studies. As case studies, they were part of bigger applied research projects. The BASF house became an in-depth experimental case study. It was the first house built within the Creative Energy Homes (CEH)[11] project (2007) and the author was the first occupant. The ten homes in Upton were real-life case studies and this research formed part of the SHINE and SHINE-TRUE[12] projects. These homes provided the opportunity to expand on post occupancy evaluation using the real case of occupied homes by way of contrast with the experimental case. Carrying out the research on the real case occupied homes presented some difficulties with regard to the whole procedure. The volunteer family list was obtained following an initial survey period in which 100 questionnaires were distributed door-to-door. Of these, 50 were completed, 10 by families who said they were willing to volunteer for this real-time energy meter trial period. Preference was given to terraced houses rather than flats; nevertheless of the ten homes, one was a flat. The **study period** for both case studies was winter, but in different years, as will be seen in the next section for each case study. Winter was chosen as the period to be studied, because that is when families in the UK consume the most energy. The other **parameters** of the research

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[11] The **Creative Energy Homes (CEH)** Project of the Department of Architecture and the Built Environment, University of Nottingham (figure 24), is a research and educational showcase of six low or zero carbon houses.

[12] "What is **SHINE TRUE?** SHINE TRUE is an East Midlands Region and European funded project to find out about how occupants interact with and use renewable technologies in their homes […]. The project also aims to understand how people use energy by looking at their energy behaviours. (Jackson, 2008)

were the decision to focus on the POE tools and techniques as a means of responding to the research questions; the fact that all the houses studied were subject to the CSH, although it was not yet mandatory. The cases studies included different types of sustainable energy technologies (SET), not commonly applied to homes in the UK at the time of the study.

3.4. Applying POE tools and techniques to the case studies

3.4.1. Collection of numerical data

The collection of numerical data for the cases studies was done mainly with three different devices, dataloggers, energy meters and tracking devices and also doing every day manual transcription of selected data taken from the panel in the kitchen in parallel to the recording textual data in comments from occupants.

For the BASF house in-depth case study, an in-built monitoring system of 48 sensors had its debut as part of the Creative Energy Homes (CEH) Project. Given the fact that it was an experimental case study, a tracking device system was also tested as a measuring tool for the post occupancy of homes. For Upton Homes, the real life case study, a similar monitoring system was planned. However, time and funds meant that other aspects needed to be added to this study, keeping it within focus. The planned and installed monitoring system was therefore replaced by real-time energy meters instead. These were commonly commercialised energy meters on the regular market. Therefore, these devices were not comparable to the monitoring system of the BASF house, as only two of the four chosen energy meters had a datalogging feature included. They were manually programmed and installed in the houses by the author for a six-week period in wintertime, while the monitoring system in the BASF House was logging data continuously.

The BASF House monitoring system

Distribution of sensors in the BASF House

For data to be reliable and aid in reaching results and conclusions, calibration, short sample evaluations and testing all needed to be undertaken to compare the electricity usage and efficiency of the different devices installed in the house, as well as the winter performance of the BASF House. The distribution of the sensors can be observed in figures 22 and 23.

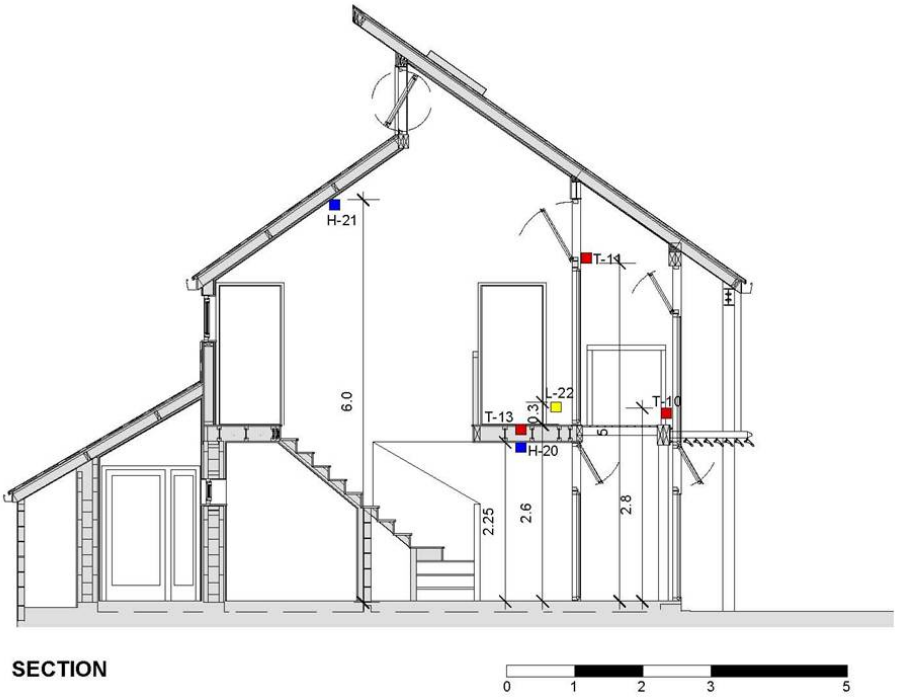


Figure 22 Section view of the datalogger location in the BASF house.

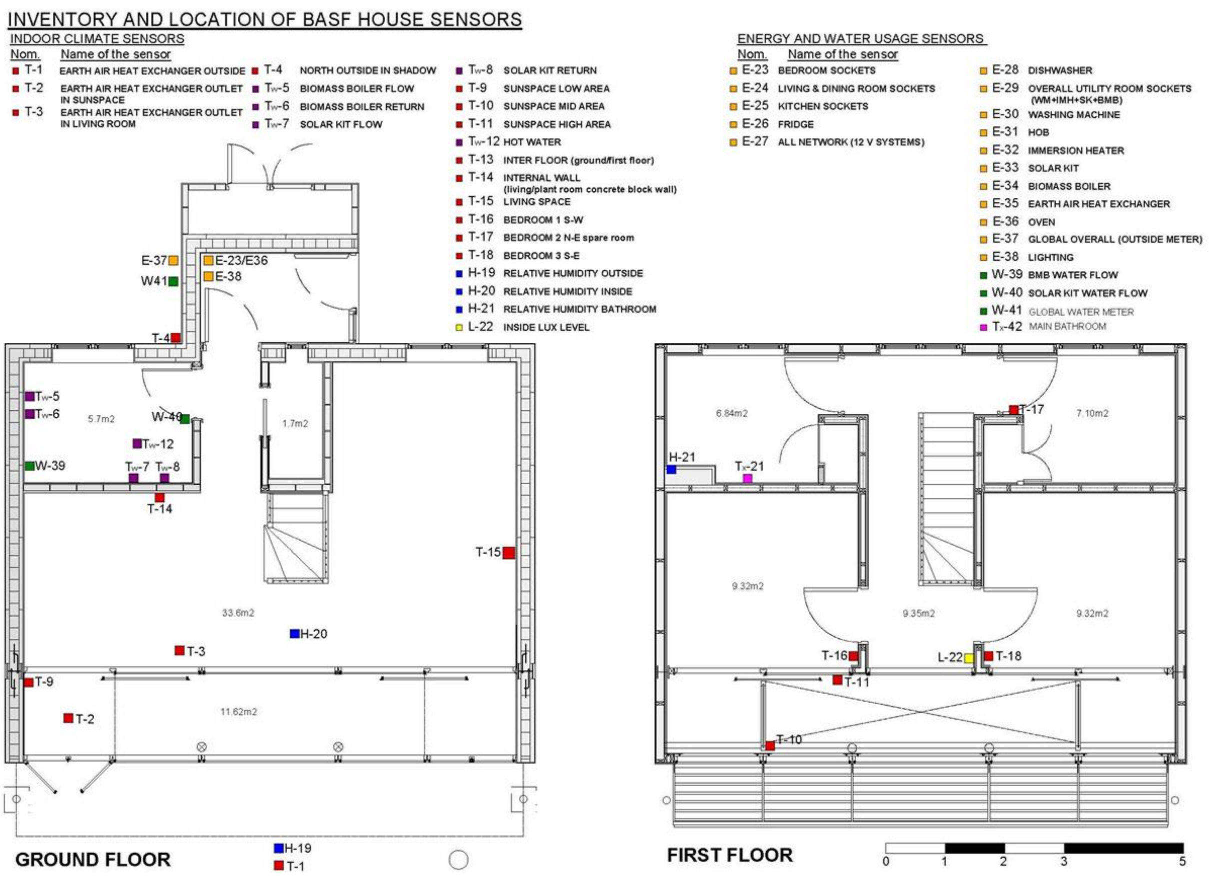


Figure 23 Plan view of the datalogger location in the BASF house.

For the data processing, the energy sensors were aggregated in the following sets:

Appliances: Sum of kitchen sockets used for toaster, microwave, blender, juicer and small electrical appliances + fridge, refrigerator and freezer + dishwasher + washing machine + hob + oven.

Lighting + sockets + network: Sum of all lighting + bedroom sockets + living and dining sockets + all network (12 V systems, led lighting, motorised windows, monitoring system, wired access unit, wireless modem and touch screen)

Immersion heater and biomass boiler: its readings were analysed independently in order to read its electrical consumption separately from the rest.

Solar system and GAHE System: these were aggregated as low energy technologies; however to read the energy demand for space cooling, the GAHE usage was also analysed by itself. To obtain the total energy consumption for a year, all the above need to be added.

Winter 1 – February 2009 – one month only: It was necessary to reach a period within winter where the occupancy of the house was normal, the monitoring system was reliable and the heating system was working properly. After some months of living in the house, the occupants had better adjusted to the use of the technology and the data logging system had been calibrated; so the data was considered reliable. It had already been necessary to fix and maintain the biomass boiler. Thus, towards the end of January 2009, the biomass boiler was in optimum condition for a monitoring period. The biofuel used was rape seed oil pellets, and the boiler was specifically set for this type of biofuel. It was therefore possible to empirically measure the efficiency and energy consumption of the biomass boiler. Thus, the first winter period to be monitored with valid data started on 30/01/2009 at 0:00 hrs and finished on 26/02/2009 at 23:59 hrs (four weeks), while the second winter period started on 01/12/2009 at 0:00 hrs and finished on 29/03/2009 at 23:59 hrs (17 weeks).

Winter 2 – December 2009, January, February and March 2010 – four months: The monitoring system functioned well over the previous winter period, and the data downloaded regularly to the server, with the exception of the whole month of March 2009 (the University carried out an adjustment to the server and readings were not recorded).

The monitoring protocol and the datalogging system characteristics

The data logging recorded in csv (comma separated values) every six minutes in an cumulative manner and it reset every day at 3 a.m.; with a total of 240 readings per day for each of the 48 sensors. Some of them are shown in figure 24. In the course of a month each sensor takes over 7000 samples. Therefore to calculate the values on a daily basis for a period of four weeks, considerable data processing was required. To refine the data, the resolution was decreased and the data sampled based on predetermined criteria, with a 30 minute interval for all calculations being established.

Figure 24 Images of the different sensors and the meters of the monitoring system at the BASF House

Steps to process the raw data downloaded from the University server

- Download of raw data from the server.
- Decompression of the csv files and organisation of the data into an Excel spreadsheet.
- Selection of the data needed for the analysis of the performance of the heating technology from determined energy sensors.
- Because energy readings are cumulative over the course of a day, they need to be changed into instant samples instead and then reduced to the scale of 30 minutes, with two samples per hour instead of 10.
- For indoor and outdoor climate readings, maximum, average and minimum hourly and daily values were calculated, as well as operative temperatures for the ground floor, the first floor as one area, and for the south bedrooms and the north bedroom.
- For temperature readings to calculate the heat output of the biomass boiler, the detailed process is explained in the following section.

- Once the data had been treated, the results could be analysed. When the results were obtained, the quantitative analysis took place. At the same time, the qualitative analysis was taking place, with the application of other methods and tools, such as SPSS (Statistical Analysis) and NVivo (Grounded Theory), to contrast and validate the data in order to deepen and better understand the findings.

Two consecutive winters were measured, so it was possible to adjust the method by adding or subtracting steps, once the first results and findings had been obtained, in order to influence the iteration and fill the gaps observed in the first procedure. In this way more accurate results and conclusions could be reached.

Procedure for calculations after data processing

Heat output from the biomass boiler and its efficiency

To calculate the heat output being delivered by the biomass boiler, the calculation needed to look at the volume of water flow in litres and the water temperature, flow and return water temperatures**,** to calculate the average ΔT in degrees Celsius for a given period of time (it was used at **30-minute intervals each day,** and 48 values were obtained - see the sample of data in table 2).

Table 2 Sample of **already treated data** from the BASF house readings

1	**2**	**3**	**4**	lt	lt	°C	°C	°C	kJ	kJ	W-h	
			BMB lt	BMB Water Fl		BMB Flow T	BMB Return T	Delta T	Output Heat			kW-h day
DATE	TIME	MIN		every 30 min	day					day		day
27/02/2010	16:18	18				58,9	28,6	30,3				
27/02/2010	16:24	24				58,9	28,6	30,3				
27/02/2010	16:30	30		30		59	28,6	30,4	3811,35		1058,71	
27/02/2010	16:36	36				58,9	28,3	30,6				
27/02/2010	16:42	42				58,9	28,5	30,4				
27/02/2010	16:48	48				58,8	28,4	30,4				
27/02/2010	16:54	54				58,6	28,4	30,2				
27/02/2010	17:00	0		30		58,4	28,3	30,1	3461,82		961,62	
27/02/2010	17:06	6				58,3	28,3	30				
27/02/2010	17:12	12				58,2	28,1	30,1				
27/02/2010	17:18	18				57,6	27,1	30,5				
27/02/2010	17:24	24				50,4	26,4	24				
27/02/2010	17:30	30		30		47,3	26,6	20,7	2566,02		712,78	
27/02/2010	17:36	36				46,5	26,9	19,6				
27/02/2010	17:42	42				46,7	27	19,7				
27/02/2010	17:48	48				47,4	27,3	20,1				
27/02/2010	17:54	54				48,4	27,4	21				
27/02/2010	18:00	0		30		49,3	27,8	21,5	3051,59		847,67	
27/02/2010	18:06	6				50,6	27,7	22,9				
27/02/2010	18:12	12				51,9	28,1	23,8				

For the boiler efficiency calculation, the same theoretical approach was taken on the first test, which is similar to the steps suggested by the Carbon Trust, In-depth guide CTG01 (2009). To determine efficiency:

> "This is accomplished by monitoring the following over a set of period:
> Heat Output (kWh)
> Weight of fuel used (kgs)
> Net calorific value of fuel as received (MJ/kg-as determined by analysis).
> Once these figures are collected for a set period, the following formula may be used to estimate the efficiency of the boiler plant" (CTG01, 2009):

$$\text{Boiler Efficiency (\%)} = \frac{\text{Heat output (MJ*)}}{\text{[Weight of fuel used (kg) x Net calorific value of fuel (MJ/kg)}}$$

Determining if the criteria set by the PassivHaus standards are met by the BASF House

The cooling and ventilation demand

For the energy demand for space cooling and ventilation, the values were taken directly from the raw data, given that they are recorded in cumulative reading. By comparing the energy readings from the GAHE sensor and the information in the diary of events, where the day and the length of time the mechanical ventilation system was being used were recorded, it was possible to obtain a very accurate value. In addition, a quite accurate analysis of the perceptions of the occupants of this has been taken into consideration.

The total energy usage

As above, the total energy consumption for appliances, domestic hot water (DHW) when using the immersion heater, and space heating and cooling can be directly obtained from the measured data.

Short sample evaluations and testing

The first winter – February 2009 – Step I. Understanding the heating system of the BASF House

Understanding the SET performance and compare their **efficiencies**, a small test of the water heating systems of the BASF House to compare the efficiency of the biomass boiler and the immersion heater from the solar system was carried out in December 2009. This was done with spot measurements taken from the displays provided by the different technologies plus the information available in manuals and specifications of the technology applied in the BASF House and similar cases. The specifications in regard to power consumption were taken from manuals for the SET.

To obtain the biomass boiler **heat output**, the raw data given by the monitoring system was processed to obtain the water flow and the temperatures, which were multiplied by the constant of Specific Heat of Water, 4.186 (kJ/lt-°C).

Biomass Boiler Heat Output (kJ) = Water Specific Heat (kJ/lt-ºC) × Water Flow (lt) × ∆T (ºC)

With this value, the energy yield in kWh for the biomass boiler could be obtained.

Processing and understanding the type of data is being logged, once the data from the first evaluation period is obtained and analysed, possible problems with readings need to be identified within results. To obtain more accurate results new steps are added to the method:

- Repetition of procedure used in the first winter to treat the data and proceed with calculations in the second winter period
- Design of test 2 to correct identified problems on previous results

- Manually separate readings for SH (space heating) and WH (water heating) and transcribe the data to a spreadsheet, as shown in Table 3
- Calculate just the space heating (SH) demand and analysed results

Table 3 Example of the two first weeks of manual recording of the switching on/off to disaggregate SH from WH delivered by the biomass boiler

DATE	BIOMASS BOILER USAGE, MANUAL READING TO DISAGGREGATE WATER FROM SPACE HEATING						
	SPACE HEATING			WATER HEATING			FUEL
	begin time	finish time	TOTAL HR SH	begin time	finish time	TOTAL HR WH	kg pellets
26/11/2009	02:15			04:20	07:15	**02:55**	**80**
27/11/2009		12:40	**10:25**				
28/11/2009	10:50	15:25	**04:35**				
29/11/2009	19:05			08:25	10:25	**02:00**	
30/11/2009		08:40	**13:35**				
01/12/2009							**40**
02/12/2009							
03/12/2009	18:10	23:40	**05:30**	08:00	08:50	**00:50**	**40**
04/12/2009	19:50	20:50	**01:00**	23:45	12:45	**13:00**	
05/12/2009	00:00	00:45	**00:45**	12:45	20:30	**08:45**	
06/12/2009							
07/12/2009	10:55	12:00	**01:05**				
08/12/2009							
09/12/2009							

Other tools for carrying out quantitative analysis

In order to complement the architectural analysis and walk-through observations, other numerical tools were applied. Only specific features offered by the tool were used for the purpose of verifying a particular aspect related to the occupants' experience of living in the experimental home, in order to help to address the research questions.

Tracking device

In parallel to the different tools applied to analyse the performance and occupancy of the BASF House, another tool was tested for this case study; an experiment within the experimental study, the descriptive analysis obtained from the application of this tool is included in appendix 12. The idea behind using this tracking device tool, which is mostly used in industries where chain production processes are taking place, was the possibility of determining the 'individual footprint' of each member of a household, in order to complement the energy usage in the home. The tracking devices used for the BASF House include a system that utilises ultra wide band for time and location tracking devices (Ubisense®), to track the patterns and times of space usage in the house. The system was also implemented in two homes of the Creative Energy Homes project. However, the goal in this study was to test the tool with people instead of products, which are usually the subject of its usage, and the possibility of adding a new tool within post-occupancy evaluation.

Steps to determine the individual footprint to complement the analysis of energy usage in the experimental home

- Learning of the specific software
- Drawing up of a simple plan view of the floors of the house showing only public spaces (ground floor)
- Identification of all the areas related to energy consumption (sockets and appliances)
- Drawing up in 3D zones the previously identified energy consumption areas, extrusion of a virtual parallelepiped volume from the plan view
- Selection and installation of a tracking device kit on all the relevant upper corners of the different rooms, kitchen, dining, living and circulation
- Definition of a random period for measurements, during which all occupants and visitors needed to wear the numbered tag while in the house
- Download, analysis and interpretation of numerical data collected by the tracking device kit
- Contrast of tracking device data with datalogged data by the monitoring system for the same day
- Establishing the relationships between occupancy and energy usage by individual, to calculate each individual footprint.

In reality, this virtual 3D zone was detected by the sensors that were installed. Cells of sensors are formed with a master sensor and three other sensors. To determine the cell locations, a virtual vector without any blocking element between the master sensor and the three ‘slave’ sensors must exist. For a multiple cell system, such as the one installed in the BASF house, one of the master sensors was the time source (see figure 25).

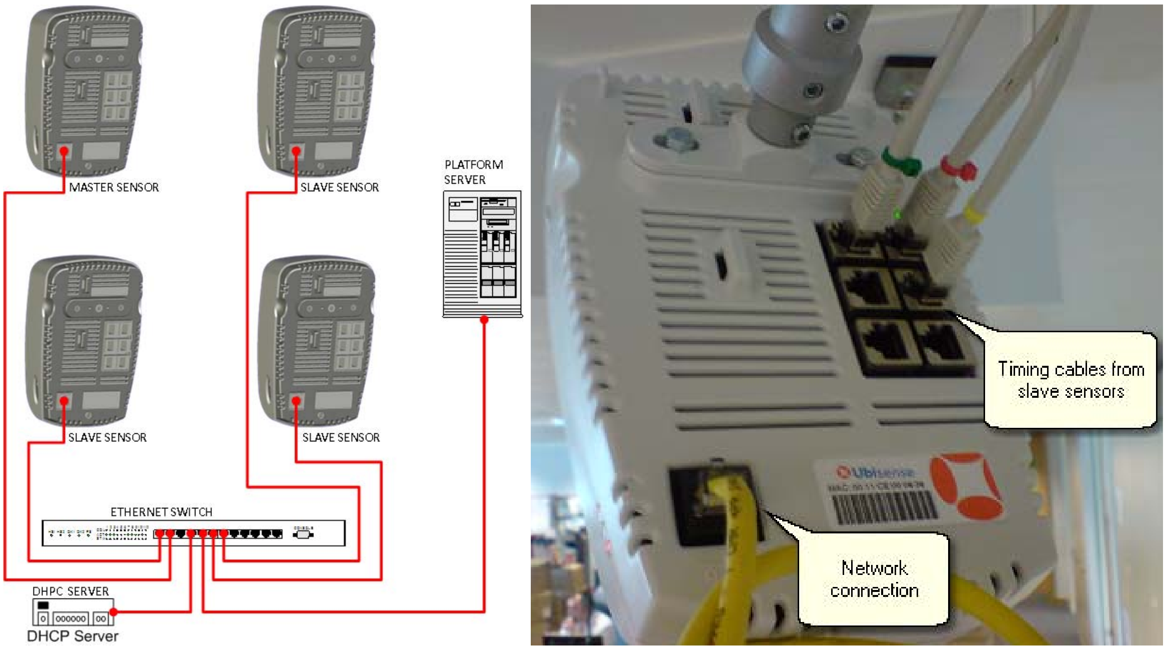


Figure 25 Ubisense tracking device kit, showing the organisation of sensors and connections.

For the sensor to record a reading point location and time, the occupant needs to wear a tag. At least two sensors should be able to see the tag, then transmit via the radio signal to the master and time source and to the computer (figure 26). During three weeks in spring 2008, the occupants and any visiting friend that stayed in the house for some hours needed to wear a tag allocated exclusively for their individual use (they were marked as occupant 1, 2 and 3 and visitor 1, 2, 3, 4, etc.)

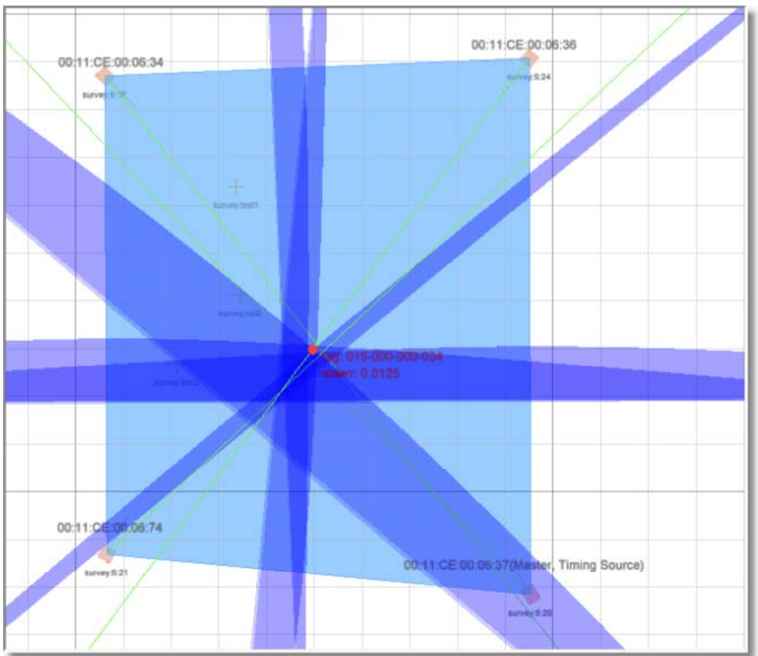


Figure 26 Scheme depicting the radio signal transmission when an occupant is wearing a tag and his/her movements are being tracked.

Every time an occupant entered the virtual parallelepiped zone or moved or stayed in any of the defined areas, this was tracked and recorded on the computer. Then, by comparing the data from the monitoring system energy sensors, when the hours of the use of the appliance or stay in a specific room coincided, that energy consumption could be attributed to that occupant. This enabled the researcher to quantify the relationships between occupancy and energy usage, and calculate each individual footprint.

Quick simulation studies and spot measurements

Simulations and spot measurements were used as quick verifying tools to complement observations and walk-through with quantitative tools with specific parameters with specific features of particular software. The sunspace and sun orientation are key features that influence the quality of natural light and comfort among occupants of homes, especially in wintertime in the UK.

Steps to determine the daylight factor to contrast with the occupants' observations

- Definition of the parameter for analysis: lighting
- Creation of the model for simulating a known software package and use of the tool for the defined parameter to carry out calculations for the same day/days that the spot measurements are going to be taken
- Identification of all the areas related to a quick daylight factor test on a day in winter
- Taking of spot measurements with a lux meter, as the protocol indicates; in the middle of each area at a table/working surface height (approximately 90 cm); for the kitchen, measurements were taken in two spots. These were taken at four different hours of the day in all the rooms and in two spots in the exterior, in the northern and southern areas adjacent to the house
- Recording of the level of natural light in lux on the printed plan view of the house
- Contrast of the measurement with the occupants' observations

Upton Homes: Ten volunteer families

As has been previously described in Chapter 1. Introduction, ten homes from the Upton homes development in Northampton were used as case studies; these homes become occupied in late 2007 and 2008 and these ten families, out of 100 consulted, volunteered to participate in this study. At the time of the study, most of the occupants had lived more than a year in their energy homes and this was their first or second winter in them. These case studies addressed the research questions and hypothesis, from a completely different approach and perspective; therefore the monitoring tools, techniques and procedure to process the numerical data were not as in-depth as those used in the BASF House. This study was also part of a major research project, so it also had to respond to other research purposes. It is also important to stress the University of Nottingham's protocol with regard to any study with human subjects, with which it was necessary to comply.

For this particular study a small trial was carried out on the use of monitoring technologies, such as energy meters, with real time display devices to test their possible influence on behaviour among home users in regard to energy consumption in recently built sustainable homes. A further goal was to evaluate four different types of energy meter offered on the market.

The real-time energy meter study general procedure (numerical and textual data)

- Application of survey 1 – list of volunteer families – 100 questionnaires delivered, 50 replied, 12 volunteered, 10 volunteers chosen (SHINE project 1)
- Selection and pre-evaluation of four real time energy meters
- offered on the market (SHINE TRUE project 2)
- Testing of the four real time energy meters
- Calendar programming of the meter installation in each volunteer home following the University of Nottingham protocol for studying human subjects
- Definition of the trial period (6 weeks total)
- Weekly downloading of data from Wattson energy meter, in parallel weekly application of survey 2 – "energy meters-energy matters"
- One questionnaire was provided for each energy meter and one questionnaire to compare them
- Programming of the verbatim interviews with a member members of each the ten volunteer families (textual data)
- Analysis and processing of quantitative, Wattson energy meter datalogged data with SPSS and qualitative data, questionnaires with SPSS (Statistical Analysis) and interviews with NVivo (Grounded Theory)
- Elaboration and contrasting of results and discussion

SPSS tool for the numerical data processing

After feeding the data in the program following all the step to identify the variables and give then the correspondent value based on the objectives of the study, the running of the programme will processed the data and the first analysis will always be a descriptive one or basic statistical analysis, these will constitute first results and can also be done manually using more simple software or a excel spreadsheet. Then, to understand the results further especially when the research is related to human behaviour, the association between variables is the following step within statistical procedures, Pearson correlation or Cluster analysis are typically used to explain certain findings related to people's behaviour, when the first one do not enhance the results, the second one or others can be applied.

Pearson Correlation

For the study in Upton homes the seeking for associations on the power consumption among the different users the association of variables using Pearson correlation was applied, as a typical approach to process data within a descriptive statistics. The correlation is a number between -1 and +1 that measures the degree of association between two variables. A positive value for the correlation implies a positive association. A negative value for the correlation implies a negative or inverse association. For the correlation a bilinear significance of 5% was used.

Clusters Analysis

> "Cluster analysis divides data into groups (clusters) that are meaningful, useful, or both. If meaningful groups are the goal, then the clusters should capture the natural structure of the data. In some cases, however, cluster analysis is only a useful starting point for other purposes, such as data summarization." (Kaufman, 1988)

There have been many applications of cluster analysis to practical problems on different fields. For this study the purpose of the clustering is to understand meaningful groups and/or classes within the seven users that share common characteristics to explain the data recorded and comprehend the results obtained in regard to the consumption of electricity. The visual representation of clusters is a dendrogram presented in a standardised way based on the Pearson distance, which associates proximity among the data that portrays power consumption by the users. When the distance is changed to an Euclidean metric, the new dendrogram depicts a high level of association among subjects on study.

3.4.2. Collection of textual data

The collection of textual data for both cases studies was done by applying within the POE several tools and techniques from social science and humanity methodologies oriented to analysing qualitative data. All the quantitative data from the **survey** collected through different **questionnaires** for the two case studies has been analysed with a computer program used for statistical analysis, widely used by researchers from the social sciences and humanities: SPSS (originally, Statistical Package for the Social Sciences). The results obtained have been used to gain a deeper understanding of the issues related to the occupancy of sustainable homes in a more holistic way within the research problem. The main objective was the evaluation to assess how well homes performed for those who inhabited them, in terms of their health, functionality, psycho-physiological comfort, safety and security and to have an understanding of how a sustainable energy home could be perceived by the general public. The qualitative data explains the numerical results in-depth, through the occupants' evaluation and perceptions from the general public. To process the **verbatim interviews,** the NVivo software was used. This helped to facilitate the qualitative analysis based on the Grounded Theory to understand the more profound meaning of living in a sustainable home and energy usage for any occupant. While tools such as **observations**, in a written form or a diary of events, architectural drawings and sketches, building construction specifications, info-graphs and photographs were being continuously used during the process of this study to complement and explain findings.

The BASF House questionnaires

To live in a home that is part of a showcase complex and is open to the public to visit two or more times a month because of being a "research sustainable home, code level 4" offered the author a valuable opportunity to explore the topic of energy efficiency and sustainability in homes from two perspectives. The first perspective related to the public's awareness about these issues, gleaned from visitors to the home, while the second was the occupant's perspective, gained as a result of the experience of inhabiting a sustainable home. Two questionnaires were created to respond to the research questions. The first related to the public's awareness about energy efficiency and the second to the satisfaction among the users of a sustainable home. The questionnaire for visitors was also designed to find out about the general knowledge and preferences the general public has regarding energy efficiency design and the technologies applied to sustainable homes in the UK and subsequently the willingness of individuals to make changes in favour of reducing carbon emissions. In parallel, the questionnaires for the occupants of the BASF house focused on the building performance and user satisfaction, to complement the quantitative analysis obtained through the parameters measured with the monitoring system.

The questionnaire for visitors to the BASF House was voluntarily and consisted of a simple, two-page leaflet with four sections on demographic information, the BASF house design, technologies and general questions, including 36 tick box questions (see appendix 7). The objective was to understand the visitors' general appreciation, knowledge and awareness of a recently built sustainable home based on a one-hour visit guided by student monitors from the University of Nottingham's Department of Architecture and the Built Environment. The answers to the questionnaire were transcribed into the SPSS software contemplating all the procedures for transcribing and classifying variables. First, questionnaires were divided into two main groups, questionnaires with 100% of responses from the ones with less than 100%. Second, another subdivision was identified: questioners completed by people who are related to the built environment and architecture, identified as "BE", and everyone who does not have any sort of connection to these areas in terms of their profession, studies, research or work, identified as "NBE". However, when findings needed further analysis the whole set was to be considered to corroborate the tendencies and validate the results.

The questionnaire given to the occupants of the BASF contemplated similar questions to the one given to visitors, however it included all the questions related to the experience of living in a sustainable home. It contemplated that respondents must have lived for at least a month in the BASF house, preferably a winter month. The purpose of the questionnaire was to evaluate the BASF house from a qualitative perspective, since its performance was being evaluated through numerical data. So the objective was to establish how comfortable the house was to them, in terms of its thermal, lighting and acoustic characteristics, by evaluating the architectural quality of the interior spaces as well as the passive design strategies and SET implemented in the BASF house.

For both questionnaires the analysis used the same descriptive procedure. The statistical analysis has been divided into two stages: stage one involves a descriptive analysis to define the demographic profile of those polled and to depict the knowledge about and the most popular preferences regarding the passive design strategies (PDS) and sustainable energy technologies (SET) applied to the BASF house. Then, a test of the independence of selected variables was applied to establish a statistical dependence between variables and related topics. The second stage involved a predictive model, where by using some independent variables, it was possible to predict answers based on selected variables.

The perceptions, evaluations and comments done by occupants on the BASF house were also transcribed and contrasted with the statistical analysis. For all the questions, a table of frequencies was applied. All the results are graphically presented and discussed.

The Upton home questionnaires and verbatim interviews

Two types of questionnaires were designed for occupants of Upton homes for the energy meter trial to be completed on a voluntary basis. The questionnaire consisted five pages of double-sided A4 (see appendix 19), which was created by the author, with the objective of understanding the residents' general preferences regarding the four different energy meters covered by this study and most important was to test their possible influence on behaviour in regard to energy consumption among the occupants of recently built sustainable homes.

There was a more or less identical questionnaire for each of the four energy meters. Each questionnaire had nine sets of questions and respondents were asked to tick where appropriate. All the questions focused on the experience of using the device for a week and how the occupants evaluated each device. The author ran the same evaluation for the questionnaire for each of the devices. Attributes such as design, display, setup, user manual, clamp, and transmitter had to be graded on a scale of one to five, where one represented meant the person disliked the attribute in that device and five meant they liked it. Some other questions asked for simple 'yes' or 'no' answers, other questions had the purpose of declaring preference or use of an attribute on the energy meter using a typical 'Livert Scale' that ranged from 1 for 'dislike' to 5 for 'like', or within five options from 'all the time' to 'never', the questionnaires also included short open questions.

For instance, question 8 asked: "Did you use historical readings on the Smart Meter?" There were three questions that were directly oriented to respond to the research objective of the study, and responses to these questions were expected to help assess the behaviour of the occupants in regard to energy consumption:

> "5. How often did you look at your consumption display on the Smart Meter per day?

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☐	☐	☐	☐

6. Did the Smart Meter have an impact on your energy consumption behaviour?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☐	☐	☐	☐

If YES how? ____

7. Did you look at your consumption display on the Smart Meter every day?"

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☐	☐	☐	☐

The fifth questionnaire was the "general smart meter questionnaire" and was divided into three sections: A. general evaluation, B. energy consumption and expectations and C. comparison of the different devices; i.e. preferences. This fifth questionnaire had 13 questions, of which 11 were directly oriented to the main objective of the study. These questions were all to be responded to in the same manner; the occupants had to tick the chosen alternative out of five choices ranked from 'highly agree' to 'highly disagree', as shown in the following example of question four:

"4. Do you think the use of a Smart Meter could change your awareness of the way you use energy?"

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☐	☐	☐	☐

The survey procedure

The survey began on 02/02/2010 and ended on 20/03/2010. All the questionnaires were left with occupants for a week, to be collected the following week when the energy meter was substituted for the next one to test. This methodology attempted to obtain 100% responses to the questionnaires; therefore ten questionnaires were distributed for each energy meter and ten for the general questionnaire and comparison. The completed questionnaires were then collected and analysed with the same methodology used to analyse the data obtained from the BASF house questionnaires, using the software SPSS for the statistical analysis.

The author visited the ten homes weekly during the entire period of the survey. All the bookings for visits normally started at 16:30 every Tuesday, to ensure the residents were at home. Account had to be taken of the fact that sometimes occupants would not be home or did not want to be disturbed; or they lost interest in the study and therefore did not complete the questionnaires. The last visit was to remove the energy meters and to carry out the verbatim interviews.

The interview procedure

The face-to-face interviews were undertaken by the author on different days during the month of April. Four open questions were put to seven interviewees out of the ten occupants of the Upton homes who were available and who agreed to be recorded. The interviews looked at:

- The possible influence of the energy meters on their energy consumption habits and energy usage awareness.
- The importance of having one energy meter at home. They were asked if they would be willing to buy one.
- The limitations of the energy meters and possible improvements that could be made.
- Their experience with the meters during the trial period, in terms of helpfulness, recommendations, use by the whole family etc.

These interviews were analysed with software as a tool to aid the methodology. The software NVivo[13] is a qualitative data analysis (QDA) computer software package produced by QSR International. It has been designed for qualitative researchers working with very rich text-based and/or multimedia information, where deep levels of analysis on small or large volumes of data are required. The software is very helpful to non specialised users to aid them to organise and analyse almost any sort of non-numerical, qualitative or unstructured data. This data information can be classified, sorted and arranged with the use of the software; examining data relationships, combining analysis, shaping, searching and modelling of the qualitative data. The goal is then for the researcher to test a theory.

[13] http://en.wikipedia.org/wiki/NVivo

Strategy for analysing the results

The Grounded Theory, which generates theory from data was applied to analyse the results. This works by applying a number of procedures through induction to generate a theory regarding the phenomenon under study.

The construction of base theories rests on the elaboration of explanatory and/or comprehensive models. The conceptual bases are built on the empirical data. This process involved three analytical actions. However, for this particular section of the study, only two of them were taken into consideration: the open coding and the axial coding; as to use a selective coding seemed excessive for this case. These actions occur in a sequential manner, while their coding could be done in a superimposed manner (Strauss and Corbin, 1998).

<u>Open coding:</u> This is the first stage of the analysis and is based on inductive logic. It involves

> "breaking down, examining, comparing, conceptualizing and categorising data" (Strauss and Corbin, 1990).

<u>The examination of data in order to fracture them and generate codes could proceed "line by line" (this is the most tedious method, but also the most generative one and it is therefore often recommended in the initial phases of analysis), by sentence or paragraph, or by a holistic analysis of an entire document.</u>

The open coding process, while procedurally guided, is fundamentally interpretive in nature, and grounded theory researchers

> "must include the perspectives and voices of the people"

whom they study (Strauss and Corbin, 1994). The main objective is to discover the concepts ("abstract representation of an event, object or action") derived from the literal transcription from the recording of the verbatim interviews (Appendix 20). The data is examined and compared to seek for similarities and differences. The concepts are phenomena identified with a designated code. Therefore, concepts are abstract representations of the events, occasions, objects and actions (or interactions) expressed by the subjects. The common characteristics and the related meanings of these events, occasions, objects and actions (or interactions) allow them to be grouped into concepts. Once the concepts begin to accumulate, the analysis should start the process of grouping or categorising under more abstract explanatory terms, in other words forming categories. This process is always carried out in a dialogue with the theory and the objectives of the research. In this way, this analysis becomes a technique for coding categories. Then the names the concepts are coded under will be subject to the context where the event, object or action took place. Table 35 is a summary of the different stages and their purposes, as explained above.

Table 4 The different stages and their purposes

STAGE	PURPOSE
CODES	Identifying anchors that allow the key points of data to be gathered
CONCEPTS	Collections of codes of similar content that allow the data to be grouped
CATEGORIES	Broad groups of similar concepts that are used to generate a theory
THEORY	Explanations that explain the subject of the research

Axial Coding

The purpose of this analysis is to begin the process of regrouping the data that was fractured during the open coding. Therefore, the open coding has to take place before the axial coding. The axial coding can be done in parallel with the open coding. However, it is recommended that several categories be identified before starting with the axial coding. Axial coding in Grounded Theory is the process of relating codes (categories and concepts) to one another, by combining inductive and deductive thinking. The analysis of categories is related to their subcategories and to other categories. Thus, more precise and complete explanations about the phenomenon under study can be found. The subcategories have the power to offer explanations by answering questions like when, where, why, how and what are the consequences of the actions/interactions related to the phenomenon. This allows the relationship between categories to be discovered. As a consequence, this type of analysis seeks to generate comprehensive models from the different aspects the data can show. When analysing the data, it is possible to observe two levels of explanation: the interviewee/informant through their own words, and the conceptualisation of the researcher of what the interviewee is saying. The interviewees are able to explain when, how, with whom and where the event happens, and the researcher then offers an interpretation of the events by explaining what is going on for that particular situation, since he/she is searching for answers to questions such as why it happens, where, when and what the results are. These questions enable relationships between the categories to be found. With this coding, it is then possible, to develop a scheme to facilitate the comprehension of a phenomenon and a central category can be identified. This scheme applies three types of conditions related to that phenomenon: causal, intervening structural and context conditions, actions and consequences.

The basic framework of generic relationships is understood, according to Strauss and Corbin (1990, 1998), who propose the use of a "coding paradigm", to include categories related to the following:

· **The phenomenon:** is the central idea. This is what is occurring, an event, an act to which the actions and interactions refer.

· **The causal conditions:** the set of events influencing a phenomenon

· **The intervening conditions:** are the conditions that mitigate or alter the impact of the causal conditions influencing the phenomena. They are the structural conditions that influence the actions and inter-actional strategies directed at managing or handling the phenomenon. They facilitate or interfere with the strategies implemented within a specific context.

· **The context conditions:** are a set of specific conditions that intertwine in the dimensions of time and place to create a set of circumstances or problems, to which people respond to through actions or interactions. Within these conditions a phenomenon takes place.

· **The actions/interactions:** strategic or routine tactics or ways directed to manage and handle different situations, problems or matters people are exposed to. In a way, the actions to solve these situations are acts that help to shape the phenomenon. The routine tactics are more habitual actions that respond to problems from everyday life. The actions are directed to goals and carried out by agents in response to a phenomenon and the intervening conditions.

· **The consequences:** are the results of an action/interaction or absence of them in a relationship to a phenomenon; they could be searched or unsearched.

· **The context:** is the set of specific properties where the phenomenon occurs.

Strauss and Corbin, 2002 suggest that the important part of this process is not to identify or enumerate causal, intervening and contextual conditions; rather the analyst should direct attention to the complex framework of happenings (conditions) that lead to the generation of problems, issues or events to which people respond with action/interaction, with some type of consequences. By considering the above the researcher is able to identify changes that occurred to the original situation which happen as a result of actions and interactions.

Other qualitative analysis tools

Observations in written form and graphics (plans, sections, perspectives, axonometric drawings, sketches, infographs and photographs) are one of the most important tools for an architect to pursue architectural analysis and research. During the entire process of this study, the author has relied on these tools to complement results, findings and graphically represent the proposal. Also, seeking and analysing building construction specifications is fundamental to building up the information, producing post construction simulations and researching technical aspects of architecture.

For the following chapters 4, 5, 6 and 7 it will be shown the most important results obtained from the application of tools and techniques used in the mixed methodology used in this thesis, some of the tools that did not report interesting results to address the research problem are described in different appendixes and the most important lessons learned from this methodological approach are included in the chapter 8 on general conclusions of this study.

Chapter 4. The BASF House Datalogging System – Numerical Data Analysis

This chapter and the subsequent one are the first part of the in-depth case study of this thesis, while chapters 6 and 7 are part of the Upton homes case study. The sequence of these four chapters is structured in a similar way. First chapters 4 and 6 narrate the information, present the results and discuss the numerical data for each case study. Then chapters 5 and 7 narrate the information related to the textual data for each case study.

As mentioned in Chapter 1. Introduction, the BASF house is an experimental sustainable home built on the main campus of the University of Nottingham (figure 15). As mentioned before, the author moved to live in the house after it had been built. The author therefore did not have any influence over decisions related to its design, construction, the appliances installed nor on the monitoring system type and specifications. The chapter focuses on the study of the performance of this home during the winter periods of 2008-09 and 2009-10, taking the month of February for the first winter and from December to March for the second winter. February 2009 was the first full winter month with regular occupancy (three adults) in the home and in which reliable data for analysis was logged; previously the monitoring system had required calibration. The monitoring and control system implemented in the house was a pioneer system, which required continuous testing and adjustment for at least a month in order for the data to be sufficiently robust. The quantitative data was obtained through the 48-sensor monitoring system for indoor climate and energy usage, as presented in previous chapter 3. In parallel, the qualitative data, which will be presented in the subsequent chapter, was obtained from questionnaires, verbatim interviews with occupants and the diary of events of the BASF House.

4.1. The BASF House – An Experimental Sustainable Home

This first section presents data for the space (space heating, SH) and water heating (WH) systems of the house for two consecutive winter periods, a sample of four weeks, starting on 30/01/2009 and finishing on 26/02/2009, and a sample of four months, from 01/12/2009 to 31/03/ 2010. These are the periods where space and water heating demand reaches its peak points. A weekly analysis of the biomass boiler efficiency has been established, and the energy delivered will be contrasted with the energy consumed (electricity and biofuel) by the biomass boiler. Also, an energy consumption comparison will be presented, between the biomass boiler and the other electrical appliances, including the immersion heater of the solar system and local electrical heaters, all of them used during wintertime to provide the needed hot water and space heating to secure comfort for occupants.

The main objective of this part of the study was to investigate the performance, focused mainly on winter periods, of a biomass boiler and the mechanical ventilation systems, Ground Air Heat Exchanger (GAHE), installed on a well-insulated and air-tight home. Three questions arise from this objective:

- Are biomass boilers the most appropriate technology to provide the residual heat load for a Code Level 4 home?
- Are mechanical ventilation systems, such as the GAHE, the most appropriate for a Code Level 4 home, like the BASF house?
- What is the efficiency of these LZC technologies on a Code Level 4 home?

The BASF House has been designed to promote sustainable development; it has been built according to the German ‘PassivHaus’ Standard in Europe (basic principles) and to reach Level 4 in the UK Code for Sustainable Homes (CSH). The house is designed to function as a conventional home and act as a prototype for new housing in the UK. The BASF House is the product of a collaborative effort by BASF (project sponsor) which supplies raw materials, Derek Trowell Architects (a local design firm from Nottingham), and the University of Nottingham. The house is currently occupied by PhD students who are pioneering innovative user control systems as well as testing renewable energy technologies, whilst monitoring every aspect of the house’s performance.

The main objectives included in the design brief of the BASF house were to achieve energy efficiency as close as possible to a zero carbon emission home and to do it in the most economical way, relying primarily on passive design features. The BASF house is a prototype for an affordable terrace house scheme and its major passive design feature is the south-oriented sunspace as can be seen in figure 27, as the thermal engine to control passively the occupant’s demand for heating and ventilation.

From an architectural perspective one of the most important architectural features of the BASF House is that it is compact and hermetic (for architectural plans and sections refer to appendix 15). Besides responding to Level 4 CSH and PassivHaus standards, from the point of view of performance, its compactness responds to energy conservation, as well as to the need to produce an affordable sustainable home solution for a terrace housing within a restricted area. This aspect also brings up issues relating to fast and easy to build construction, modularity and simplicity.

Figure 27 The sunspace of the BASF house

The hermetic feature is achieved through understanding the climate and using appropriate materials for the contextual climatic conditions. These design decisions are undertaken to produce a high quality thermal envelope where fenestrations and sections are carefully thought through in order to obtain good natural light quality as well as indoor air quality. The pictures in figures 28 and 29 in next page were taken in the afternoon on two winter days, one on 23/11/2010 at 4:51 pm and the other on 12/11/2008 at 2:26 pm respectively. On sunny days, the light quality is really appreciated, especially after many short overcast days.

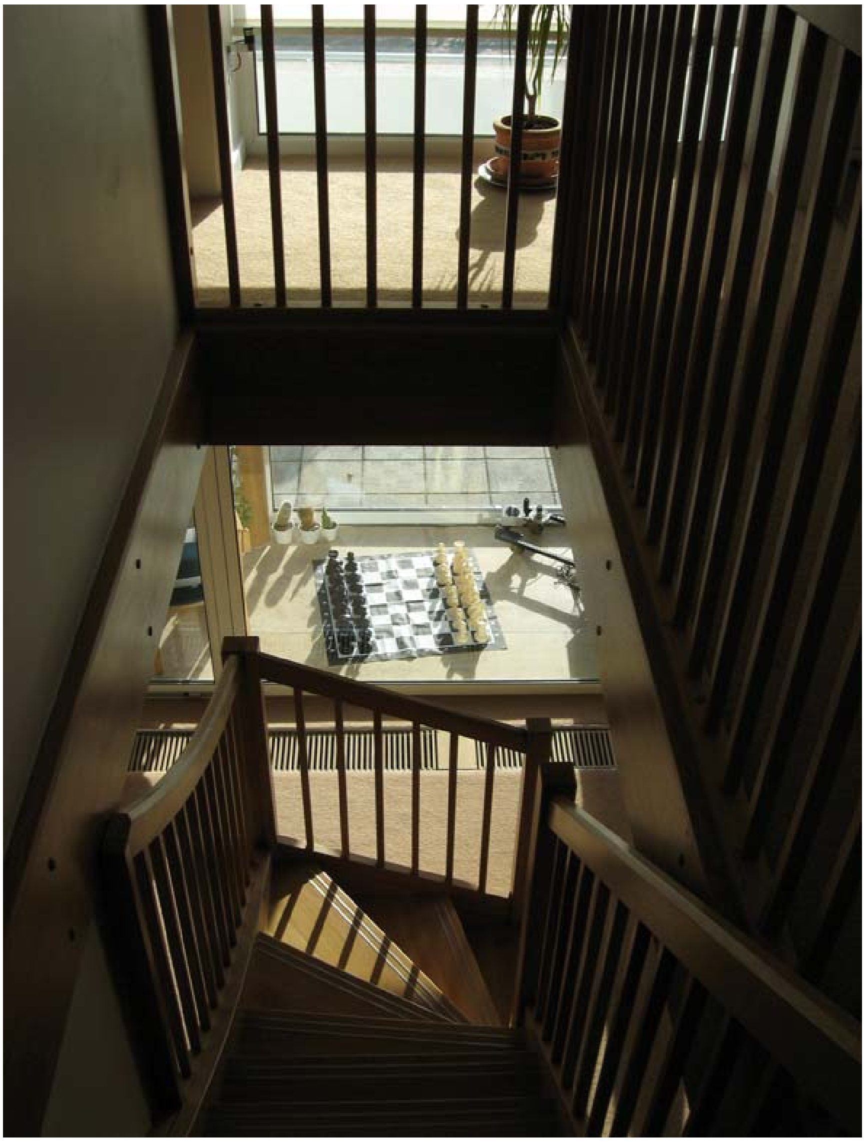


Figure 28 BASF House interior picture taken on 12/11/2008 at 2:26 pm from the top landing of the stairs.

The proportion of height versus the footprint produces the apparent extension shown in figure 30, which is reiterated as an interior language, expanding the compactness and reduced area by amplifying the interior to the exterior. As can be observed in figure 89, this is achieved with the shallow section and the light bridges that are created by the east and west fenestrations.

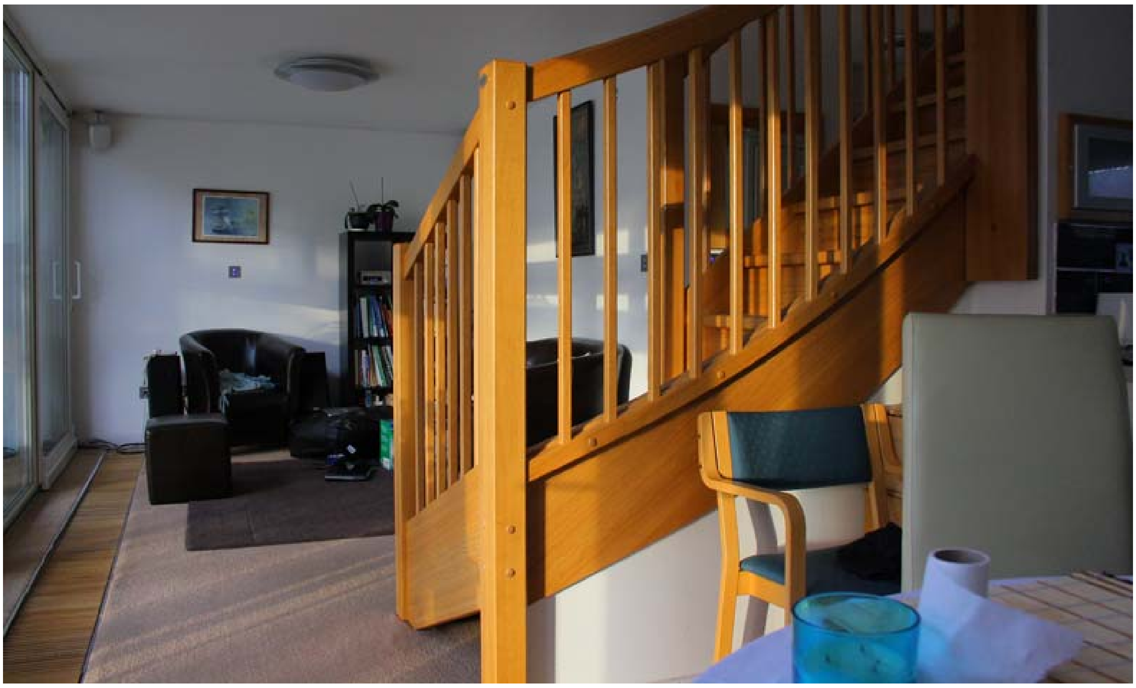


Figure 29 BASF House interior picture taken on 23/11/2008 at 4:51 pm from the south east corner of the dining room at the ground floor.

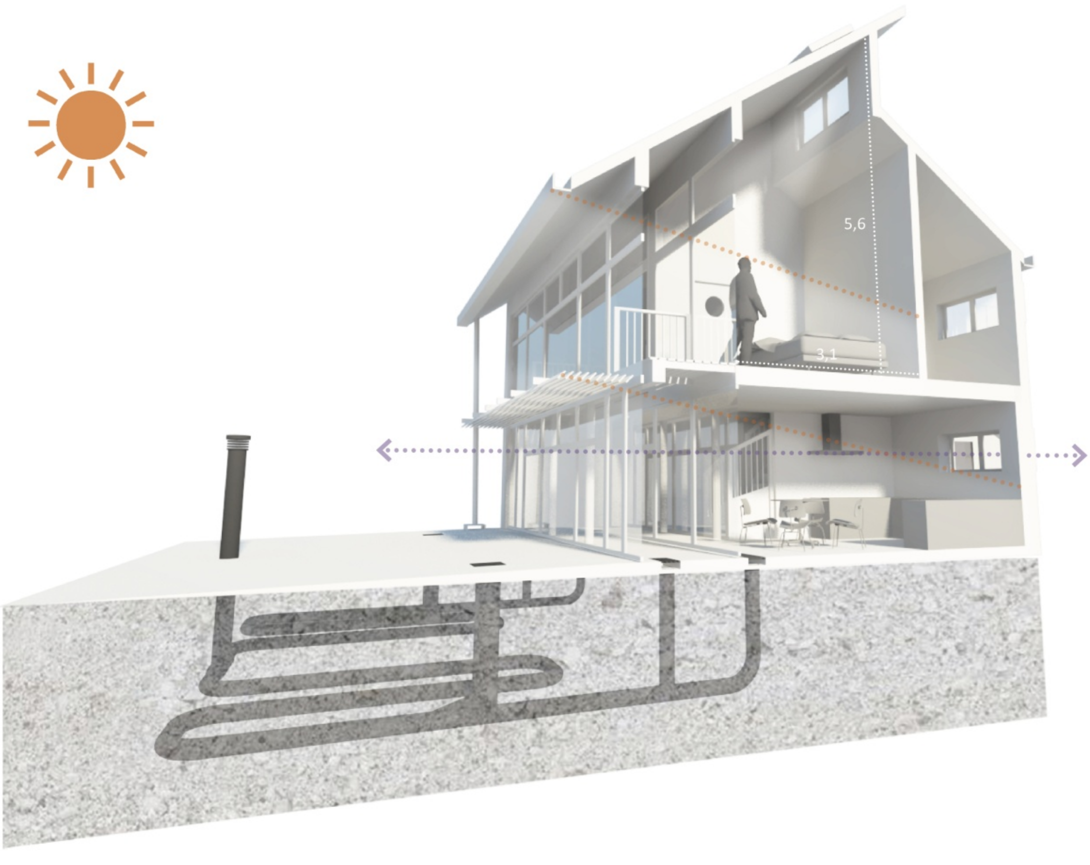


Figure 30 Scheme of the south-north section depicting the effect of amplification of the shallow section, and the reach of the sunlight on a winter day.

The house is based on a compact design and simple geometry to achieve the most continuous and airtight envelope. The height of the house was designed to aid natural ventilation by stack effect to achieve thermal comfort, as shown on the following scheme in figure 31 in next page.

Figure 31 Scheme of the natural ventilation passive design feature of the BASF house

Figure 32 Northern façade of the BASF house

Besides the south-oriented sunspace, the BASF House has high levels of insulation incorporated into its envelope, small fenestrations on the northern façade, as can be observed in figure 32, good air-tightness and a natural ventilation system. It also possesses other renewable energy and low carbon technologies and materials to enhance its energy performance.

The renewable energy technologies include a ground-air heat exchanger (GAHE), a biomass boiler, a solar water heating system, and a water conservation and rainwater harvesting system, shown in figure 33. For construction materials, BASF has provided insulation solutions, insulated concrete formwork (ICF) for the floor, and ground floor walls and structural insulated panels (SIP) for the first floor, standing steel cladding for the roof coated with a solar reflective pigment, encapsulated phase change materials (PCM), 'smart board' for one of the partition walls and ceiling and permeable paving among other features.

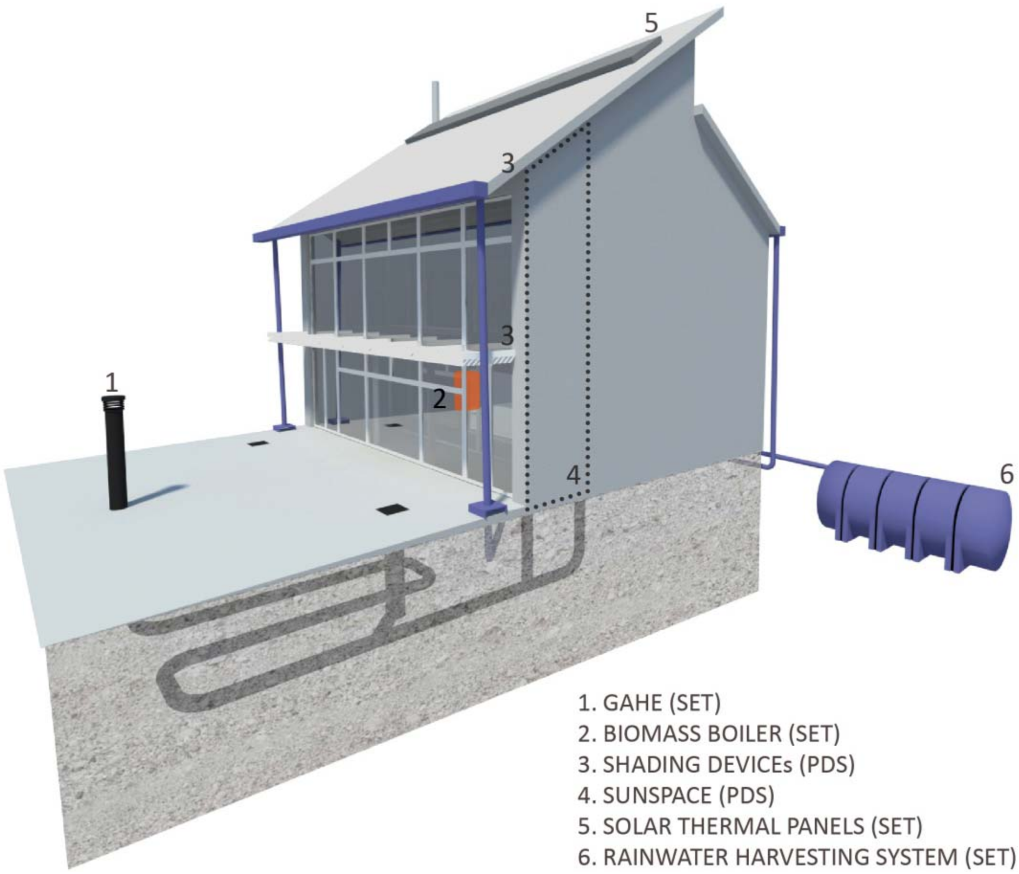


Figure 33 Scheme with the most relevant passive design strategies (PDS) and sustainable energy technologies (SET) of the BASF house.

The thermal characteristics of the construction materials used for this house are key for achieving the expected performance.

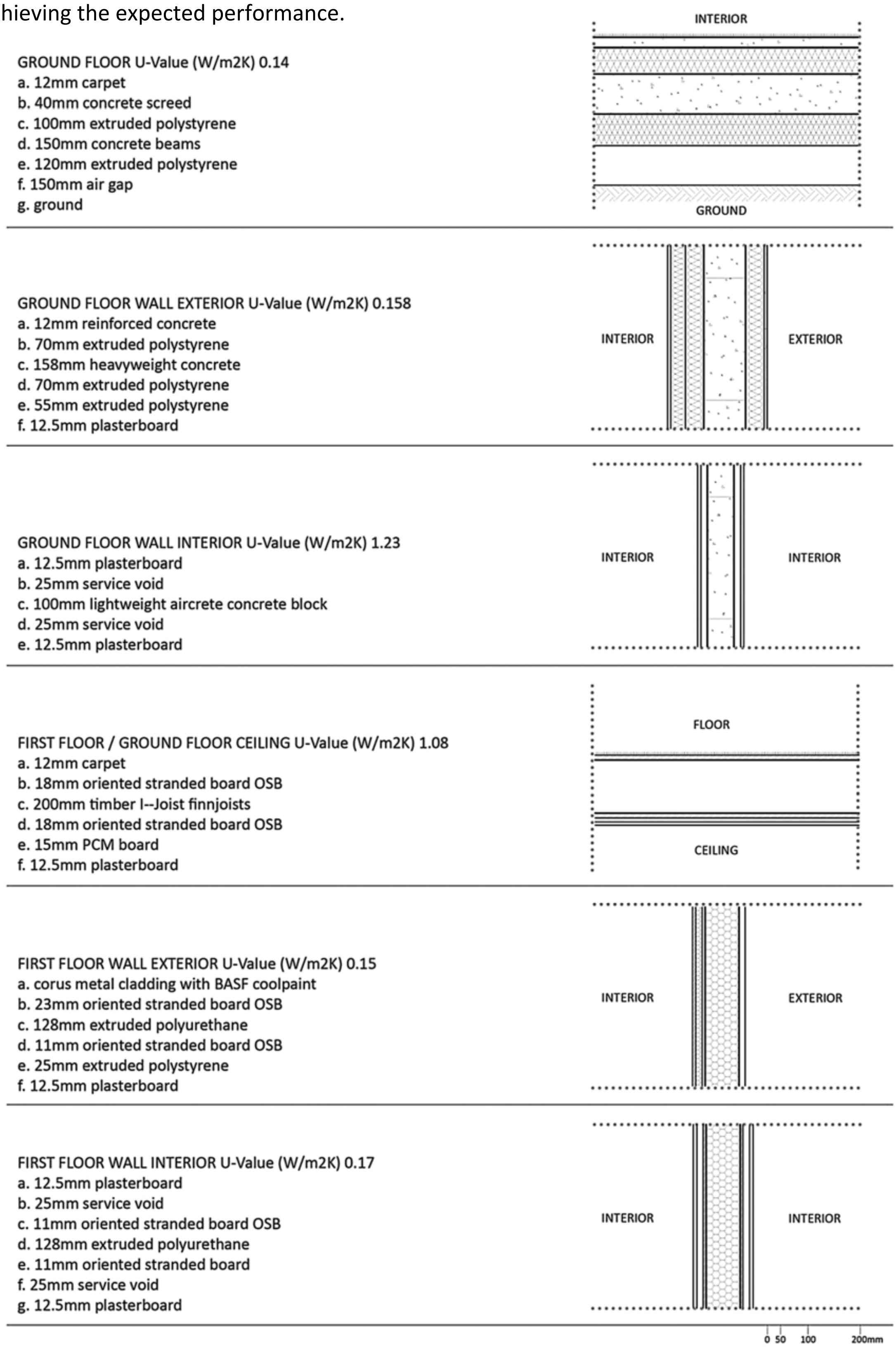


Figure 34 Walls, floor and ceiling sections of the BASF House (drawing source: Lucelia Rodrigues, 2009)

The U values for the different components of the envelope are; for the walls and roof, 0.15 W/m²°C; for the southern façade conservatory, the internal double glazed curtain wall 1.7 W/m²°C and the external double glazed curtain wall, 2.7 W/m²°C; and for the northern façade double glazed windows, 1.66 W/m²°C. Figure 34 shows the graphical specification for all the opaque construction details related to the high thermal quality envelope of the BASF House, which are the most influential aspect to obtain a good thermal performance especially for the wintertime period Beyond the thermo-physical characteristics of the construction materials used in the BASF House, the scheme in figure 35 (3 schemes) represents how the BASF House is in itself a heavily insulated jacket, where the main activities of the household are nested within this protective layering, in the same way clothes protect our bodies from the elements.

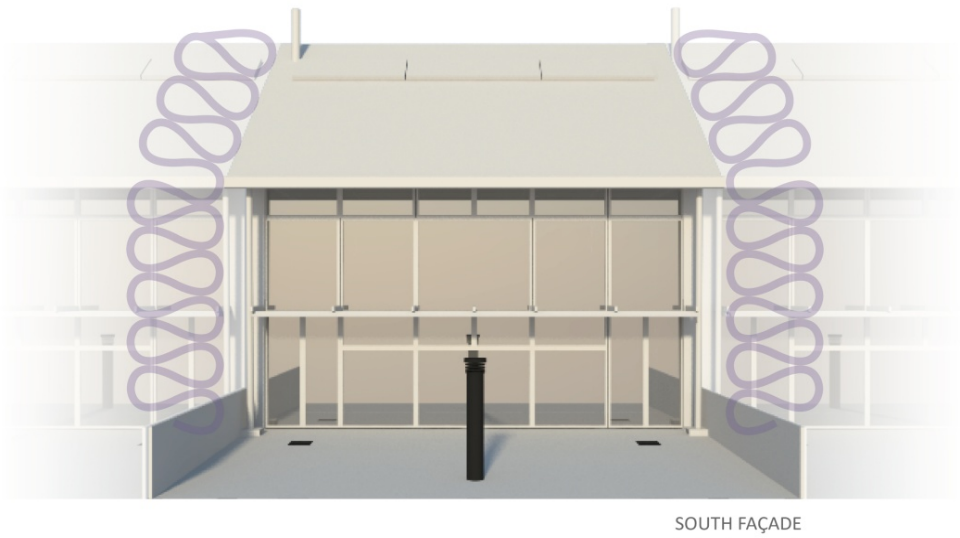


Figure 35-A Scheme of the south elevation depicting a super insulated envelope

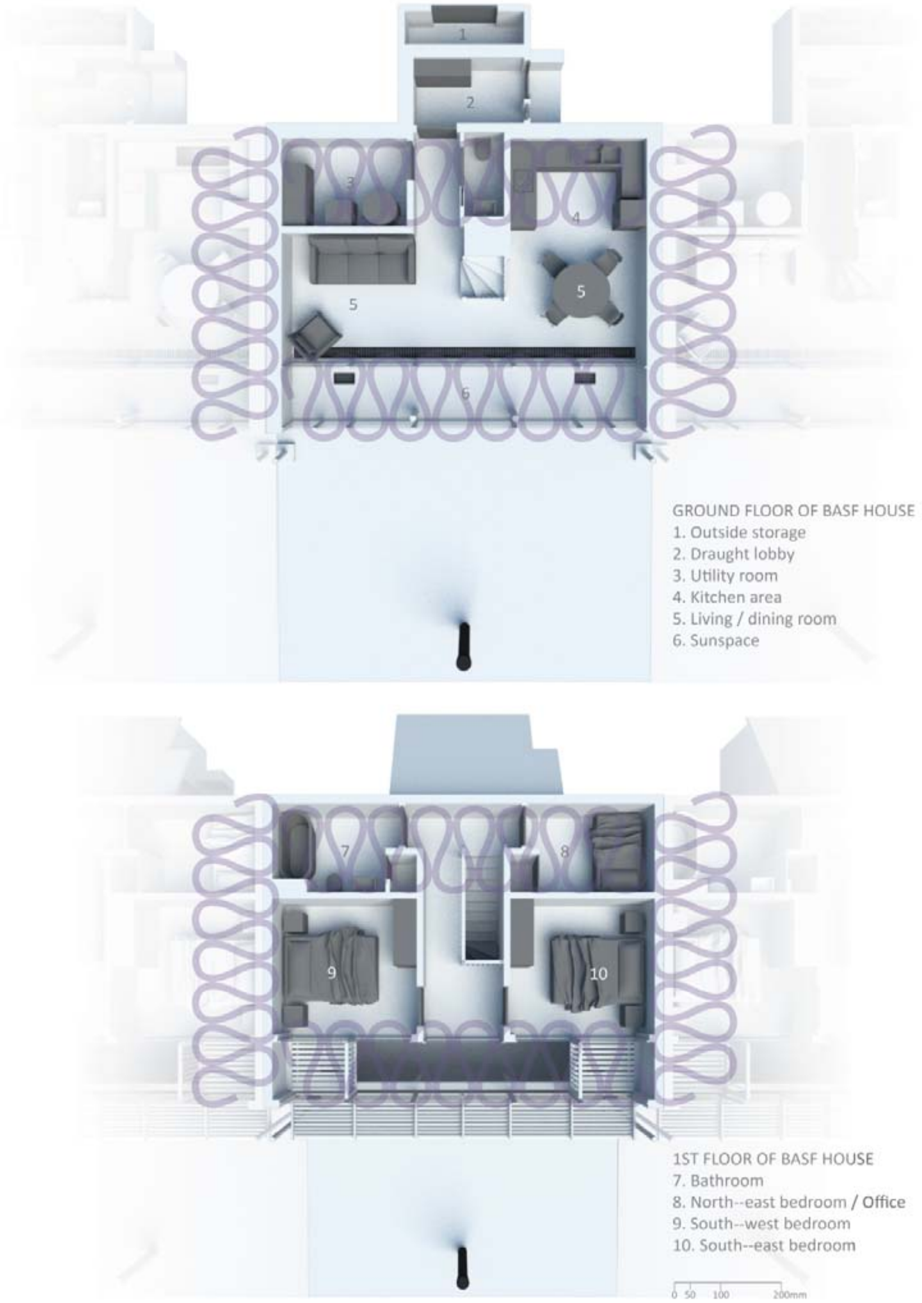


Figure 35 Scheme of the plan view of ground and first floors and south elevation depicting a super insulated envelope

Since June 2008, the house has been occupied by three adults. One of them, the main author of this thesis, did not have any influence over or involvement in the decisions related to the design of this experimental energy home (architecture, construction, installation of SET or monitoring system, etc.). The thesis studied the occupants' comfort and the performance of some of the renewable energy technologies, whilst monitoring every aspect of the house's performance in regard to energy consumption and the daily events related to it. The house employs a monitoring system of 48 meters designed and provided by a private company for the CEH project. It has a touch screen in the kitchen, which acts as a control panel and reports on energy usage and the indoor climate (figure 36). The system enables the occupant to control which spaces require heat, light and ventilation, and informs occupants of the instant reading on energy consumption both globally and by individual appliance. While all these operations are being recorded by the monitoring system, the system also allows certain settings and operations, like opening windows and turning lights on/off, to be automated and controlled online.

Figure 36 The touch control panel and one of the occupants of the BASF house, located in the kitchen

The hybrid water and space heating system of the BASF House

For the BASF House to reach the CIBSE recommended comfort criteria for homes in wintertime it was necessary to enhance the passive design features with heating technologies (figure 37). Therefore, to cover the residual heat load for winter, a biomass boiler was installed. In winter, the biomass boiler delivers its heat through a trench eight metres in length located on the ground floor, along the dining and living rooms, and two radiators located on the first floor, main bathroom and north bedroom respectively. The two south-facing bedrooms do not have radiators. It was expected that the heat would ascend from the ground floor and travel horizontally from the first floor, which implies that the south-facing bedroom has to have its doors open.

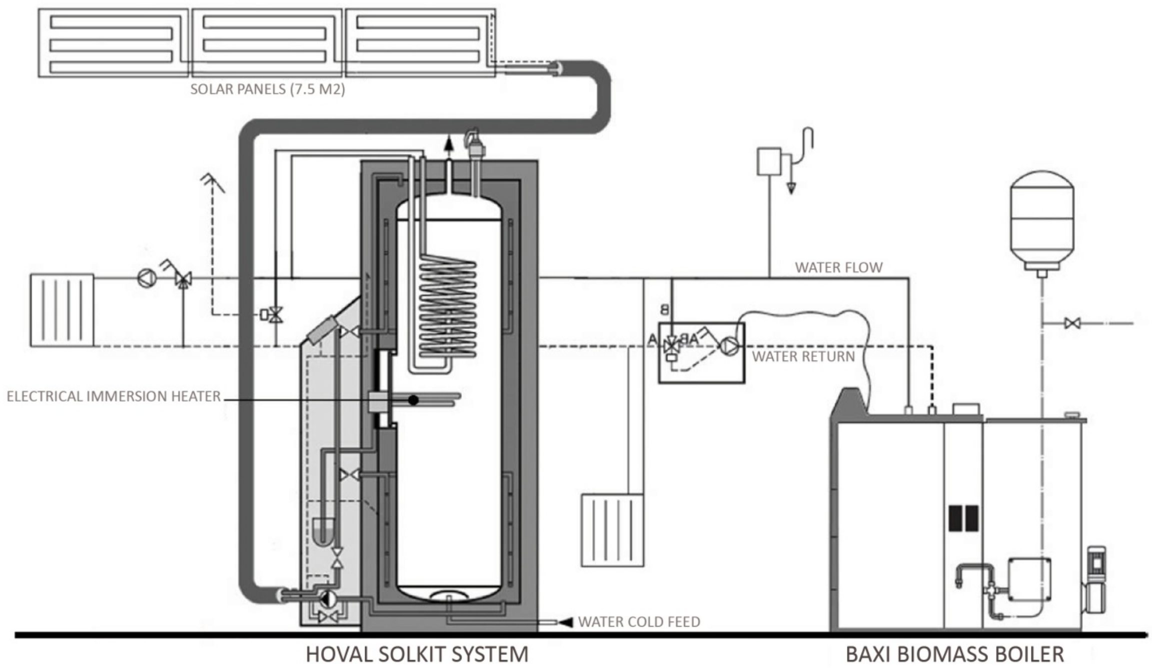


Figure 37 Scheme of the biomass boiler and the solar thermal combined technologies of the BASF House.

As stated by BASF (2007), the objective in regard to the heating load was:

> “to reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand. [And]… This will also provide an additional hot water supply on winter days... The BASF House will be using a boiler which runs on renewable energy from the waste meal of rape seed… locally grown biomass…” (BASF, 2007).

For the solar water heating system it states:

> “Solar power will provide up to 80% of the hot water using Hoval’s Solkit® solar system... This is a compact system for solar-powered domestic hot water (DHW) generation. It is combined with solar collectors… 470 litre DHW capacity” (BASF, 2007).

For the passive and Mechanical Ventilation Systems, the house relies on a Ground-Air Heat Exchanger (GAHE):

> “one of BASF’s key partners in the project was REHAU who supplied their Awadukt Thermo® ground-air heat exchanger system for controlled ventilation. Fresh air is drawn through an underground network of pipes and is then either pre heated in the winter or pre cooled in the summer by exploiting the energy stored in the ground” (BASF, 2007).

There is one inlet pipe in the south garden area in front of the sunspace; this pipe detours into four pipes, the air is conducted through the serpentine formed by the four pipes to four outlets located in the interior of the house. There is an indoor pair with one outlet into the dining room and the other into the living room, while the second pair has one outlet on either side of the solar space, as shown in figure 38.

"During cooler months, the air entering the solar space will be warmed by the sun before it enters the open plan living and dining room areas." (BASF, 2007)

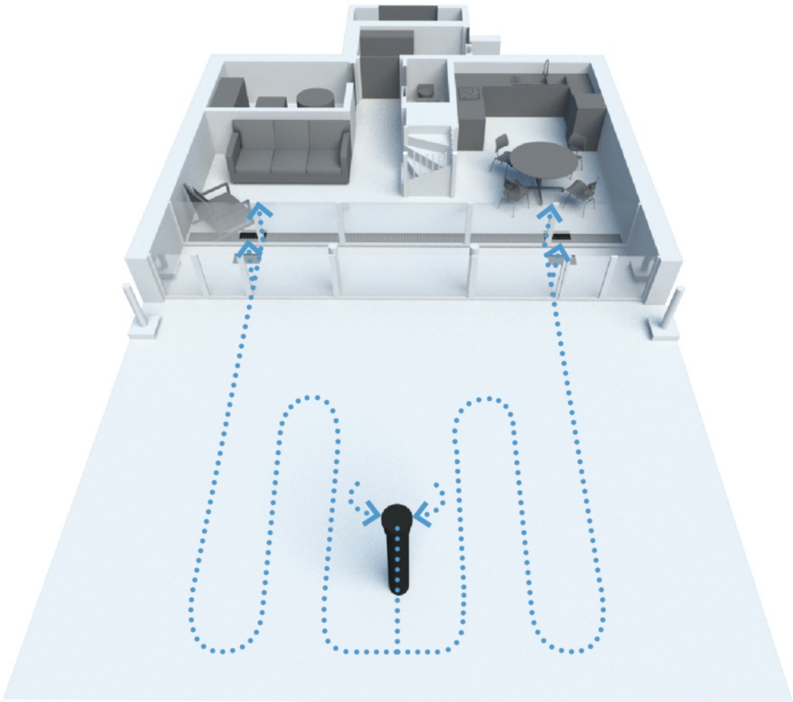


Figure 38 Scheme of the GAHE system depicting the pipe serpentine from the air intake pipe to the four outlets into the BASF house.

4.2. The BASF house data – processing and calculations towards results

The data corresponded to two consecutive winters determined as the evaluation periods. The first winter started on 30/01/2009 January at 0:00 hrs and finished on 26/02/2009 February at 23:59 hrs (four weeks), while the second winter period started on 01/12/2009 at 0:00 hrs and finished on 29/03/2010 at 23:59 hrs (17 weeks). Based on the experience of inhabiting the BASF House over two winter periods, the energy demand for space heating in the BASF House is concentrated into 3.5 to 4 months per year approximately (a few days of November, December, January, February and a few days of March), even though the second winter was much colder and lasted longer than the first. This assumptions regarding energy demand were made based on the first winter of occupancy of the BASF House, February 2008 as well as on the experience of inhabiting the BASF House over two whole winter periods in 2008-9 and 2009-10.

Results of the efficiency comparison between the biomass boiler and the immersion heater to understand the heating systems

The calculation of efficiencies relied on the specifications found in the manuals of the respective SET with regard to power consumption, shown in table 2. Working at nominal output (which corresponds to the recommended working temperature of 80°C in the user manual) the biomass boiler produces 1 kWh of energy in about four minutes, consuming approximately 230 grams of biofuel (rape seed oil pellets).

Table 5 Specifications of BM boiler and immersion heater technologies of the BASF House

BAXI Biomass Boiler	Nominal output: 15 kW, Fuel consumption: 3.4 kg/h, Working temperature: 80°C
Masstock biofuel	Energy yield - Rape Seed Oil Pellets: 22 MJ/kg
Wood pellets biofuel	Energy yield: 18 MJ/kg (used on the second winter)
Immersion Heater	Output: 3 kW

By contrast, the immersion heater delivers energy of 1 kWh in about 20 minutes.

The following was measured: Water heating using the immersion heater: in one hour, the temperature of the top third of the tank rose 12.3°C, from 35.4°C to 48.1°C. Empirically, 4.18 kJ of energy are required to raise the temperature by 1 litre (1 kg) of water in 1 degree Celsius.

Since the tank contains 470 litres of water, the total amount of energy needed to produce the measured temperature rise is equal to:

$Q = 4.18\ kJ/kg\ °C \times 470/3\ kg \times (48.1 - 35.4)\ °C = 8.3\ MJ$

The total energy delivered by the immersion heater in one hour is equal to:

$E = 3\ kJ/s \times 3{,}600\ s = 10.8\ MJ$

The efficiency of this type of heating at use, immersion control, is therefore 77%. However, it should be close to 100%. It could be that some heat losses occurred in the ducts.

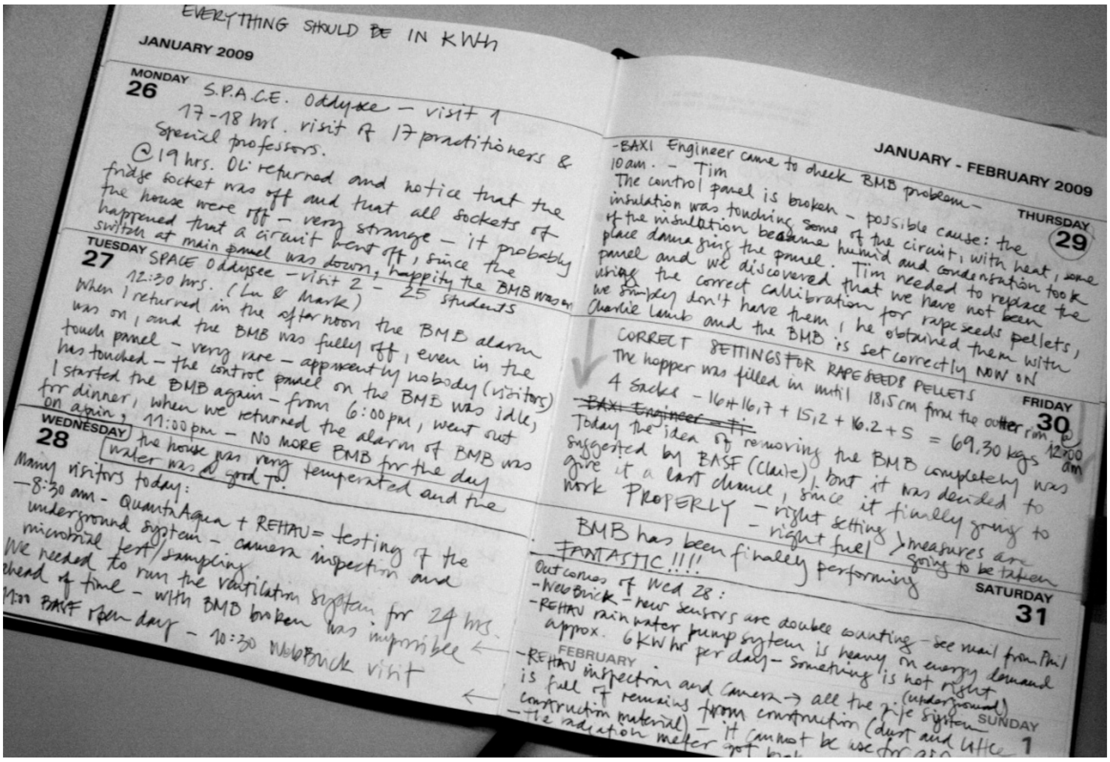
With regard to water heating using the biomass boiler, with the boiler set at a temperature of 80°C, the temperature of the upper third of the water tank rose from 34.2°C to 52.6°C (a total of 18.4 degrees) in 30 minutes. The rate of heating was constant, at about 3 degrees per minute.

The energy necessary to produce this heating is 12.0 MJ: At a power of 15 kW (the temperature of the boiler varied between 78°C and 73°C while heating the water), the total energy consumption in 30 minutes should have been about 27 MJ (corresponding to approx. 1.7 kg of fuel). The efficiency of this type of heating at use, biomass boiler, appears to be about 44%.

This calculation was based on the way the biomass boiler was being used during the first part of winter 2008-2009 (December and January), being lit and extinguished on a daily basis and set to its maximum of 80°C for “large heat requirement (LHR)” as indicated in the manual. Unfortunately, the biomass boiler was not set properly for the type of biofuel that was being used, and later, when it was reset by a BAXI technician with the correct settings, “small heat requirements (SHR)”, for the biofuel type according to the manual, the temperature control was changed to take 65°C as the maximum and it was set to work in the SHR setting at all times.

After the first period, explained above, the monitoring system was tested and calibrated to prevent erroneous readings, so the data recorded was reliable. This coincided with the biomass boiler problem being fixed after a period of not working properly and undergoing major repair and maintenance. Figure 39 shows the regular cleaning occupants had to do to the boiler for it to run properly. Consequently, the technologies involved in the evaluation were in good standing; the monitoring system was logging robust data and the diary of events of the BASF House was receiving daily input from the occupants during the period of the study. Figure 40 is an image of the notes made during the last week of January 2009. Appendix 1 contains the transcriptions of the diary of the house. The textual data complemented the numeric data and contributed towards more robust results and a more thorough evaluation of this real-life experiment.

Figure 39 Regular maintenance of the biomass boiler by occupant of the BASF House depicting the cleaning of the 12 fire tubes, winter 2010.



EVERYTHING SHOULD BE IN KWh

JANUARY 2009

MONDAY 26
S.P.A.C.E. Oddysee – visit 1
17-18 hrs. visit of 17 practitioners & Special professors.
@19 hrs. Oli returned and notice that the fridge socket was off and that all sockets of the house were off – very strange – it probably happened that a circuit went off, since the switch at main panel was down, happily the BMB was on

TUESDAY 27
SPACE Oddysee – visit 2 – 25 students
12:30 hrs. (Lu & Mark)
When I returned in the afternoon the BMB alarm was on, and the BMB was fully off, even in the touch panel – very rare – apparently nobody (visitors) has touched – the control panel on the BMB was idle, I started the BMB again – from 6:00pm, went out for dinner, when we returned the alarm of BMB was on again, 11:00pm – NO MORE BMB for the day

WEDNESDAY 28
the house was very temperated and the water was good too.
Many visitors today:
–8:30 am – QuantaAqua + REHAU = testing of the underground system – camera inspection and microbial test/sampling
We needed to run the ventilation system for 24 hrs ahead of time – with BMB broken was impossible
11:00 BASF open day – 10:30 WebBrick visit

JANUARY - FEBRUARY 2009

THURSDAY 29
–BAXI Engineer came to check BMB problem –
10am. – Tim
The control panel is broken – possible cause: the insulation was touching some of the circuit, with heat, some of the insulation became humid and condensation took place damaging the panel. Tim needed to replace the panel and we discovered that we have not been using the correct callibration for rapeseeds pellets, we simply don't have them, he obtained them with Charlie Lamb and the BMB is set correctly NOW ON
CORRECT SETTINGS FOR RAPESEEDS PELLETS

FRIDAY 30
The hopper was filled in until 18,5cm from the outter rim @ 12:00 am
4 Sacks – 16+16,7 + 15,2 + 16.2 + 5 = 69.30 kgs
~~BAXI Engineer – Ti~~
Today the idea of removing the BMB completely was suggested by BASF (Claire), but it was decided to give it a last chance, since it finally going to work PROPERLY – right setting – right fuel } measures are going to be taken
BMB has been finally performing
FANTASTIC!!!!

SATURDAY 31
Outcomes of Wed 28:
–WebBrick – new sensors are double counting – see mail from Phil
–REHAU rainwater pump system is heavy on energy demand approx. 6KWhr per day – Something is not right

FEBRUARY

SUNDAY 1
–REHAU inspection and Camera → all the pipe system (underground) is full of remains from construction (dust and little construction material) – it cannot be use for ...
–The radiation meter got ...

Figure 40 Sample of the diary of events of the BASF House

To obtain the biomass boiler heat output, the raw data given by the monitoring system was processed to obtain the water flow and the temperatures, which were multiplied by the constant of Specific Heat of Water, 4.186 (kJ/lt-°C).

Biomass Boiler Heat Output (kJ) = Water Specific Heat (kJ/lt-ºC) $\times$ Water Flow (lt) $\times$ Δ T (ºC)

With this value, the energy yield in kWh for the biomass boiler was obtained.

The biomass boiler was set at SHR (small heat requirement), with 65°C as the maximum temperature. The initial experience had shown that it was not necessary to set it to the LHR (large heat requirement) of 80°C (higher temperature, higher energy consumption). Also in order to use the biomass boiler properly and more efficiently it was specified that it should be kept 'on' at all times. It was lit on Friday, 30/01/2009 at 12:00 hrs, loaded with 69.5 kg of biofuel and set to its minimum. It was switched off after a week (running out of biofuel, difficulties in buying a new supply). The 69.5 kg of biofuel were fully consumed in 7.17 days (156 hours); therefore the average daily consumption rate of pellets was 9.7 kg per day, which implies 60 kWh of biofuel consumption per day approximately.

After six days, the new supply arrived, and the hopper was filled with 80 kg of biofuel. The house was only occupied by one of the occupants for the weekend of the third week of the measuring period; so again the biomass boiler was turned off, and during that weekend the immersion heater was used to warm up the water. During this period the house remained warm and the heat accumulated for a couple of days, so no extra space heating, using electrical heaters, was required. From then on, the biomass boiler was lit as needed, and it was confirmed that when it was lit for shorter periods instead of being lit continuously, the efficiency diminished and the consumption of biofuel was higher (65% higher, increasing from 9.7 kg to approximately 15 kg per day, as shown in Table 3 in column 6).

Table 6 Biomass Boiler Weekly Energy Consumption from 30/01/2009 to 26/02/2009

WEEK	WEEKLY BIOMASS BOILER ENERGY DELIVERED	WEEKLY BIOMASS BOILER ELECTRICITY CONSUMED	TOTAL WEEKLY BIOMASS BOILER ENERGY CONSUMED (elect+fuel)	WEEKLY OTHER ELECTRICAL ENERGY CONSUMPTION	WEEKLY BIOMASS-FUEL CONSUMPTION (Oil seed rape pellets)	DAILY BIOMASS-FUEL CONSUMPTION	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON' PER WEEK	TOTAL AMOUNT OF DAYS BIOMASS BOILER 'ON' PER WEEK	TOTAL AMOUNT OF HOURS ELECTRICAL HEATERS 'ON' PER WEEK	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK	WEEKLY AVERAGE OUTDOOR TEMPERATURE	WEEKLY AVERAGE INDOOR TEMPERATURE
units	kW-h	kW-h	kW-h	kW-h	kg	kg	h	day	h	%	°C	°C
week 1	53		413	0	63	9.7	156	6.5	0	13	1.1	21.3
week 2	15		136	81	30	15	48	2	30	11	0.5	19.2
week 3	14		133	24	28	15.5	44	1.8	4	10	5.8	19.8
week 4	30		166	10	36	15	58	2.4	2	18	7.6	21.3
MONTH or DAY TOTAL	112	93	848	114	157	13.8	306	12 .7	36	13	3.8	20.4

Table 6 portrays a 4-week period summary of calculations based on the processed raw data obtained from the readings of the monitoring system, from 30/01/2009 to 26/02/2009, showing the weekly sum of the energy consumed and delivered, from the different appliances available in the BASF House for space and water heating. The third column is the addition of the electricity consumption of the biomass boiler given by the monitoring system in addition to the calculated energy consumption from the biofuel. It shows also the amount of hours the biomass boiler was 'on', the kilograms of rape seed oil pellets used and the energy efficiency of the biofuel per week, the biomass boiler readings for space and water heating were aggregated readings. The two right columns show the weekly averages of interior and exterior temperatures.

In the second column for the row "week 1", the high value calculated for the biomass boiler weekly energy consumption of 413 kWh depicted the first indication of a possible erroneous classification of this technology as a low to zero carbon (LZC) technology. This consumption is a surprising result because, when comparing the other measurements in weeks 2, 3 and 4 for the periods of time the boiler was on, the fuel consumption was double, for these three weeks local electrical heaters were used as well. However, when adding electrical consumption of the two heating systems the consumption of the first week is still too high compared to the other three weeks, 217 kWh for week 2, 157 kWh for week 3 and 176 kWh for week 4 respectively, more than double in most cases, while the efficiency of the boiler remains similar over the four weeks, detailed discussion on these results is on the following pages. It is also important to point out that the best way for the boiler to function in optimum conditions is when it is “on” continuously during a period.

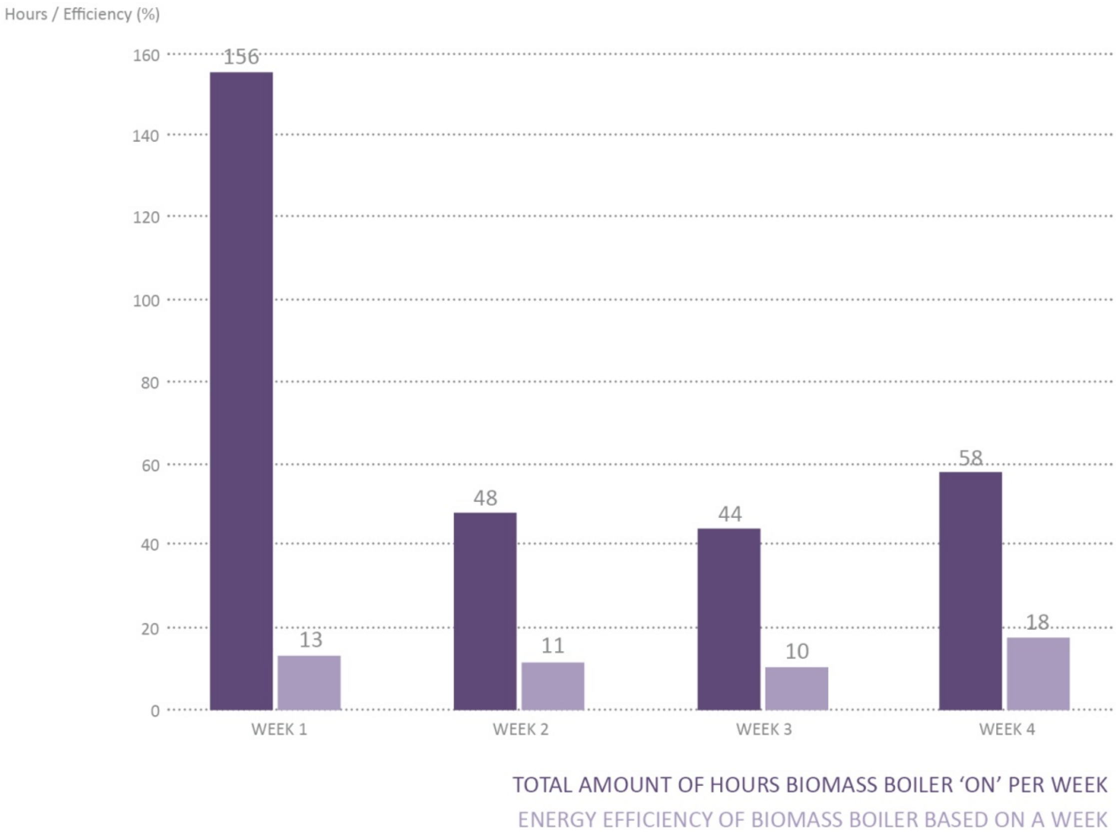


Figure 41 Graph of the weekly biomass boiler average usage (hours) versus efficiency (%) for February 2009.

Table 7 Weekly biomass boiler average usage (hours) versus efficiency (%) for February 2009

WEEK	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON' PER WEEK	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK
units	H	%
week 1	**156**	**13**
week 2	**48**	**11**
week 3	**44**	**10**
week 4	**58**	**18**
Month total	**306 = 12.75 days**	**13**

Once this surprisingly low efficiency of the biomass boiler was noticed, as depicted in figure 41 and table 7 showing the amount of hours the biomass boiler was lit per week (the same as in column 7 of the above table 3) and the corresponding efficiency; which was calculated based on the hours the boiler was lit, it was important to review the data for possible errors. More than ever, it was crucial to ensure the temperature readings were reliable and this was checked by carrying out a spot measurement test. The small ΔT between flow and return temperatures made us think the readings could be wrong. Then, on 25/03/2009, the biomass boiler was lit to carry out a test to do a parallel spot measurement with probes to the flow and return temperatures to contrast them with the temperatures logged by the monitoring system. The probes were installed in the same positions as the monitoring system sensors are located and the differences were insignificant, ranging from 0.01 to 0.10 degrees Celsius within compared temperatures. The samples taken by the monitoring system of the house were constantly contrasted with spot measurements, the house mains electricity meter and the weather stations installed on campus within the Architecture Department area.

The second winter – December 2009 to March 2010

After the first winter an analysis of the data revealed it was necessary to manually record data from system readings in order to disaggregate space heating (SH) from water heating (WH). On 26/11/2009 the mechanical heating period for the BASF House started. During this period, the biomass boiler was the main source of water and space heating. It was running 24/7, but usage was not regular for various reasons; some observations have been transcribed from the diary of the BASF house in table 5 (second column). The problems with the boiler promoted the use of other heating devices for heating. On 18/01/2010, the biofuel type was replaced and wood pellets were used instead of the rape seed oil pellets. However, the new supply of biofuel took some time to reach the home, so during that period small electrical heating devices for space heating and the immersion control heater for water heating were used to keep occupants in comfort. Table 5 shows the monthly summary in hours of the usage of the different devices for SH and WH respectively. A detailed distribution of the period allocated for the usage of the different heating devices is depicted in appendix 2.

Table 8 Examples of observations from occupants in parallel to readings from the monitoring system on the use in hours of the water and space heating devices for the second winter in the BASF house

MANUAL RECORD OF IMPROTANT EVENTS FROM THE BASF HOUSE DIARY			TOTAL HOURS OF USAGE PER MONTH OF THE DIFFERENT DEVICES FOR WH AND SH		
	DATE	OBSERVATIONS	BOILER 'ON' FOR WH + SH AGGREGATED	ELECTRICAL HEATER 'ON' FOR SH ONLY	IMMERSION HEATER 'ON' FOR WH ONLY
NOV	26/11/2009	Biomass boiler lit for the winter season at 13:00 hr.	**103 hrs. (4 days)**	**0**	**0**
DEC	04/12/2009	Extra heating needed: electrical heater on SW bedroom.	**292 hrs. (12 days)**	**127 hrs.**	**23 hrs.**
	07/12/2009	The boiler shut off, after 12 days of having the boiler 'on' continuously.			
	08/12/2009	Three days without boiler.			
	11/12/2009	Four days with biomass boiler 'on' continuously.			
	16/12/2009	No more biofuel. Immersion heater for WH. Electrical heaters for SH when needed.			
	18/12/2009	Occupants left the BASF House for Christmas season. House empty for 16 days.			
	03/01/2010	Return after Christmas break.			
JAN	04/01/2010	Two weeks without biomass boiler for heating. Immersion heater for WH. Electrical heaters for SH when needed.	**373 hrs. (16 days)**	**210 hrs.**	**52 hrs.**
	18/01/2010	Change of fuel type, from rape seed oil to wood pellets			
	31/01/2010	Biomass boiler on/off all day. Change of fuel type, from rape seed oil to wood pellets			
	01/02/2010	Biomass boiler went off at night, lit at noon. Very smoky.			
FEB	28/02/2010	Biomass boiler off for the season at 23:00	**672 hrs. (28 days)**	**3 hrs.**	**0**
MAR	11/03/2010	Biomass boiler for space heating only.	**276 hrs. (12 days)**	**13 hrs.**	**6 hrs.**

The previous winter had shown that the monitoring of the biomass boiler usage did not have separate readings for SH (space heating) and WH (water heating), and these two types of consumption needed to be disaggregated in order to evaluate just the space heating (SH) demand. The delivery of heat from the biomass boiler was therefore manually activated through the touch panel in the kitchen. Then, every single time the biomass boiler was in use, a manual record to disaggregate SH from WH was written down on a printed data sheet posted in the same place as the system controls. Therefore every time either of the two tenants switched on/off the SH or WH, the hours were recorded on the corresponding day. The author then transcribed the data weekly to a spreadsheet, as shown in Table 6. Then by contrasting these manual records with the processed data from the monitoring system readings, it was possible to calculate the distribution of the time allocated for SH and WH and determine the percentage of the total hours the boiler was lit corresponding to heat delivered for the different purposes.

Table 9 Example of the two first weeks of manual recording of the switching on/off to disaggregate SH from WH delivered by the biomass boiler

DATE	BIOMASS BOILER USAGE, MANUAL READING TO DISAGGREGATE WATER FROM SPACE HEATING						
	SPACE HEATING			WATER HEATING			FUEL
	begin time	finish time	TOTAL HR SH	begin time	finish time	TOTAL HR WH	kg pellets
26/11/2009	02:15			04:20	07:15	**02:55**	**80**
27/11/2009		12:40	**10:25**				
28/11/2009	10:50	15:25	**04:35**				
29/11/2009	19:05			08:25	10:25	**02:00**	
30/11/2009		08:40	**13:35**				
01/12/2009							**40**
02/12/2009							
03/12/2009	18:10	23:40	**05:30**	08:00	08:50	**00:50**	**40**
04/12/2009	19:50	20:50	**01:00**	23:45	12:45	**13:00**	
05/12/2009	00:00	00:45	**00:45**	12:45	20:30	**08:45**	
06/12/2009							
07/12/2009	10:55	12:00	**01:05**				
08/12/2009							
09/12/2009							

4.3. Results

Biomass Boiler Efficiency

The most important result obtained from this period was the better average value obtained for the energy efficiency of the biomass boiler, 55% for the second winter. In fact, during the first 12 days of usage of the biomass boiler, the efficiency almost doubled compared to the level of efficiency obtained during the first winter with the same setting and the same biofuel, although the rate of pellet consumption was better the previous winter (this can be observed on appendices 2, 3 and 4, which contain detailed tables with all the processed data). The main difference resides in the water flow rate, which became three or even four times greater than the rate recorded the previous winter. As has been mentioned, during the previous year, the readings obtained from the monitoring system were contrasted with manual spot measurements and very similar readings were obtained for the flow of water for periods of 30 minutes. It was therefore assumed that the monitoring system of the BASF House was working properly.

Regardless of the small difference between the calorific values of the two types of biofuel, of 22MJ/kg for rape seed oil pellets and 18MJ/kg for wood pellets, the efficiency became even better when the biofuel was changed from seeds to wood pellets and the settings of the biomass boiler were adjusted for wood pellets, in accordance with the user manual suggestion for small heat requirement (SHR). As the biomass boiler was on continuously for longer periods, the rate of pellet consumption diminished and the energy efficiency increased. Figure 43 and table 10 show the biomass boiler usage in hours and the increase in efficiency for the month of February 2010, second winter.

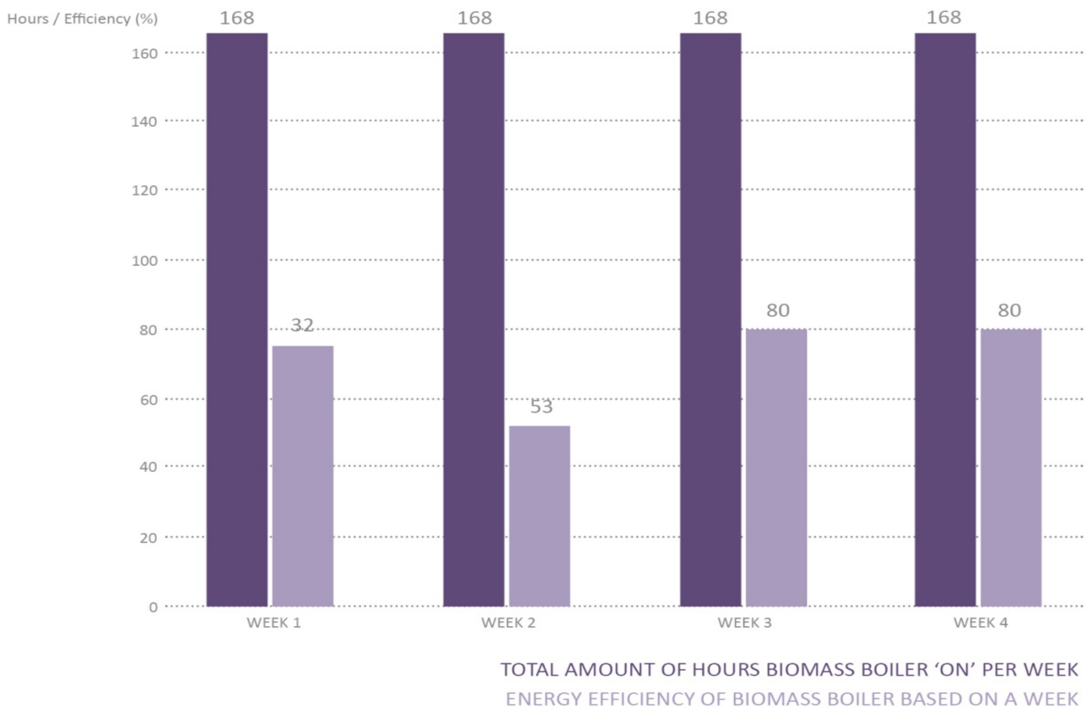


Figure 42 Graph showing the weekly biomass boiler average usage (hours) versus efficiency (%) for February 2010.

Table 10 Weekly biomass boiler average usage (hours) versus efficiency (%) for February 2010

WEEK	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON' PER WEEK	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK
units	h	%
week 1	**168**	**77**
week 2	**168**	**53**
week 3	**168**	**80**
week 4	**168**	**80**
Month total	**672 = 28 days**	**72.5**

For the days with the lowest exterior temperatures, the number of hours of SH demanded by the occupants was evidently higher and the efficiency of the biomass boiler reached its peak at 80%, as can be observed in figure 39 and table 7 for the last two weeks of February.

Through the manual readings, it was possible to determine the exact number of hours the biomass boiler was used for WH and SH respectively, while the biomass boiler was 'on' at all times. The fact that the biomass boiler has to be always 'on' and it is inside the house, in the plant room, in the north-western area of the ground floor, means that it is constantly delivering heat around it; and the latent heat also increases, which helps greatly to maintain the space constantly heated. The door of the room was normally kept open and clothes were dried in the plant room. In both winters, the biomass boiler was stopped at the end of February. For the first winter, from 27/02/2009, the house relied mostly on the solar system for WH and the sunspace for SH. The biomass boiler was not lit for almost eight months and was lit again for just four days in November 2009, from 10 to 13 November, when an abrupt drop in the exterior temperature occurred along with a reduction in the solar radiation, thus affecting the passive heating for the indoor space and the water temperature.

After eight months, the biomass boiler was lit again on 26/11/2009 on a regular basis for the second winter season, although there were periods when the boiler was switched off for diverse reasons (maintenance, lack of fuel, winter vacation, etc.). Prior to this date, there were occasions when the use of the immersion heater to warm up the water (WH) was required, and electrical heaters were used to heat up the space (SH) for some hours, especially at night. However, the weather conditions did not really justify the lighting of the biomass boiler until late November. The occupants turned off the biomass boiler on 28/02/2010. However, in March 2010, it was relit on two occasions, the first for two days and the second for four days. On other days in March, the electrical and immersion heaters were required for short periods of time to avoid the hassle of lighting the biomass boiler. All the above can be observed on appendixes 2 and 3, which contain the detailed results from data processing on all the monitored technology of the BASF House for the second winter.

Energy Consumed: Comparison of Water and Space Heating Appliances

During both winters the issue of delays in biofuel delivery forced the occupants to use alternative systems for SH and WH, as the weather conditions were quite extreme during those periods, as shown in the graph in figure 43 in next page. Therefore, the immersion heater needed to be used for WH, while for SH, the only alternative was to use electrical heaters in each bedroom. It is therefore possible to compare the energy consumption during both winters for water and space heating in the BASF House for three different heating technologies: biomass boiler (WH and SH), immersion control for domestic hot water (DHW) and electrical heaters (solely for SH). For this comparison the sensors that record the biomass boiler readings do not separate water from space heating readings; therefore the readings will always be analysed together. However, for the second winter, readings were taken manually to separate SH from WH; so the WH can then be subtracted from the total heating load.

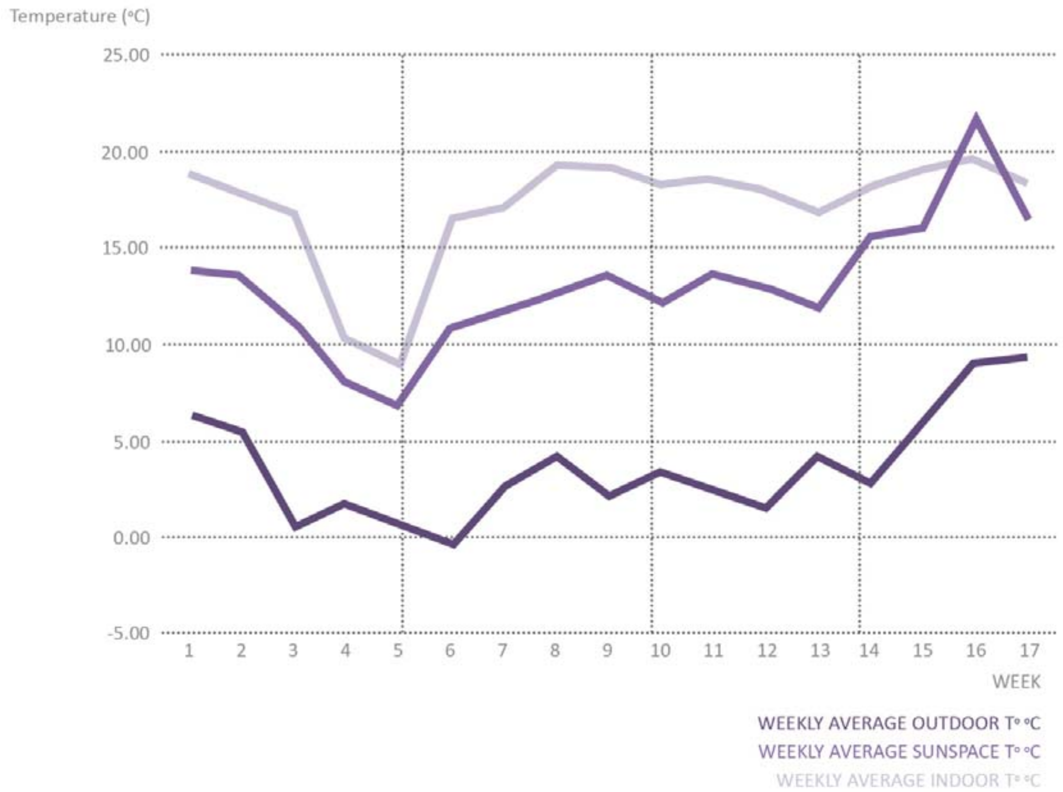


Figure 43 Weekly average temperatures for winter 2009-2010 in the BASF House.

For the comparison, the efficiency of both the immersion heater and the electrical heater was assumed to be 100%. However, on the many occasions the immersion heater was used, the efficiency was actually closer to 85-90%, except when used in the middle of winter, when the temperature of the water drops more rapidly. In the case of the electrical heaters, all the heat is delivered directly into the room; therefore 100% of efficiency was taken for granted, which means that the electricity consumption is equal to the energy delivered by these devices. For the first winter, in February 2009, it can be observed from figure 44 and table 11 in next page that the demand for WH and SH was reduced abruptly. The second pair of columns represents week 2 of the studied period. The energy consumption of the biomass boiler, which includes the biofuel plus the electricity consumed during two days (48 hours), was calculated as 136 kWh, while the energy consumption of the immersion (eight hours) plus the electrical heaters (30 hours) during the rest of the week (five days – 72 hours) was calculated as 81 kWh. It was shown that for one day's heating, the biomass boiler energy consumption is four times greater than that of the other two heating devices. For the biomass boiler, the daily consumption was 68 kWh per day, while for the secondary heaters it was 16.2 kWh per day.

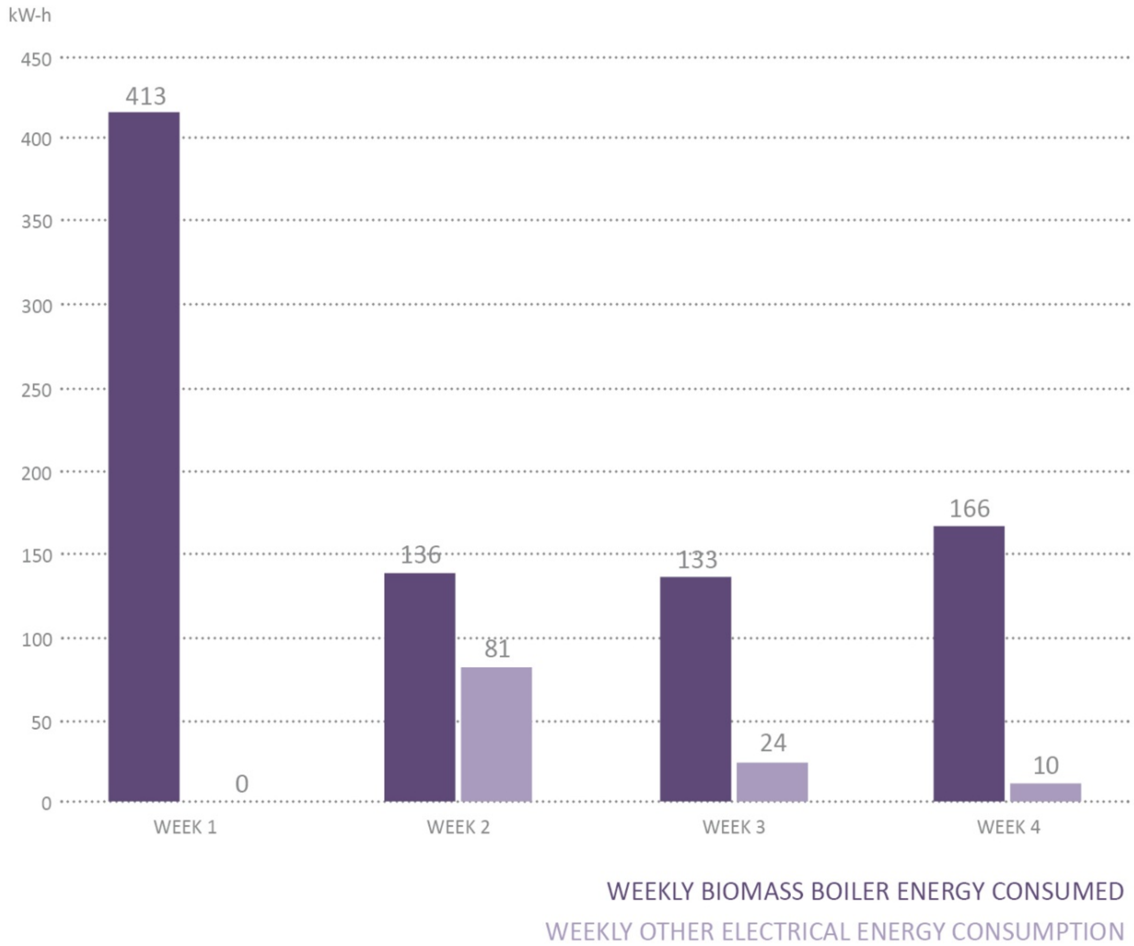


Figure 44 Graph comparing weekly electricity consumption (kW-h) between the biomass boiler (CH+WH) versus electrical heaters (Elect. H for CH) and immersion heater (for WH)

Table 11 Comparison of weekly electricity consumption (kW-h) in hours between the biomass boiler (CH+WH) versus electrical heaters (Elect. H for CH) and immersion heater (for WH)

WEEK	WEEKLY BIOMASS BOILER ELECT. ENERGY CONSUMED (kW-h)	BMB 'ON' (h)	WEEKLY OTHER ELECTRICAL ENERGY CONSUMED (kW-h)	Elect. Heater (h) + Imm. Heater (h)
Week 1	**413**	**156**	**0**	**0**
Week 2	**136**	**48**	**81**	**30 + 8**
Week 3	**133**	**44**	**24**	**6 + 4**
Week 4	**166**	**58**	**10**	**2 + 2**
Month totals	**848**	**306**	**114**	**52**

For the second winter, the sixth week, 05-11/01/2010, was the coldest one of the 17-week period studied, as can be seen in the graph of average temperatures in figure 47. It coincided with the return of the occupants after the Christmas season. During a period of 16 days, from 03/01/2010 to 18/01/2010 (half of week 5; week 6 and week 7), for SH and WH, the occupants relied mostly on electrical devices, the immersion and electrical heaters, used upon demand, as can be observed in figure 42 below.

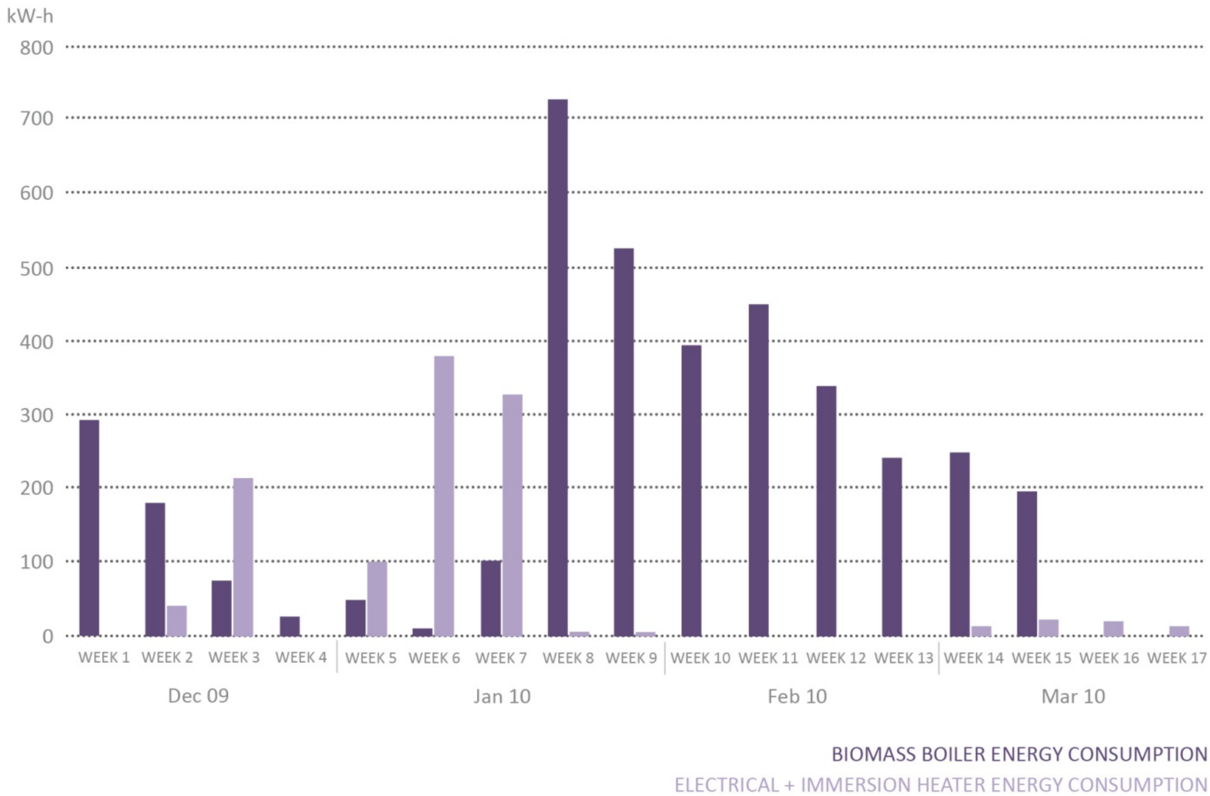


Figure 45 Comparison of weekly electricity consumption (kW-h) of the biomass boiler (CH+WH) versus electrical heaters (Elect. H for CH) and immersion heater (Imm. H for WH) in the BASF House.

The highest weekly energy consumption of these devices was 382 kWh consumed on week 6 (figure 45), while compared with the energy consumption of the biomass boiler during the subsequent period, from week 8 to week 12, when the biomass boiler was on 24/7, total energy consumption (electricity plus biofuel) is higher most of the time and at its highest during week 8, reaching 728 kWh (table 9), almost double that obtained with the heaters in week 6, while the efficiency of the biomass boiler was 67%. In the following week (week 9), the energy consumption diminished slightly to 527 kWh, but the consumption of wood pellets increased to its worst rate of 20kg per day and the efficiency dropped again to 48%, as shown in table 9 for the corresponding week. At the same time, in week 13, from 23-02/02/2010, the biomass boiler achieved its best performance, obtaining the lowest weekly consumption of 243 kWh and - for the first time in both winters - lower consumption compared to the electrical devices in similar weeks, as is shown in graph of figure 45 and table 12. This week was part of the longest period (four weeks) the biomass boiler worked continuously without any problem or need to switch it off.

The reasons for the greater variations in the efficiency of the biomass boiler were not easy to identify. They could be attributed to the type of fuel, the continuity of usage, since it was indicated the machine should run continuously for a season, or to the setting, which was changed to the best indicated by the manufacturer, but ultimately its performance was random, where the biomass boiler was mostly inefficient, as its energy consumption was always higher than the delivered energy.

Table 12 Biomass boiler energy and biofuel consumption, hours of being 'on' and efficiency for the 17 week period of winter 2 from 01/12/2009 to 29/03/2010

MONTH	WEEK	BIOMASS BOILER ENERGY DELIVERED	BIOMASS BOILER ELECTRICITY CONSUMPTION	TOTAL BIOMASS BOILER ENERGY CONSUMPTION (electricity+fuel)	BIOMASS-FUEL CONSUMP (wood pellets)	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON'	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK
Dec-09	Week 1. 01-07/12/2009	94	23	295	80	168	32
	Week 2. 08- 14/12/2009	86	27	182	0	96	47
	Week 3. 15-21/12/2009	49	26	71	0	28	69
	Week 4. 22-28/12/2009	11	27	27	0	0	39
Jan-10	Week 5. 29/12/2009 to 04/01/2010	10	27	48	0	13	20
	Week 6. 05 - 11/01/2010	6	10	10	0	0	62
	Week 7. 12 - 18/01/2010	68	2	102	80	24	67
	Week 8. 19 - 25/01/2010	487	28	728	80	68	67
	Week 9. 26/01/2010 to 01/02/2010	252	27	527	60	168	48
Feb-10	Week 10. 02 - 08/02/2010	302	28	394	80	168	77
	Week 11. 09-15/02/2010	238	28	450	80	168	53
	Week 12. 16-22/02/2010	269	27	338	0	168	80
	Week 13. 23/02/2010 to 01/03/2010	194	27	3	80	168	80
Mar-10	Week 14. 02 - 08/03/2010	41	24	248	40	8	17
	Week 15. 09 - 15/03/2010	107	15	195	0	8	5
	Week 16. 16 - 22/03/2010	0	0	0	0	0	0
	Week 17. 23 - 29/03/2010	0	0	0	0	0	0

UK EPC SAP prediction and PassivHaus targets

The calculation of the total energy demand for space heating and cooling was based on the obtained data and the surface of 82.6 m^2 for the treated floor area of the BASF house, as defined by the PassivHaus Planning Package (PHPP). This is the area to be heated, after subtracting the sunspace, porch, walls and partition walls, as can be observed in figure 46.

To obtain the annual value, the year was calculated as starting in April 2009 and finishing in March 2010.

The total energy delivered to heat the space and the water during the monitored year was 3267 kWh, of which 2125 kWh were provided by the biomass boiler and 1142 kWh by other electrical appliances.

Figure 46 Treated floor area of the BASF House [82.6 m²] to calculate the total energy demand as established by PHPP.

To disaggregate this value into SH and WH, the amount of hours the biomass boiler was switched on for the different uses was manually recorded, as shown on the example in table 6; the complete table is in appendix 5.

The total energy delivered to heat the space for the winter period was 1421 kWh thus 1421 kWh / 82.6 m² = **17.20 kWh/m² year.**

The GAHE system was used for a few days during the summer time for cooling purposes during the hottest days of the year, when the average temperatures were over 23°C (30/06/2009 and 1 and 2/07/2009) or on the days with the higher solar radiation (over 240 W/m² on 24, 29, 30 and 31 May 2009, 11, 12 and 30 June 2009 and 1 and 2 July 2009). The total energy delivered for cooling during the year, concentrated over those days, was 1.9 kWh, mostly observed around midday. Therefore, the cooling demand was [1.9 kWh / 82.6 m²] = **0.02 kWh/m² year,** which is negligible; however the stand-by annual energy consumption of the GAHE is 84.69 kWh, which is added to the total electricity value. In contrast with the case of the biomass boiler, as the GAHE system cannot be shut down, it continuously consumed approximately 10 watts of electricity. This however can easily be solved to avoid this minimal, yet constant waste of energy.

To obtain an approximate annual value for total electricity consumption for the BASF house, the measured data obtained by the monitoring system for a period of 12 months during the second year were simply added, beginning on 1 April 2009 and finishing on 31 March 2010. As the data for March 2009 was not recorded, this can be observed in figure 47 and all the detailed data that originated this summary graph is included in appendix 6.

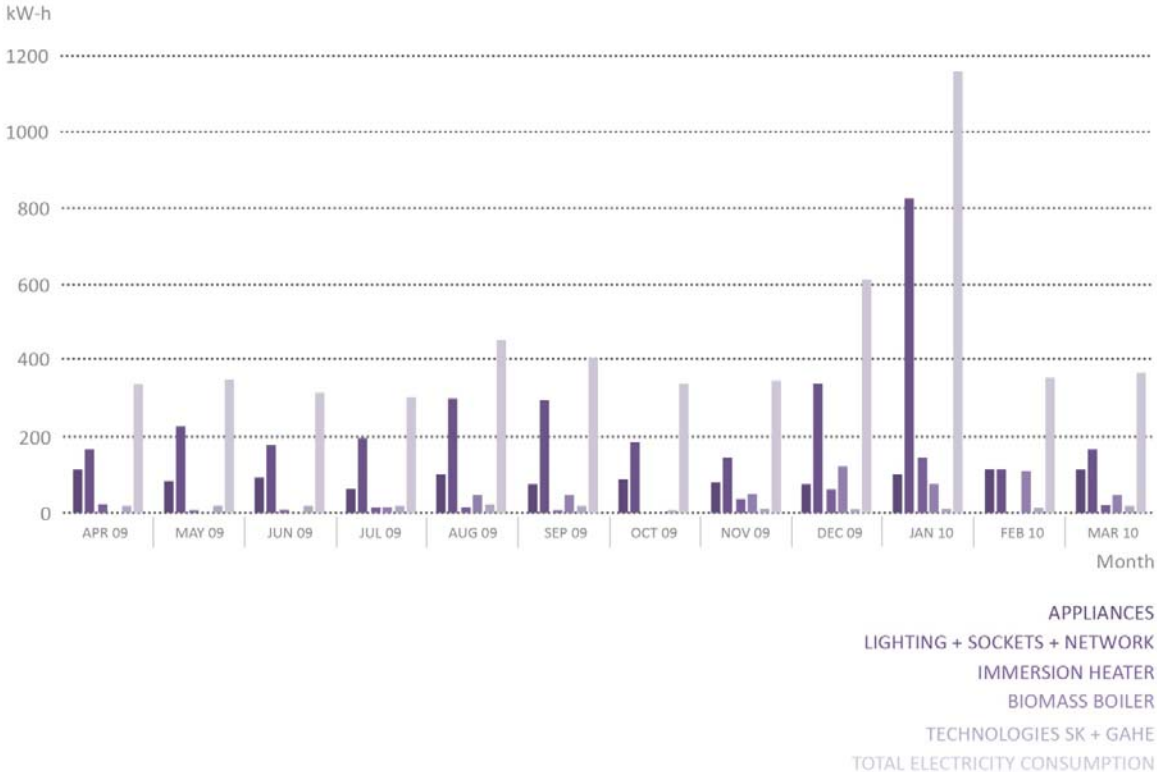


Figure 47 Annual electricity consumption of the BASF House from 01/04/2009 to 31/03/2010 calculated from the readings recorded by the monitoring system.

The total energy consumption of all the electrical devices plus the water heating of the BASF House is 5,442-177 kWh/82.6 m² = **63.75 kWh/m² year**. It can be observed from the graph in figure 47 that there was very high electricity consumption during the months of December and January (wintertime). This is due to the use of electrical heaters for space heating, which is reflected on the second column, where the item sockets is included and the use of the immersion heater for water heating also shows its highest peak in electricity consumption in January, when the boiler was working very irregularly. The data from the different appliances was aggregated in regard to the readings, as shown in table 13.

Table 13 Distribution of the readings on energy consumption in the BASF House

APPLIANCES	Kitchen Sockets (toaster, microwave, blender, juicer, kitchen small appliances) + Fridge + Dishwasher + Hob + Oven + Dishwasher
LIGHTING + SOCKETS + NETWORK	All light bulbs + All sockets + Motorized windows + WebBrick system + Wired access unit + Touch screen + Modem wireless
IMMERSION HEATER	Resistance to heat up water when solar radiation is not enough and BMB is not in use
BIOMASS BOILER	By itself
TECHNOLOGIES	Solar Kit System + Ground Source Heat exchanger

In conclusion, the energy consumption of the BASF House was very close to the estimates. The UK EPC SAP calculation estimated 104 kWh/m²/year of energy use and the house actually used a total 80.97 kWh/m²/year, therefore 78% of the amount forecast. With regard to the PassivHaus standard of 15 kWh/m²/year for heating and cooling, the house obtained 17.22 kWh/m²/year, 15% over this target.

4.4. Discussion

The major contradiction emerging from this case study, taking into consideration that it is an experimental energy home, is that while the BASF House itself had such an outstanding performance, the heating system showed such a poor performance. This portrays the great risk involved in concentrating solely on targets and taking the most out of incentive systems to reach good standards. It is certainly possible to produce and deliver Code Level 6 homes, but do they perform as such in all areas? Are there Code Level 6 occupants? After medium- to long-term occupancy, does the home still perform to Code Level 6? The BASF House meets the criteria for Code Level 4, and the results shows that it is very close to reaching PassivHaus standards; however can the low efficiency of one of the LZC technologies and the discomfort for users, the impact on costs and health and the levels of dissatisfaction be classified as good standards? Case studies for houses are mostly very individual; and the results will vary greatly from case to case because of various unknown factors (the pattern of usage of their home for example). For instance, a home occupied by PhD students from a department of architecture and the built environment, as in this case study, will be used in a totally different way to a home with a household of three or four members, such as a young couple with two small children. The features of the households need to be taken into consideration when analysing performance and comfort in homes.

In March 2011, Matthews Bush from the Metropolitan Housing Partnership (MHP) reported on the three-year study, called "The Homes of our Times, 2011 Report (Year 1)" to support the investment in customers and their homes,

> "MHP has a good track record of building and delivering award winning sustainable new homes and refurbishments, but do we know if our customers are achieving the intended savings, emitting less carbon and using less energy as a result?" (Bush, 2011).

They recognise the major gap between designing and building a 'good standard' sustainable home and the use the occupants make of that sustainable home. To live sustainably and manage household energy consumption means a change of paradigm today and it involves efforts over and above simply changing all the lighting to low energy light bulbs or keeping windows closed when the heating is on.

Low or Zero Carbon (LZC) Technologies

The biomass boiler of the BASF House

<u>From the analysis of the efficiency:</u> One of the most important lessons from this analysis is that the energy efficiency of the biomass boiler for the first winter is far lower than expected and for the second winter, although it is certainly better, it is still much lower than that indicated by the manufacturer ("Very high efficiency (87%-90%) with a variety of fuel types"). There is nothing to be gained from running a machine 24/7 if it is really only going to be used half the time (37% SH and 13% WH) as was the case with the biomass boiler usage in the BASF House. The nominal output of 15 kW indicates that, given the thermal characteristics of the BASF House, the biomass boiler is oversized for the heating demand of the house. It is not the appropriate technology for it; considering that we are not analysing the quality of the technology in this study. Also, it has been demonstrated through the analysis of the data that in regard to energy consumption for water and space heating, the biomass boiler consumed four times more than the electrical and immersion heaters combined. Therefore a careful analysis of the embodied energy and carbon emissions indicated the need for a further extension of this research, as well as an analysis of the air quality and pollution.

All of this suggests that the biomass boiler was oversized for the thermal characteristics of the BASF House. The motivation to install it was based on the idea of obtaining extra available credits for compliance with the regulations for implementing Low or Zero Carbon (LZC) Technologies. It therefore scored 2 out of the 8 possible credits, 25%, in the assessment criteria by CSH to reach Level 4 and ≥44% of improvement of the Dwelling Emission Rate (DER) over the Target Emission Rate (TER) to comply with the carbon emissions reduction criteria. The need to comply with regulations is not under debate, but the need to exercise caution in this area should be considered and consideration given to choosing the most appropriate technology for a specific home typology and design. The considerations regarding estimating risks mentioned in the study of "Sick Building Syndrome and Environmental Conditions" by Wilson et Al in 1987 are more valid now than ever before and highly applicable to the home construction industry. For this particular case study, three of these considerations have been highlighted:

> "1. Failure to appreciate how technological systems function as a whole;
> 2. Over-confidence in current scientific knowledge;
> 3. Failure to consider the ways in which human errors can affect technological systems" (Bordass and Leaman, 1997).

Sometimes regulations could be promoting actions that may result in side effects, in such a way that the outcomes may not meet expectations, and they could even have a negative impact on occupants and the environment, as well as on the technology itself. Nevertheless, the worst aspect on the LZC technology is that this type of biomass boiler is definitely not a LZC technology, as has been clearly demonstrated by the results obtained from the analysis of the measurements.

<u>From the BASF House heating load demand perspective:</u> The house proved to have a low demand for space heating. The passive design features and building materials, as well as the high levels of insulation, the airtightness and the conservatory, all contribute greatly to achieving an excellent thermal performance. This is shown by the energy demand. From the everyday observation of occupants and the analysis of the annual data for indoor climate and energy consumption, it can be predicted that the solar system works extremely well for water heating on days when it is not overcast. It is therefore recommended that other technologies for space and water heating which are more appropriate to the thermal characteristics of the house be reviewed, since it is clear that, in winter, the house needs to rely on alternative technologies to cover the residual heat demand.

<u>From the BASF House airtightness and ventilation technologies:</u> The airtightness and ventilation SET in the BASF house were shown to be complex. The way in which the GAHE (Ground Air Heat Exchanger) technology was used in the BASF House was complicated for occupants to operate. It is recommended by the Approved Code of Practice (ACOP) that the ventilation systems are inspected and tested for hygiene levels annually as a minimum requirement, and that a record of this maintenance should be kept. This is to ensure

compliance with workplace (Health, Safety and Welfare) regulation 1992 and in particular regulations 5 and 6[14].

This system was difficult to use during the course of daily domestic activities and, while it was intended to be both user friendly and intuitive (similar to traditional window ventilation), this proved not to be the case. In fact, between the options for opening and closing the inlets and the seven opening positions for each of the vents that draw the fresh cool air indoors, as shown in figure 46, there were 4,096 possible settings.

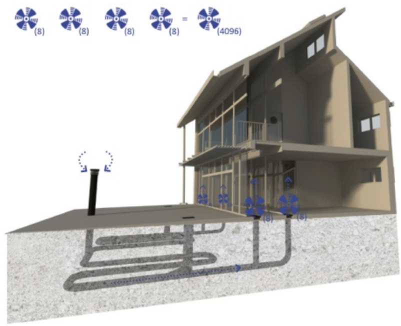


Figure 48 Scheme of mechanical ventilation settings for the Ground Air Heat Exchanger

Some examples of those combinations that were experienced by the occupants are shown in figure 47; each of the combinations that required mechanical air movement was subject to the purpose, season, weather, time, etc; and to add more options, the setting could be combined with the opening of certain windows.

[14] The approved code of practice (ACOP) associated with these regulations clearly states that regular maintenance (including, as necessary, inspection, testing, adjustment, lubrication and cleaning) should be carried out at suitable intervals on mechanical ventilation systems. This is to ensure that they are kept clean and free from anything which may contaminate the air.

CASE A

(a passive cooling, just windows openings)

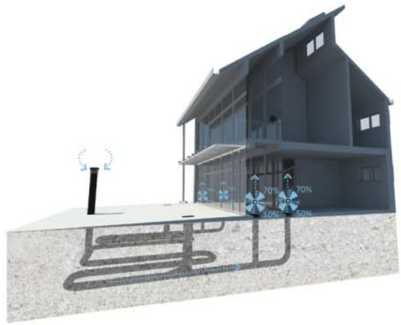
Season: Summer
Month: July
Time: 12:00
Time length: 2hrs
Purpose: Cool
Sunspace vent 1 and 2: 0%
Indoor vent 3 and 4: 0%
Outer curtain wall windows: Open
Inner curtain wall windows: Open
Upper high north windows: Open

CASE B

Season: Winter
Month: January
Time: 18:00
Time length: 5-15min
Purpose: Ventilate cooking smell
Sunspace vent 1 and 2: 0%
Indoor vent 3 and 4: 30%
Outer curtain wall windows: Close
Inner curtain wall windows: Close
Upper high north windows: Open above stairs

CASE C

Season: Summer
Month: July
Time: 14:00
Time length: 1hrs
Purpose: Cool
Sunspace vent 1 and 2: 50-70%
Indoor vent 3 and 4: 50-70%
Outer curtain wall windows: Close
Inner curtain wall windows: Close
Upper high north windows: Close



CASE D

Season: Summer
Month: July
Time: 8:00
Time length: 4hrs
Purpose: Ventilate bedroom
Sunspace vent 1 and 2: 20%
Indoor vent 3 and 4: 30%
Outer curtain wall windows: Close
Inner curtain wall windows: Open bedroom
Upper high north windows: Open bedroom

CASE E

Season: Winter
Month: January
Time: 20:00
Time length: 10-20min
Purpose: Move heat upwards
Sunspace vent 1 and 2: 0%
Indoor vent 3 and 4: 10%
Outer curtain wall windows: Close
Inner curtain wall windows: Close
Upper high north windows: Close

Figure 49 Five schemes of samples of combination of settings for the GAHE occupant’s experienced.

From the BASF House passive design features, sunspace and insulation: The airtightness and solar space are excellent features of the BASF house. When analysing the performance of the sunspace through the temperatures in any winter day and all year long, the temperatures of the sunspace compared to the exterior and the interior temperatures tend to sit always in between, as can be observed in the following figure 50 for the whole month of February 2009 and figure 51 for the 17 weeks of the second winter. These values are average air temperatures calculated from all sensors located in each space, three in the sunspace and three in the interior.

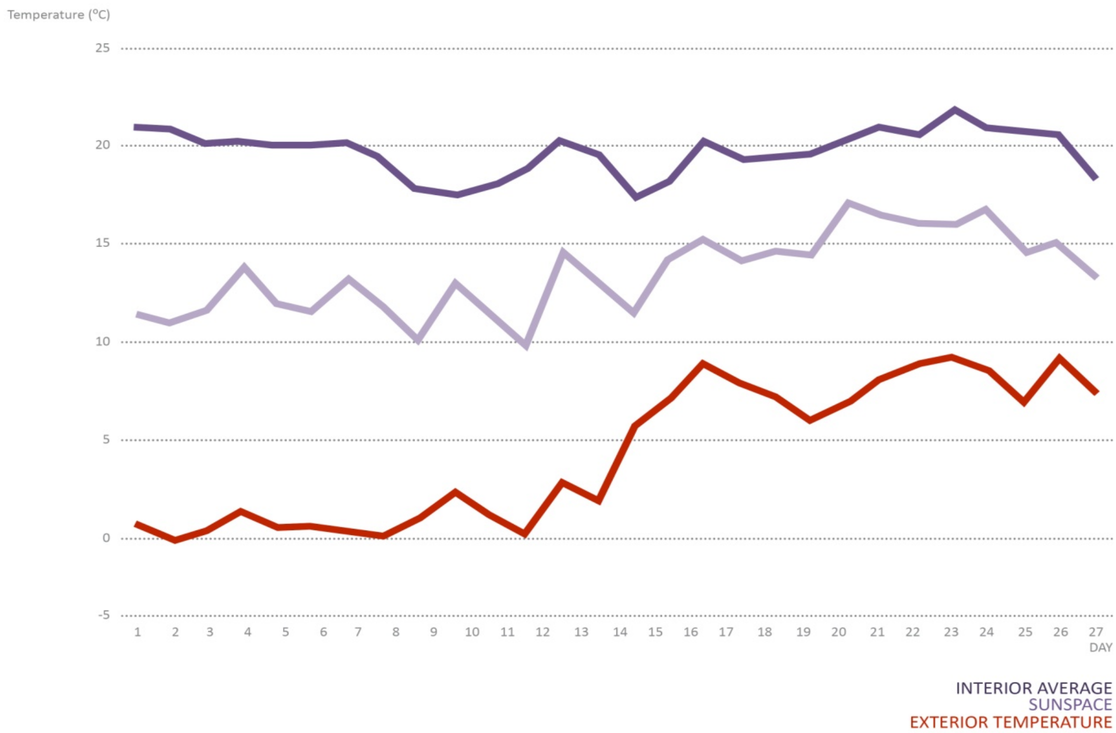


Figure 50 Graph of February 2009 temperatures of the exterior, sunspace average temperatures and interior average temperature in the BASF House.

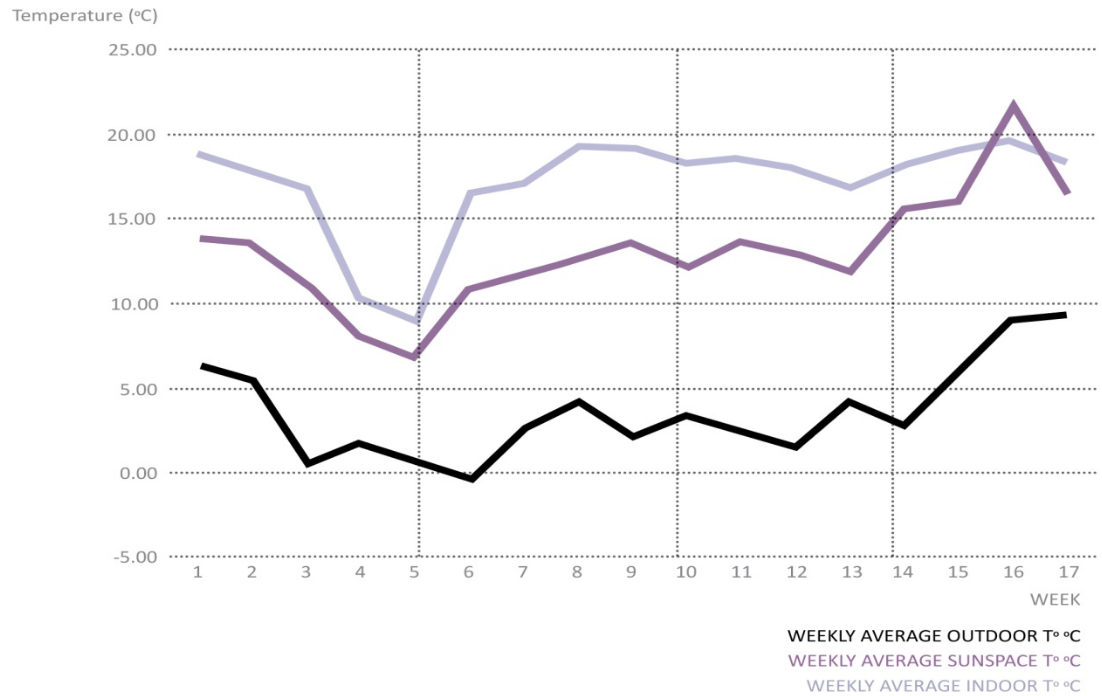


Figure 51 Graph of winter 2009-2010 temperatures of the exterior, sunspace average temperatures and interior average temperature in the BASF House.

4.5. Chapter Conclusions

First of all, to be able to conclude that the BASF House is quite close to meeting expectations for both requirements is a very positive outcome. The UK EPC SAP calculation estimated 104 kWh/m²/year of energy use and the house actually obtained a total 80.97 kWh/m²/year in one year, so it outperformed this estimate by 22%. With regard to the PassivHaus standard of 15 kWh/m²/year for heating and cooling, the house obtained 17.22 kWh/m²/year, so was 15% over this target. However, this excellent result is offset by the performance of the LZC technology, such the biomass boiler. While there is great motivation to install this type of technology in UK homes, this device performed with very low efficiency during the first winter and, while it improved considerable in the second winter, it obtained a very poor evaluation from the occupants, as it had a negative impact on their quality of life in winter. As this is an experimental home, a new heating system was installed in replacement of the existing one for the winter 2010-2011. The new system was more suited to the thermal characteristics of this home. The first year its performance will be analysed is wintertime 2011-2012.

An important lesson learned in regard to the monitoring system for both case studies is that sensors, dataloggers and/or meters need to be carefully calibrated and tested, and the data they log needs to be analysed, contrasted and compared prior to the start of the period to be measured. It is very difficult to fix problems while the numerical data that is going to be analysed for the particular study is being collected, especially when the data is related to people's lives.

For studying/research purposes, space heating (SH) needs to be monitored and logged separately from water heating (WH). For the second winter this was recorded manually, but this is less accurate. It is important to disaggregate the readings to reach a more robust evaluation. To get the most from a monitoring system, it should be tested and validated before the occupants move in, since to evaluate any real-life application, the data logging system needs to be reliable. From the experience of the BASF House, much precious time and funds were wasted on the datalogging at the beginning of the first winter because the system had not been calibrated and tested.

The BASF House has low demand for space heating, although it is greater than had previously been calculated through simulations, which show that the house was designed to meet the 15 kWh m^2 per year target. The high levels of insulation and the good quality of its envelope are perfectly adequate for this latitude, and the passive design of the sunspace contributes greatly to the experience, excellent thermal performance and comfort. The sunspace is an excellent buffer zone, as can be observed from the temperature comparison in the graphs in the section on indoor climate data in appendix 6. The main demand for energy to heat up the water and space is concentrated into a quarter of a year. While the data analysis of the Hoval SolarKit system has not been carried out yet, it was seen that when the weather is not overcast, the solar system is very effective for water heating; a few hours of solar radiation produced enough energy to warm up the water for showers. However, as there are many short, overcast days during the winter the occupants needed to rely on the immersion heater, so this cannot be specifically classified as a LZC technology. Again the need for better alternatives for residual heating is crucial. The biomass boiler was very effective at heating the water. Two hours (5 kWh approximately) per day during colder days was plenty to satisfy the demand for hot water, while for less cold days, one hour per day was enough. The water tank of the system stratifies the water and is very well insulated.

When the biofuel type was changed to wood pellets (£290 per ton+VAT+delivery), the biomass boiler performed much better in regard to the users' comfort; it no longer smelled, was easier to light, produced little smoke and the pellets moved in the hopper with greater ease. However, in the beginning, 80 kilos lasted four days (the pellet consumption was 20 kilos per day), which implies that the hopper needed to be loaded more often. The energy yield was 17

MJ/kg and, as the biomass boiler was running continuously, the biofuel consumption reached 9 kg per day. The energy efficiency of the system also improved. However, the delivered energy was always much lower than the consumed energy, which means that the classification of biomass boilers as an LZC technology needs to be reviewed.

The SET for heating, ventilation and airtightness applied in the BASF House were not user-friendly. They were also over-dimensioned and, in the case of the biomass boiler, not really LZC. The mechanical ventilation system, GAHE, was over-sophisticated. As a whole, the SET ended up complicating the domestic life of the occupants. If pure PassivHaus standards in regard to airtightness are to be applied in the UK, many further studies of real cases will need to be undertaken, as the BASF house's airtightness is showing the first signs of problems, such as mould, leaking and a damp smell. This requires very special attention considering the climate and airtightness design. Therefore well-insulated, breathable walls need to be carefully considered and inspected some time after homes become occupied.

Finally, to study the use and performance of sustainable homes is a topical subject in the UK, which involves very complex methodologies and expensive processes; in a way each home is a case study in its own right. Much prior knowledge is taken from commercial POE experiences (offices, schools, hospitals, etc), where the conditions and patterns of use are very different from those in homes , for the evaluation of homes could vary completely from one occupant to another. De Groot (2008) questioned 10,000 home occupants, and no two responses were exactly the same. It appears that culture and education are extremely influential factors. It is therefore a mammoth task to constantly integrate qualitative and quantitative data and there is still much work to be done on POE for homes. However, the challenge of integration is no easy task; the mixed methodological approach implies pursuing two types of research in parallel, where disciplines tend to favour one; the amount of data to be processed with distinct and separate strategies, tools and techniques is huge; and furthermore, carrying out research with a methodology based on using mixed strategies entails multidisciplinary work involving a group of researchers.

The data logging of quantitative parameters related to indoor climate and energy consumption is crucial to undertake a more robust occupancy evaluation of sustainable homes. However a great deal of time needs to be spent calibrating the monitoring system. This research is expensive and the processing of data is long and tedious. Thus, the definition of the parameters to be measured has to be clearly established at the beginning of the research, because homes are extremely complex and it is impossible to study everything related to any one home in a limited period of time. It is always very tempting to find so much more to do when analysing the data, because the same data is useful for many different analyses. For the POE research to be successful, it is important to remain focussed on the research question. This real-life research has opened up many new research questions in the search for better quality of life in sustainable homes.

Chapter 5. The BASF House Surveys - Statistical Analysis

This chapter describes and discusses the statistical analysis and results obtained from the two questionnaires related to the BASF house. The first part covers the questionnaire given to people who visited the BASF house when it was open to the public. The second part covers the questionnaire given to eight different tenants who lived in the house for different periods of time from 2008 to 2011, thereby experiencing life in a sustainable home for the first time in their lives. They responded to an extended post occupancy questionnaire prior to the change of heating system. Although one of the occupants, the author did not respond the questionnaire; however the chapter does includes written observations from the author throughout the different sections.

The questionnaires of the BASF House concentrated on energy efficiency and sustainability in homes from two perspectives. The first looked at the visitors' awareness of these issues (first section of the chapter). The second focussed on the experience of inhabiting a sustainable home from the occupant's perspective (second section of the chapter). In this way, the results were able to contribute to the objectives and research questions of this study, especially that related to basic and general knowledge about sustainable homes and sustainable energy technologies:

- **Does the inclusion of the sophisticated forms of renewable energy technology required to achieve energy efficient standards presume that the occupants have a certain level of education or that they have received adequate training in the specialised maintenance of the equipment?**
- **Do energy efficient and sustainable homes provide the occupants with the comfort of a "standard" home and with equal ease of use?**

In addition to the research questions, the visitors' questionnaire was designed to find out the willingness of people to refurbish their homes in order to make them sustainable.

5.1. The BASF House visitors' questionnaire

The questionnaire for visitors to the BASF House was voluntary and consisted of a simple 2-page leaflet with four sections on: demographic information, the BASF house design and technologies and general questions, including 36 questions to be marked with a tick (see appendix 7). The first two sections cover the results obtained from the quantitative data analysis carried out on a survey of 480 people out of the 928 who attended the open house visit to the BASF house during one year, starting on June 2009 (appendix 8 on CEH visits booking calendar). The 480 people represent 51.7% of the visitors. They responded voluntarily to the printed questionnaire that was handed to every visitor who attended the open-house exhibition. Of these, 202 questionnaires were completed in full and had answers to all of the questions.

Demographic visitor information

After the data had been processed with SPSS software, the most relevant data was used to define the profile of the interviewees. It was established that 36.6% were female and 63.4% male. The age ranges are shown in figure 52, from which it can be seen that the main groups were concentrated in the 20-35 and 36-50 years old, which correspond to 84.1% of the surveyed group.

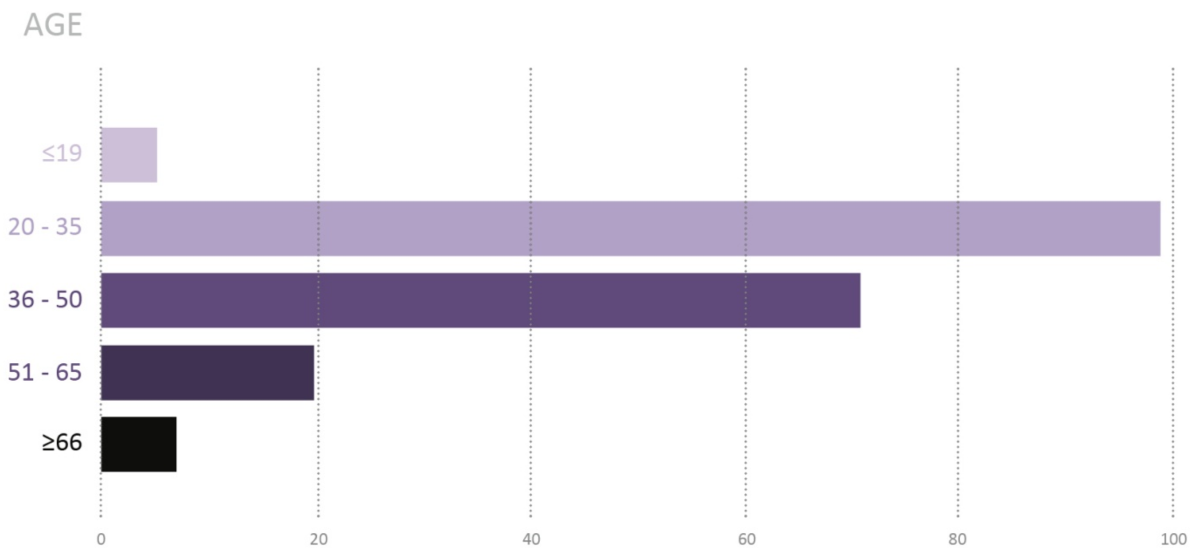


Figure 52 Ages of the interviewees

61.9% of this group had no relationship to professions or jobs within the built environment. 58.9% were homeowners and figure 53 shows the type of housing they inhabited. From this table, it can be seen that more than 60% of the responses corresponded to the occupants of detached or semi-detached houses, which are the types of housing which have more envelope exposed and therefore have a higher heat load. Terraced houses and flats accounted for over 35%.

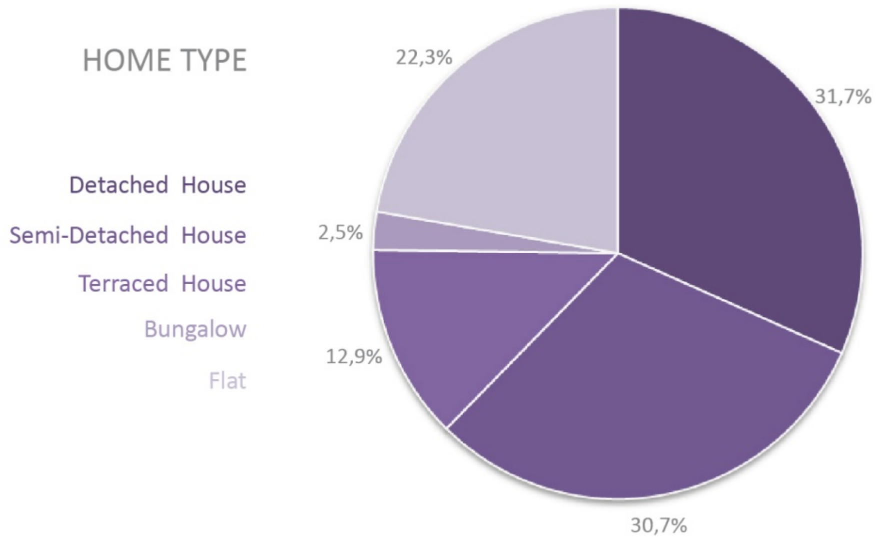


Figure 53 Percentage of the type of home interviewees live in

Passive design strategies (PDS) and sustainable energy technologies (SET)

The columns in figure 54 correspond to the distribution of responses between people who were related to the built environment and architecture, identified as “BE”, and those who did not have any sort of connection (profession, study, research or work) to these areas; this column is identified as “NBE”.

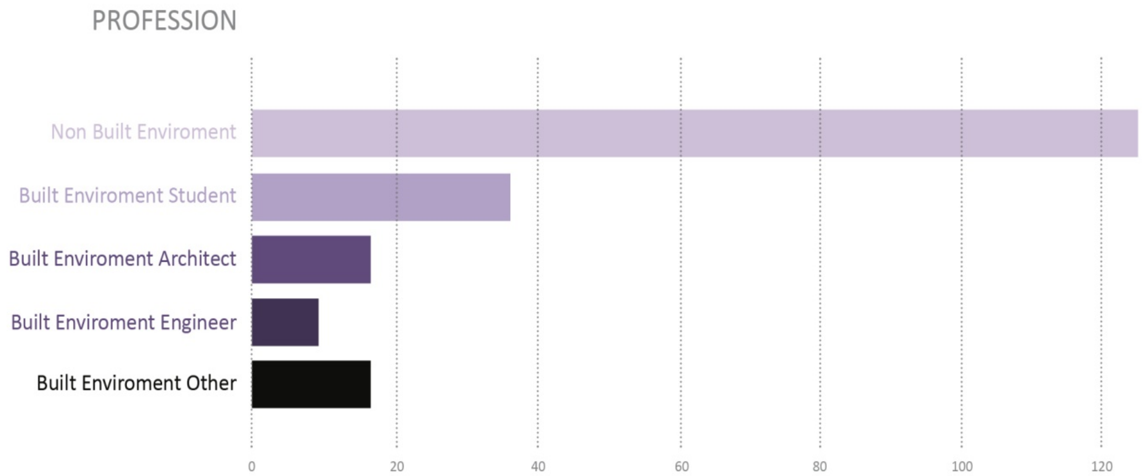


Figure 54 Distribution of interviewees in relation to whether their field of work was related or not to the field of the built environment (BE)

Figures 55 and 56 depict a summary of the total percentage distribution obtained from the answers to question **“before your visit were you aware of any of the passive design strategies and architectural features utilised in the BASF house?”,** which was responded to with ’yes’ or ‘no’. Overall, it is possible to ascertain that there is a good general awareness in regard to energy efficiency and the architectural aspects that can be included in the design of a house. As expected, sun orientation, natural light quality, airtightness and natural ventilation mechanisms are the most well-known features with regard to an energy efficient strategy for buildings; all of them obtained positives responses of close to or higher than 80%. The only design strategy applied to the BASF house that the visitors were less aware of as a particular feature used for natural ventilation was the use of high ceilings, with 58.5% awareness. The columns to the left in light green in figure 55 correspond to responses from people related to the BE, while the columns to the right in purple correspond to responses from NBE

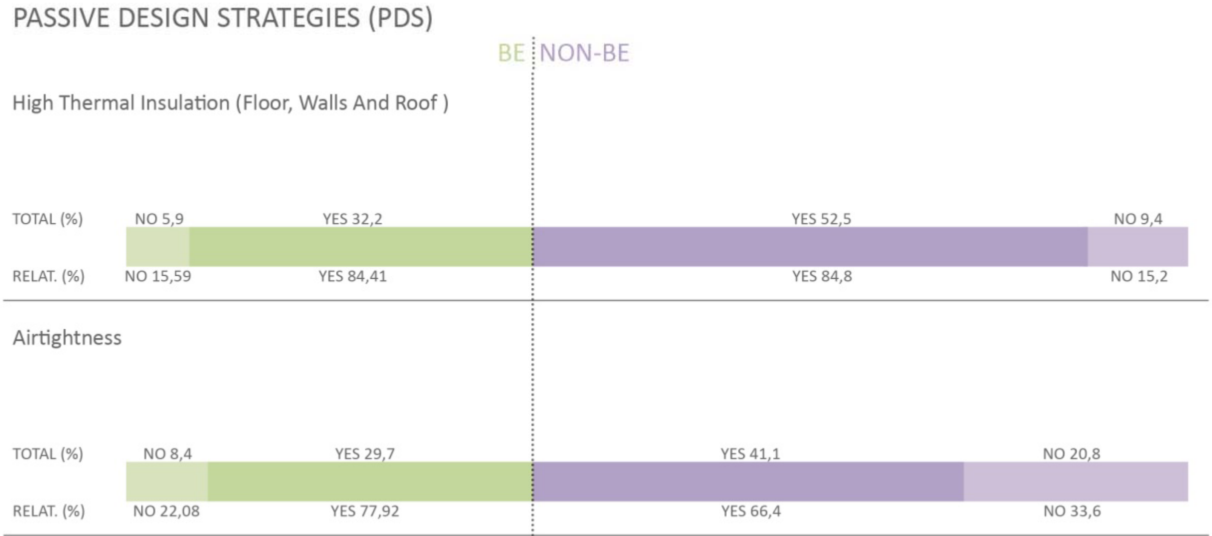


Figure 55 General knowledge about passive design strategies (PDS). Comparison between BE and NBE interviewees.

Figure 56 General knowledge about passive design strategies (PDS). Comparison between BE and NBE interviewees.

In relative terms, when analysing people related to the built environment first, the features that were better known were sun orientation and natural light quality, followed by high thermal insulation and sunspace, being all close or higher than 80%. The least known factor was the use of high ceilings, with 64.93% awareness. The answers from the NBE group show greatest awareness of sun orientation, high thermal insulation and natural light quality, but showed less awareness than the BE group about sunspace. The least known feature was reduced window size, with only 61.6%.

However, there was good general awareness of passive design strategies and the least known strategy obtained 60%. When it came to sustainable energy technologies awareness, some were very well known, whilst others were almost unknown, as could be expected because when technologies become more sophisticated and very specialised, knowledge of them tends to be less. Thus, figures 57 and 58 depict a summary of the total percentage distribution obtained from the answers to the question **"before your visit were you aware of any of the technologies utilised in the BASF house?",** which was responded with 'yes' or 'no'. The technologies referred to are the mechanical systems in the BASF house. The results are presented as in the previous figures, where the columns to the left in green are for the BE group, while the purple columns to the right show the NBE responses from the different visitors to the BASF house.

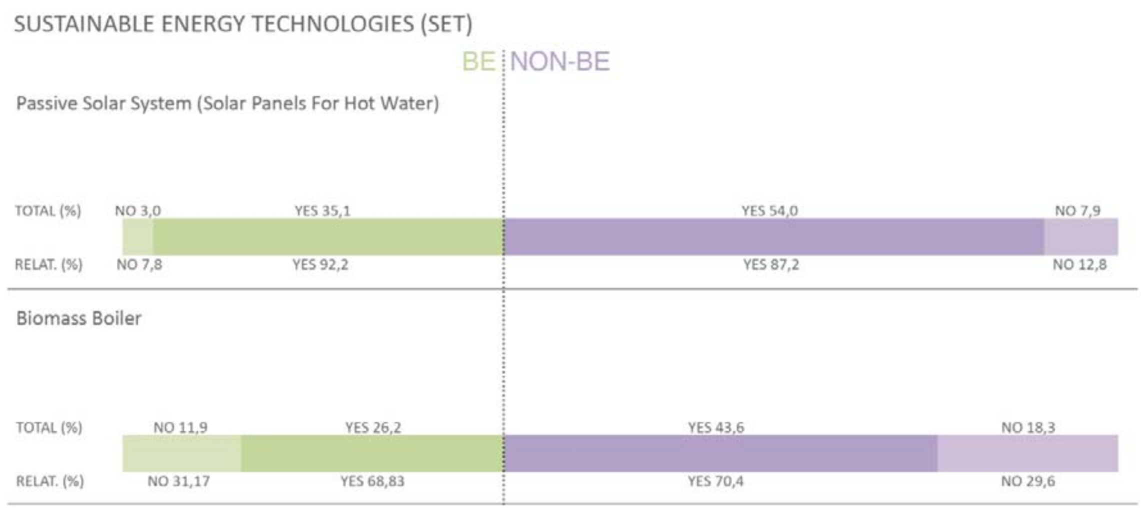


Figure 57 General knowledge about sustainable energy technologies (SET). Comparison between BE and NBE interviewees.

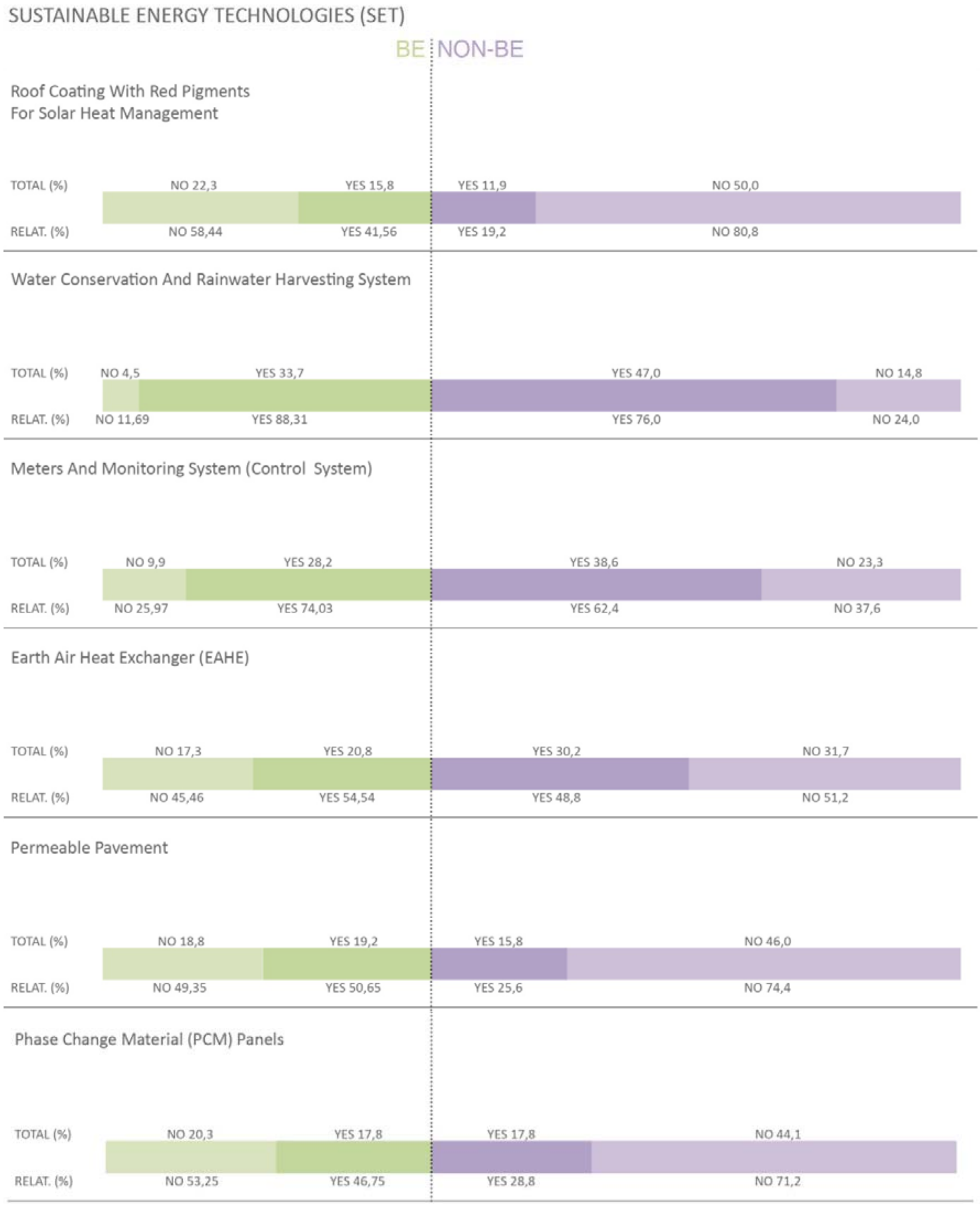


Figure 58 General knowledge about sustainable energy technologies (SET). Comparison between BE and NBE interviewees

Technologies such as passive solar systems (solar panels for hot water) and water conservation and rainwater harvesting systems, were quite well known, with responses of over 80% while the roof coating with red pigments for solar heat management obtained just 27.7% when analysing the total of the two sub categories; BE and NBE.

Looking at each group, for the BE group the most well-known SET were as expected, the same as above with 90% awareness. The least known strategies were the roof coating and the phase change material (PCM), with awareness close to 45%. When looking at the NBE group, the most known technologies were also the passive solar system and the water conservation and rainwater harvesting systems, with 82.2% and 76% respectively and the least known ones were the roof coating with red pigments for solar heat management with 19.2% and permeable paving with 25.6%.

The following set of graphs in figures 59 and 60 in next page depicts the preference and value people gave to the sustainable design features and technologies applied to the BASF house. The preference values go from 1 to 5, where 1 represents the less favourite and 5 the most favourite. It could be observed that the reduced window size on the northern façade was the least preferred design strategy, followed by airtightness and high ceilings. For the sustainable energy technologies, the least popular was the biomass boiler, followed by the roof coating with red pigments for solar heat management and the permeable paving.

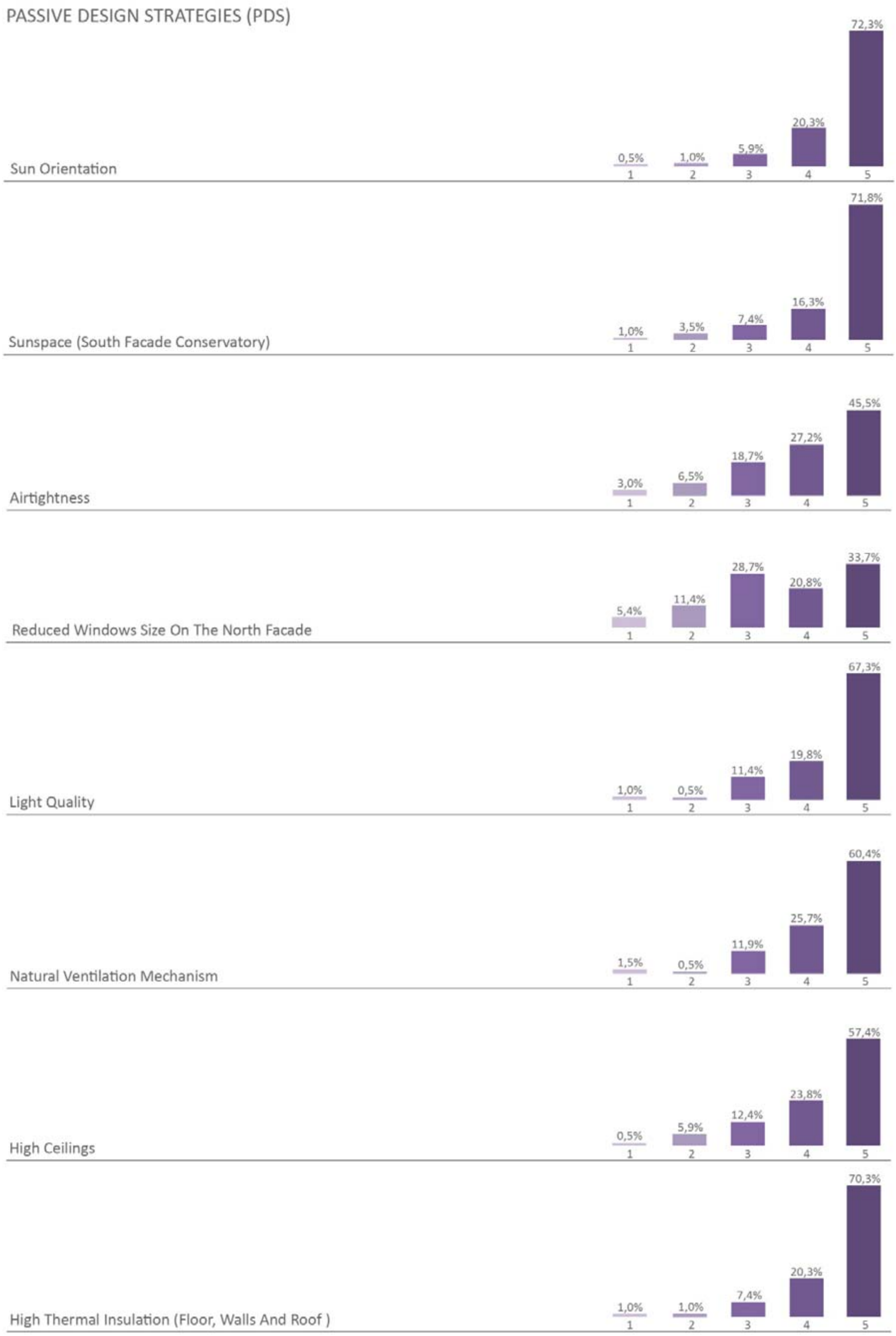


Figure 59 Interviewee preferences regarding Passive Design Strategies (PDS).

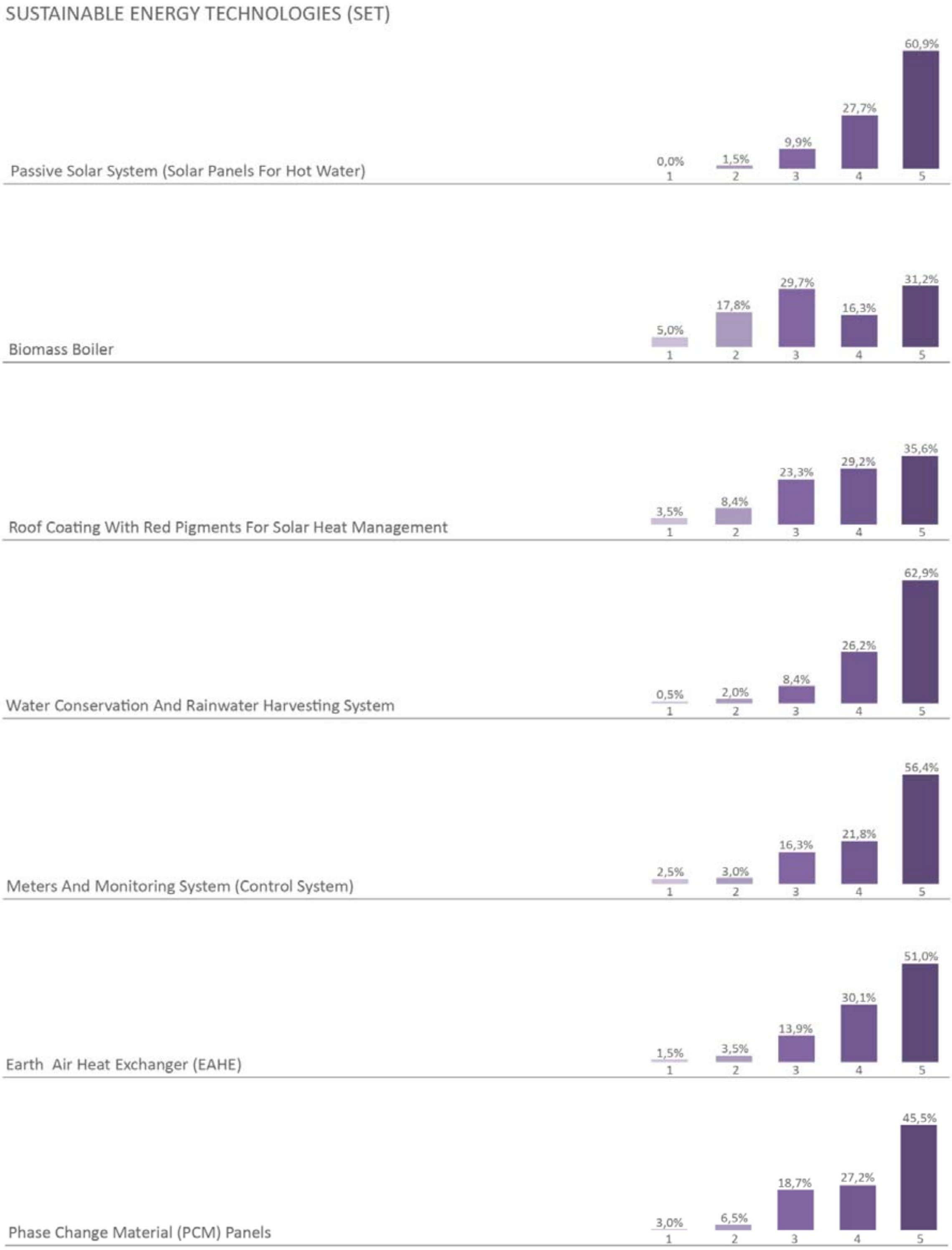


Figure 60 Interviewee preferences regarding Sustainable Energy Technologies (SET).

When it came to the general questions, in response to the question "Should houses have visible meters to read the energy consumption and the cost of it?", 98% responded 'yes', while just 2% marked the contrary. To the question "How do you like the overall appearance of the

BASF House?” and in regard to the Interior versus the exterior appearance, in order of preference from 1 to 5, as can be seen in figure 61, people preferred the interior appearance to the exterior one.

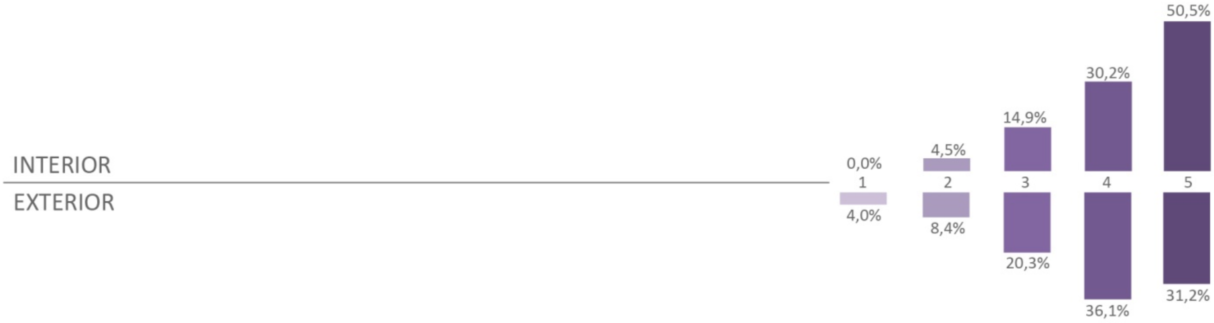


Figure 61 Interviewee’s preferences regarding the exterior versus the interior design of the BASF house

In regard to the questions that imply changes and costs to homeowners: “How much extra are you willing to pay for a Zero Carbon Home?”, the graph on the left of figure 62 shows that 80% of the interviewees were willing to pay only 15% more for the cost of a zero carbon home. With regard to refurbishment, the visitors were asked “In how many years will you expect pay back?” As the graph on the right of figure 63 shows, the most popular option is between 6 to 10 years, with 58.9%.

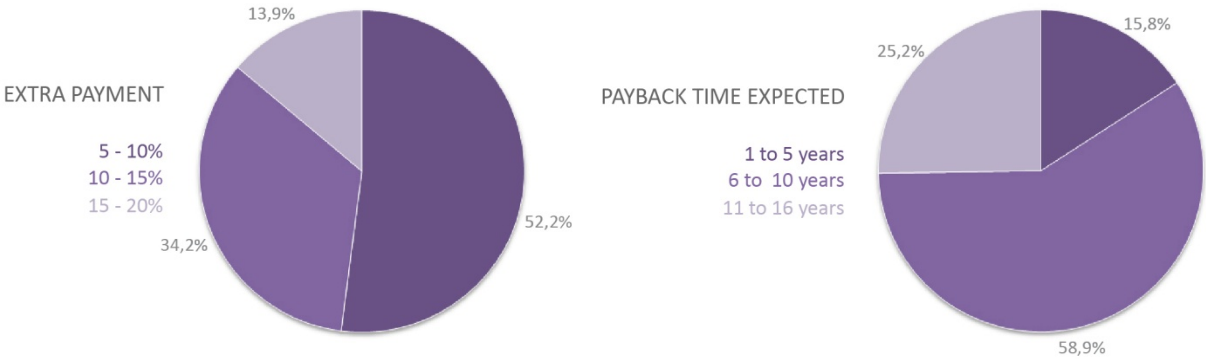


Figure 62 Interviewees’ preferences regarding investment and payback time expectations on SET.

Tendency corroboration: quantitative analysis of the whole set

The following analysis depicts the results of the total number of answered questionnaires, 478, of which 202 were answered in full, while the rest varied from 50% to 99% of responded answers. The main purpose of amplifying the set is to enhance the analysis of the previous section to corroborate tendencies and to verify possible distortions and differences that could affect the robustness of the conclusions obtained from the analysis of the smaller set of questionnaires.

In total terms, it can be observed that the most well-known passive design strategies are the sun orientation and natural light quality, both over 80%, while the least known strategy is the use of high ceilings one; the same as in the previous section, see appendix 9.

In relative terms, the results obtained are very similar. For the BE group, sun orientation and natural light quality were the most well-known, while the use of high ceilings was the least known. For the NBE group, the sun orientation and high thermal insulation were the most known and the reduced window size on the north façade was the least known strategy.

The same pattern can be seen with regard to the answers related to questions regarding awareness of sustainable energy technologies. There is no difference in the tendencies, regarding preferred passive design strategies and sustainable energy technologies. It was therefore possible to conclude that the 202 questionnaires were sufficiently representative that their analysis and conclusions would be as valid as working with the 478 questionnaires. When contrasting both sets of questionnaires, for the more incomplete questionnaires, interviewees were more inclined to leave blank answers regarding questions related to preference than those about awareness. Also the answers to certain questions are conclusive, with the whole set of responses reaching close to 100%. For instance, the question regarding awareness of the sun's orientation as a passive design strategy, 99.8% of the people responded positively. Later, when contrasting this result with the occupant's questionnaire results, it could be concluded that natural light and sun radiation are among the most important factors for latitudes where sunlight is scarce. This fact was reaffirmed when applying the Pearson Correlation to establish the analysis of dependence among variables (see appendix 9), which was done to prove the relationship between all variables that were related to the sun, window sizes and orientation, natural light and insulation. It can therefore be concluded that the thermal and lighting design aspects in housing in the UK are key factors.

5.2. The BASF House occupants' questionnaire

This questionnaire was much longer than that given to visitors, extending to 13 pages (see appendix 9). However, the general section of the questionnaire was based on the visitor's questionnaire so as to be able to compare the results. The most specific and major part of it was focused on the experience of living in the BASF house. It included six sections composed of simple multiple choice answers to be marked with a tick, tables to be completed and open questions that required written answers. The six sections included:

a. Demographic information;
b. Period of occupancy of the BASF house;
c. Use of spaces in the BASF house by the occupants, typical weekly routine (separated into working days versus weekends);
d. Adequacy of space in the BASF house: Distribution, size and spatial relationship, Heating/cooling and ventilation (temperature and air quality), Lighting and acoustics, Plumbing/electrical, finishing materials, floor, walls, ceilings, colours, etc.
e. Adequacy of the passive design features and low to zero carbon technologies applied to the BASF house;

5.3. The BASF House and its occupants

This experimental case study was a first-person research; the author of this thesis was one of the first occupants of the BASF House is the person who has lived longest in it to date, for a period of two and a half years, and is also the only tenant/researcher involved with this research. The other residents that have lived or are currently living in the house are academically related to the university. All the occupants, with the exception of their visitors were familiar with general issues related to energy efficiency. However, none of them, including the author was involved in the design process or the development of the project in any aspect. Their fields of work and research are not directly related to sustainable homes and the author, the second person to live in the house, became involved in the project after moving into it. The BASF House is the property of the University and is managed by the Estates Office; it is also an exhibition home, which is visited by the general public two or more times a month. The tenants pay half of the monthly rent and their electricity and biofuel consumption.

Climate adaption

The non-British group was not fully adapted to the local climate; they are more sensitive to indoor/outdoor temperature changes, not used to the central heating and definitely not used to UK winters, while the British occupant is more resistant to the cold climate and more accustomed to indoor heating. This was particularly seen on the days when the British occupant was alone in the house. This occupant rarely felt the need to light the biomass boiler for heating and was able to adapt quickly to abrupt temperature changes from outdoors to indoors and vice versa.

Periods of occupancy of the BASF House

The house has been occupied since February 2008. The first rental period started on June 15 2008 and extended until the end of August 2009. During Christmas and over the summer, the occupation of the house changes a great deal, and around the holidays the house has been unoccupied. From October 2009 to September 2010, there was a new rental contract with two non-UK residents, including the author. The occupants received visitors for longer periods, over than a month each, which also added extra information in regard to the qualitative aspects. In October 2010, the author moved out of the house and three new tenants moved in, who were still there at the time at the time of writing this thesis. During this period, the biomass boiler heating system was replaced for an air source heat pump (ASHP) system.

During the first winter, 2008-2009, the house was shared by three tenants, two women and a man, consisting of the author and her husband (both non-British) and a flatmate, whose partner visited at weekends (both British). From mid December until the end of February, a fourth person (a non-British male) was living temporarily in the house. The house was unoccupied for almost a month, from 17 December to 12 January.

In the second winter of 2009-2010, the house was shared by two women, the author and a new tenant, both non-British. The partners (non-British males) of the tenants each stayed for more than a month during this winter. The tenants were from the same culture and had very similar patterns of living, such as similar schedules for working, eating and cooking, similar heating and ventilation habits, and their daily routines tended to follow the same pattern each week.

In the third winter of 2010-2011, the house was inhabited by three new tenants, all males, two from same culture, both non-European and one British resident. A new heating system replaced the existing one.

Demographic information about the occupants

The following figures present the general aspects obtained from the set, describe the profile of the interviewed occupants. Figure 63 depicts the range of ages of the occupants, which is 50% male and 50% female. Among them, 12.5% are homeowners and 87.5% are tenants. The majority (87.5%) of the occupants experienced living in the BASF House during winter months. Figure 64 shows their professions and whether or not their professions were related to the built environment.

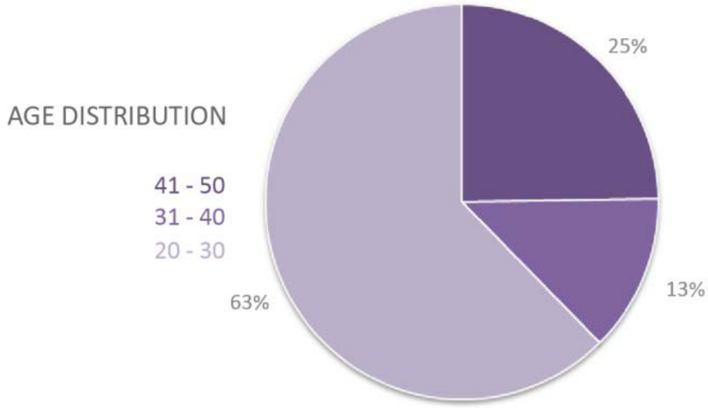


Figure 63 Age distribution of the occupants of the BASF House.

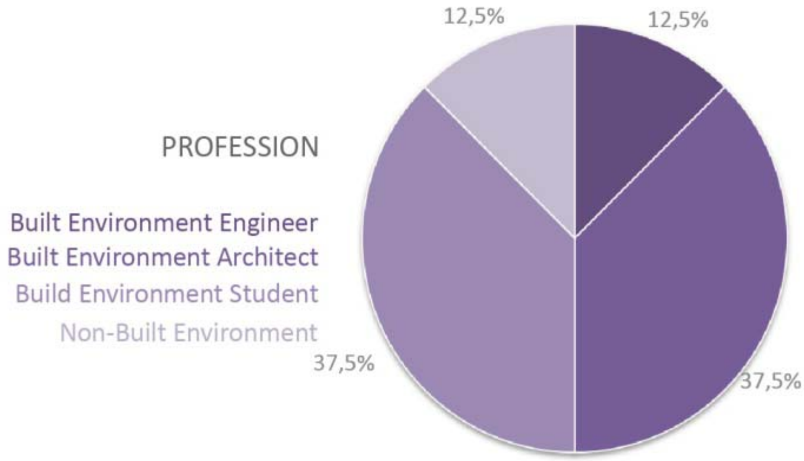


Figure 64 Profession distribution of occupants of the BASF House.

Space/room preferences

This section presents the evaluation of the different interior spaces and rooms by the eight occupants of the BASF house. First it shows a ranking of each interior room or space in the house, where the four possible choices to qualify them in general terms were *'excellent, good, fair and poor'* and a second set of possible answers were more specific for each space, related to the architectural quality, including thermal, lighting and acoustic comfort, which was also qualified with the same four choices of value, from *excellent* to *poor*. Both sets of answers are translated into percentage of preference in regard to quality. With these sets plus the written comments, it is possible to understand the evaluation given by occupants to each interior room or space.

Most of the tables of this section are included in the appendixes 11 and 12. However the most representative ones are shown as follows.

It is possible to rank the general preferences, by taking just the choice "excellent". For the ground floor the ranking from most preferred to least preferred was the kitchen, dining room, sunspace, living room, toilet and plant room, where the sunspace obtained a mark on all the four possible quality choices. For the first floor, the order was the main bathroom, which obtained the highest evaluation of all the rooms and spaces of the BASF house, followed by the two south balconies, bedroom 2, bedroom 1 and the north bedroom. Finally, for the circulation areas the ranking, from the most excellent to the most poor, was the landings, stairs, entrance porch and shed. The rooms and spaces were analysed in a more detailed manner by combining the two highest options, *excellent + good* and the two lowest ones, *fair + poor* respectively.

5.3.1. Aspects of the design quality of the BASF house

The following section will depict an overall appreciation of the quality of the different aspects of the design of the BASF house, including 33 characteristics to be evaluated. They are all related to the quality of architectural design as a whole. In the above section the emphasis was put on a particular space or room, while in this section the focus is on passive design strategies, construction and building material quality, installations, comfort, appliances, technologies and finish.

The following set of figures, from 65 to 68, depict the 33 aspects of the house that were evaluated in regard to quality within four subcategories; aesthetic, environmental, building materials and installations. Within these four groups, specific aspects were rated *excellent, good, fair* or *poor quality.* Overall the BASF house was fairly well evaluated as a whole by its occupants, mostly between *good* and *fair* options. The maximum score of *excellent* was 37.5%, obtained by just four features: the ceilings, windows, entrance porch and electrical installations. If the choices *excellent + good* are taken together, 18 features scored 75% or more; that is more than half of the features. The ranking from highest to lowest evaluation was as follows: the lighting in winter, quality of building materials, floors, ceilings and windows all obtained 100%; next came the lighting in summer, ventilation, air quality, security, maintenance, walls, pavement, electrical and appliances, which obtained 87.5%; then environmental quality, comfort and the quality of building installations obtained 85.7%, followed by the temperature and entrance porch, which each obtained 75%. For the analysis of the quality evaluation of the many features of the BASF House, given that most of the evaluation done by occupants was concentrated in the middle, therefore most of the time the aspects were analysed adding *excellent + good* and *fair + poor* to obtain more robust results.

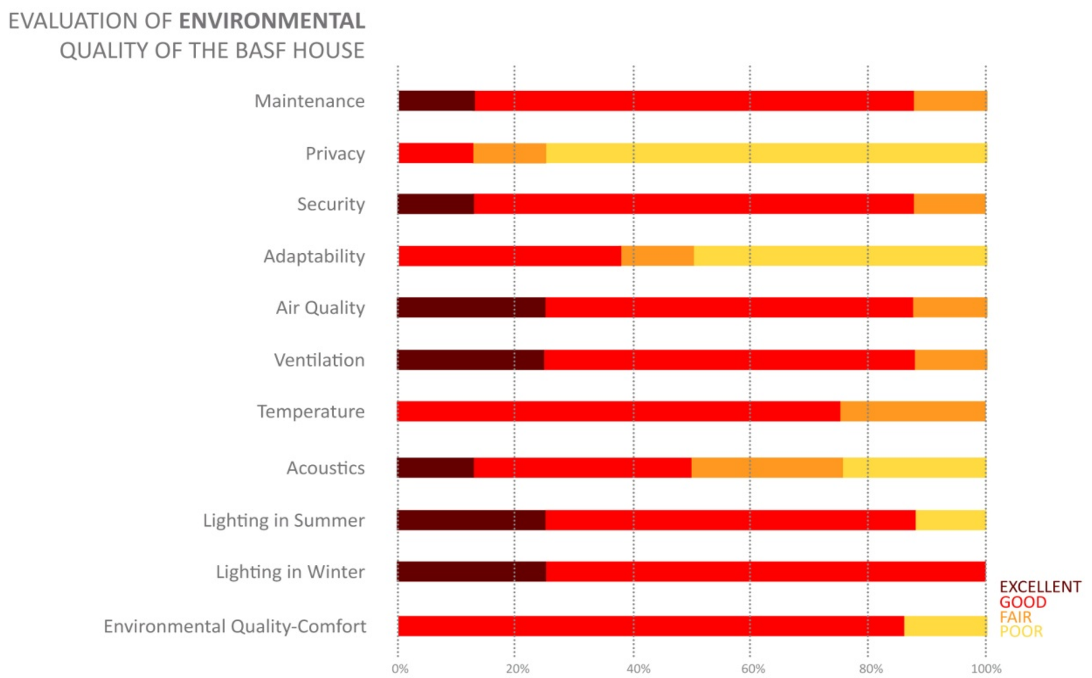
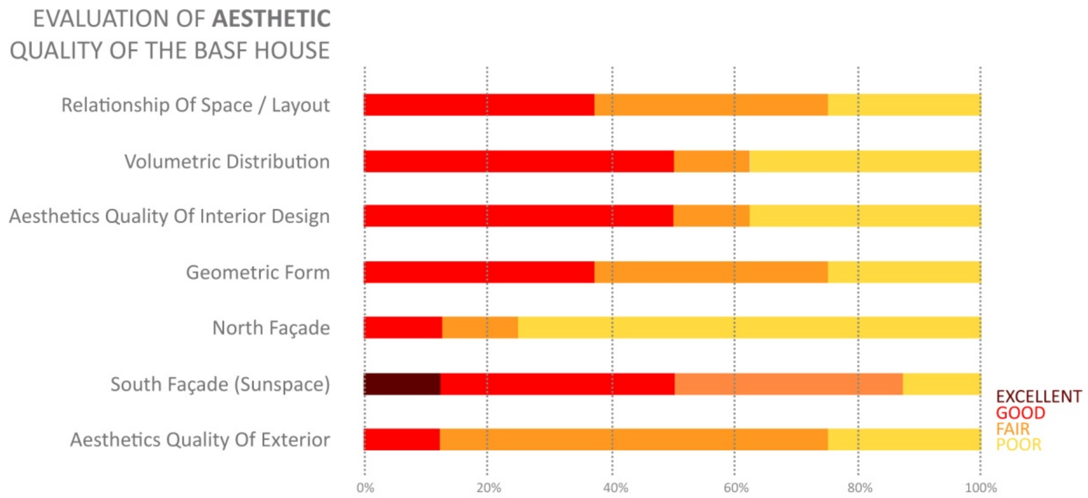


Figure 65 Graph: evaluation of the environmental quality measured from excellent to poor for each feature of the BASF House.



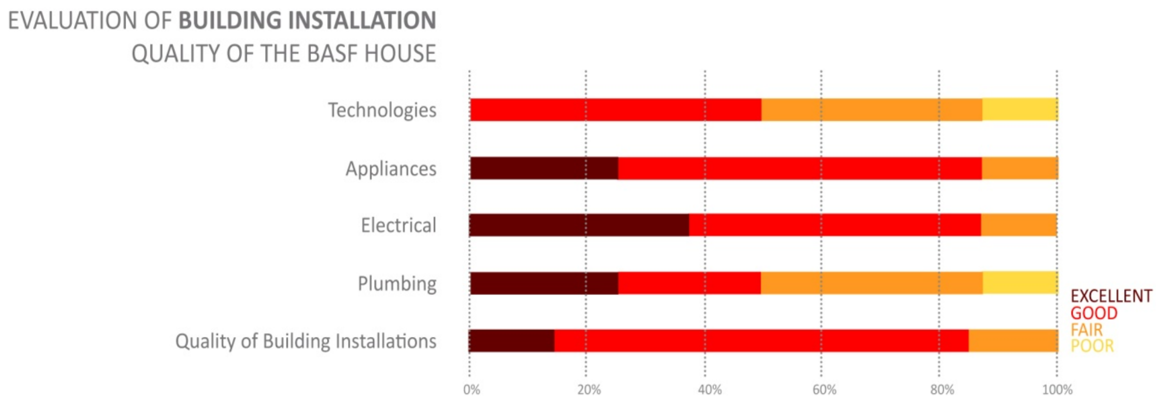


Figure 66 Top graph: evaluation of the aesthetic quality. Bottom graph: evaluation of the building installation quality. measured from excellent to poor for each feature in the BASF House.

The above set of graphs depicts how the quality of four sets of design features (figures 67 and 68) were evaluated. This data was obtained from the analysis of questionnaires completed by the occupants of the BASF House. The graphs in figure 65 evaluate the environmental quality of the BASF House, and figure 66, containing three graphs that evaluate the aesthetic quality, building installation quality and building material quality.

The design aspects that obtained the lowest scores when their *fair + poor* rankings were added are the aesthetic quality of exterior, north façade and privacy, with 87.5%, and the latter two were ranked *poor* by 75% of the occupants, the worst evaluated features of all those evaluated in the BASF House. The geometric form, adaptability and relationship of space/layout obtained 62.5% when *fair + poor* rating, being the three aspects worst evaluated after those previously mentioned. However adaptability received 50% just for *poor*. Therefore, six out of the 33 design aspects evaluated were qualified above or equal to 62.5% as regards *fair + poor* quality and seven scored 50% within the same category. For the four possible quality classifications for each design feature, the results show that all the higher values are concentrated in the middle, being classified as *good* or *fair* quality.

5.3.2. Evaluation of the Passive design strategies (PDS) and sustainable energy technologies (SET) of the BASF house

This section presents the evaluation of the different passive design strategies and the sustainable energy technologies by the eight occupants of the BASF house. As with the previous sections evaluating the PDS and the SET, the range of the four choices *'excellent, good, fair and poor'* was used to rate between three and ten characteristics for each feature. Both set of answers are translated into percentages in regard to preferences. With these sets plus the written comments, it is possible to understand the evaluation given by occupants to each PDS and SET applied to the BASF house. Most of the results of this section are included in appendix 11 and 12. However the most representative ones are shown below. Figure 67 shows the evaluation for the sunspace as an example of well evaluated PDS.

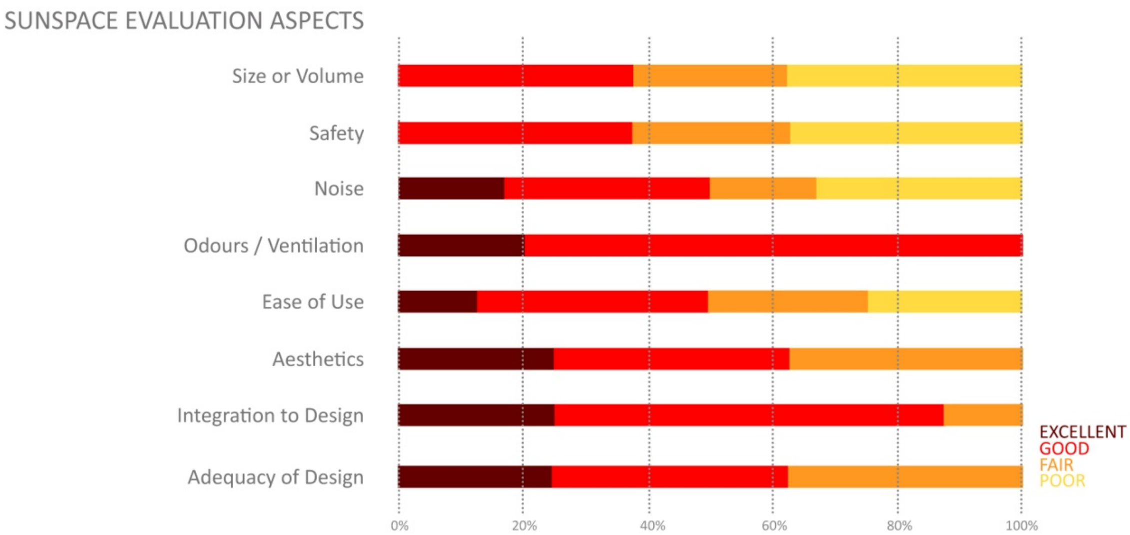


Figure 67 Sunspace quality evaluation, eight aspects evaluated by occupants of the BASF House.

Passive design strategies (PDS)

Sunspace Excellent + good PDS quality: of the seven characteristics, five were evaluated at 50% or more, odours/ventilation with 100%, integration into the design with 87.5%, followed by aesthetics, adequacy of design, ease of use and noise, from 65.5 to 50%. The items ranked between poor + fair for PDS quality were safety and size/area (m^2) with 62.5%, where 37.5% was for the choice *poor* only.

Sun orientation Excellent + good PDS quality: all four characteristics were evaluated at 66.7% or more, with ease of use scoring highest with 100%, followed by adequacy of design, integration into design and aesthetics, from 83.3% to 66.7%

Reduced window size on the north façade Excellent + good PDS quality: four of the eight characteristics were evaluated at 66.7% or more, with safety being the highest evaluated feature with 83.4%, followed by noise, adequacy of design, ease of use and odours, obtaining from 80% to 66.7%. Those characteristics scoring poor + fair in terms of PDS quality were size/area (m^2) at 75%, aesthetics at 73.4% of which 66.7% was for *poor* quality, and integration into design obtained 57.2%.

Natural ventilation mechanism Excellent + good PDS quality: six of the eight characteristics obtained a very high ranking, of 73.4% or more. Odours and safety were the highest evaluated features, obtaining 100%, followed by adequacy of design, integration into design, aesthetics and size or volume obtained, ranging from 87.5% to 73.4%. Of those features ranked poor + fair for PDS quality, only **noise** scored poorly with 75%, of which the choice *fair* obtained 62.5%, as can be observed in the image in figure 68.

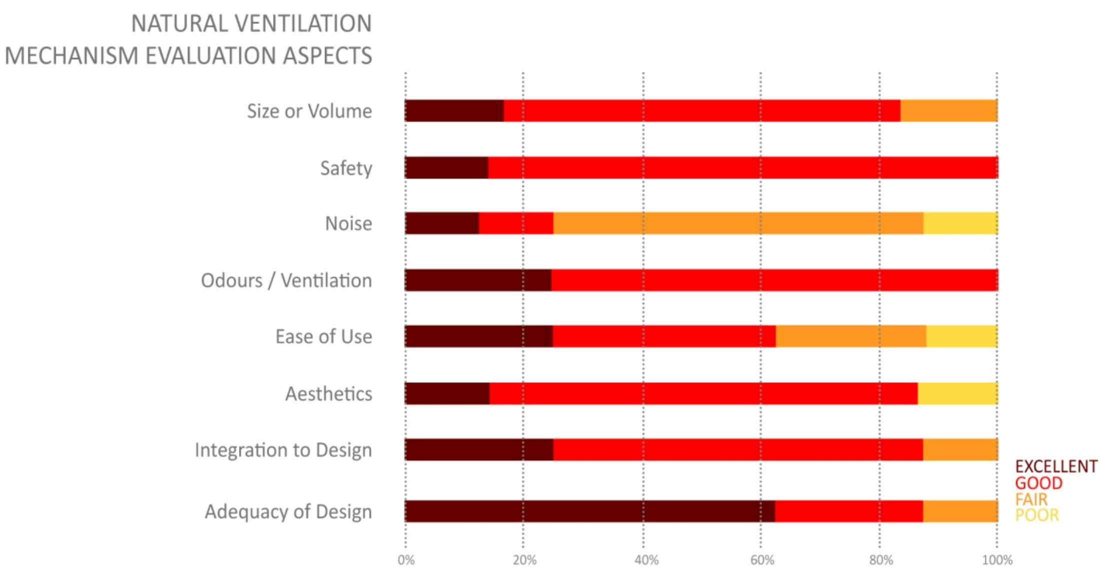


Figure 68 Natural ventilation quality evaluation, 8 aspects evaluated by occupants of the BASF House.

Author's observations as an occupant on the natural ventilation

Aspects such as the air flow in buildings and indoor air quality are key to the comfort and wellbeing of the occupants of a building. It therefore seems important to consider the ventilation and cooling habits of the occupants as well as how they used the devices for ventilation and cooling installed in the BASF house. These habits are closely related to each occupant’s culture and to the influence of the local climate. The following describe the occupant’s experience in regard to domestic routines:

Passive ventilation patterns through windows

As could be expected, the thermal comfort of all the occupants varies greatly. Therefore the opening and closing of windows was subject to individual demand and weather conditions. The occupants could operate certain windows remotely and they could also inform themselves about the indoor temperature conditions through an internet connection, but they rarely did so.

For the first winter, the different patterns of use and different schedules for opening and closing of windows were observed. The non-British opened their bedroom windows every single day in the morning for a short period of time, for at least one hour after taking a shower; however, this was not as frequent for the British user. All the occupants had the practice of opening the main bathroom window on a daily basis and they left the window open until lunchtime normally, unless it was a very cold day.

For the second winter, the occupants had very similar ventilation habits. It should be mentioned that both were non-British and from the same country:

- Bathroom windows: The occupants were in the habit of opening the windows throughout the year to ventilate the bathroom and avoid condensation. The windows were opened daily, in the tilted position after morning or evening showers, on cold days, the windows were opened until the bathroom was free of steam and moisture.

- South-facing bedroom windows, the occupants opened the sliding doors to the sunspace almost daily, normally after getting dressed and tidying the bedrooms. On very cold days, they closed them soon afterwards, whilst on warm sunny winter days, they left them open as long as the temperature permitted. In appendix 6, in the section of indoor climate data for years 2009 and 2010, the temperatures of the bedrooms throughout the whole year are given. The very high windows facing north were opened/closed from the kitchen control panel or elsewhere using the internet almost every day in autumn and spring, until lunch time, when the occupants returned home.

- The central core opening of the windows located in the centre of the outer and inner curtain walls and at the top of the stairs, was typically opened/closed on summer days to ventilate and cool down the whole house in a passive way when not much cooling was required. They could be remotely operated from the control panel in the kitchen or elsewhere through an internet connection.

Combined ventilation through windows and Ground Air Heat Exchanger (GAHE)

- The ground floor windows, sliding doors and windows were rarely opened on cold days; sometimes they were open briefly for ventilation at lunch or dinner time, to eliminate cooking smells or when a social activity raised the indoor temperature and the air became stuffy. The windows that were normally open on these occasions were the kitchen ones, in tilted position, which is operated manually. However, when the cooking smells were too strong, the automated central window set was operated, opening just the highest pair at the top of the stairs, which was operated remotely from the control panel in the kitchen. When this occurred, on most occasions occupants were careful to closing all the bedroom doors as well, to keep odours out of them.

Figure 69 shows a scheme to operate the mechanical ventilation system in which fresh cold air (at underground temperature) is introduced to ventilate the house for a short period. This fast ventilation procedure was very effective in removing strong smells when cooking, indoor overheating or stale air due to the presence of many people in the house; the operating time in winter was never longer than 10 minutes and the dining and living room vents were opened to a maximum of 30%.

Figure 69 Scheme showing the combined strategy to ventilate the BASF house when is smelly or stuffy.

High ceilings Excellent + good PDS quality: three of the eight characteristics obtained the higher ranking, all with 75%: adequacy of design, integration into the design and safety, and noise with 66.7%. For the choice *excellent,* the highest value was 37.5%, obtained by the second aspect. Only ease of use was ranked poor + fair for PDS quality, with 66.7% equally distributed between the two choices.

High thermal insulation Excellent + good PDS quality: two of the three characteristics scored 100%, namely adequacy of design and integration into design safety and aesthetics with 75%. For the choice *excellent,* the higher value was 37.5%, obtained by the second aspect.

Airtightness Excellent + good PDS quality: most of the eight characteristics obtained the highest value of 100%; followed by adequacy of design, with 87.5%. However this characteristic was that with the most *excellent* rankings, with 50%; the rest were below and odours obtained 60%, based completely on the choice *fair.*

Sustainable energy technologies (SET)

Solar system Excellent + good PDS quality: five of the seven characteristics 5 were evaluated with 50% or more: odours/ventilation with 100%, integration into design with 87.5%, followed by aesthetics, adequacy of design, ease of use and noise, from 65.5% to 50%. Those ranked poor + fair for PDS quality were safety and size/area (m²) with 62.5%, where 37.5% was for the choice *poor* only.

Solar system (solar panels for hot water) Excellent + good PDS quality: five of the seven characteristics were evaluated at 50% or more: odours/ventilation with 100%, integration into design with 87.5%, followed by aesthetics, adequacy of design, ease of use and noise, from 65.5% to 50%. The factors ranked poor + fair for PDS quality were safety and size/area (m^2) with 62.5%, where 37.5% was for the choice *poor* only.

Biomass boiler Excellent + good PDS quality: **this appliance was the worst evaluated.** It did not obtain any positive evaluation of its aspects and nobody ranked it as *excellent*, except noise with 16.7%*.* The item clear user manual obtained 40% for the choice *good* entirely. A ranking of poor + fair for PDS quality was given to absolutely all its aspects of between 60 to 100%, where aesthetics, ease of use, odours, maintenance and safety obtained 100%. All of them, except for clear user manual were ranked over 70% in the *poor* category. Integration into design obtained 85.7%, followed by adequacy of design and noise with 83.3% and clear user manual with 60%.

Roof coating with red pigments for solar heat management Excellent + good PDS quality: of the six aspects, only adequacy of design was evaluated over 50%, with 87.5%, where 25% was for the choice *excellent.* Only aesthetics received over 50% ratings of poor + fair PDS quality, with 62.5%. The other four aspects were evaluated with 50%.

Water conservation and rainwater harvesting system Excellent + good SET quality: adequacy of design, integration to design, ease of use and noise, were evaluated with the maximum 100%, divided between the two choices, followed by size with 66.7%, entirely for the choice *fair.* The ranking of poor + fair SET quality were given to noise, with 66.7%, distributed equally between both choices and aesthetics with 57.1%, entirely for the choice *fair*.

Meters and monitoring system Excellent + good SET quality: noise and size were evaluated with 100%, adequacy of design with 87.5%, integration into design with 75% and aesthetics 71.5%. The aspects ranked poor + fair SET quality were clear user manual with 100% and maintenance with 75% both with high values for the choice *poor*.

Ground air heat exchange (GAHE) system Excellent + good SET quality: safety obtained the best value with 100%, six of the other aspects: adequacy of design, integration into design, aesthetics, ease of use, odours, noise and size were evaluated at between 75% and 66.7% and safety obtained the highest value for the choice *excellent* entirely with 62.5%. The rankings of poor + fair SET quality were given to clear user manual with 100%, distributed equally between the two choices and maintenance with 50%, where 33.3% was for the choice *fair* only.

Author's observations as an occupant on the mechanical ventilation/cooling system

The GAHE system for ventilation was almost never used in wintertime and rarely in summer. However, the occupants did use it as a fan to move warm air upwards, as can be observed in the scheme in figure 70. This was because the south bedrooms did not have radiators for heating, and it had been assumed that the flow of warm air would reach the bedrooms, especially if they were cold. However, in fact, they were usually colder that the ground floor.

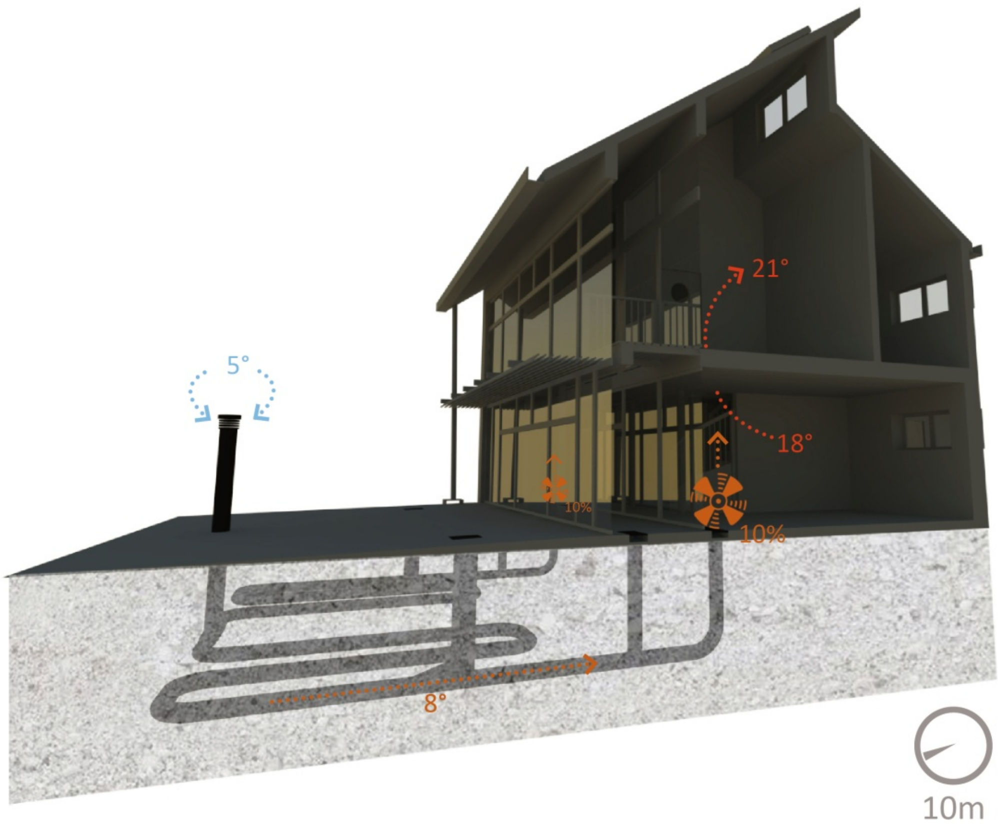


Figure 70 Scheme of the operation of the GAHE to move warm air upwards, from the ground floor to the first floor, for short periods of time (10 min.) and with a minimum fan velocity (10%).

The heat from the ground floor trench and the radiators on the first floor was supposed to ascend/move towards and heat up the bedrooms (keeping doors open), but it never really happened. At night time in winter, especially after supper, when the bedrooms felt colder than the rest of the house, despite the temperature readings showing the contrary, the south bedrooms were the warmest in the house, as can be observed in figure 71. The GAHE was set with the dining and living room vents 30% open, while the two intakes of the sunspace were locked, allowing the cold draft to pass through the floor radiator pipes connected to the biomass boiler, which were at a temperature of over 25°C. This practice was done at bedtime for short periods of time to avoid the house getting cold.

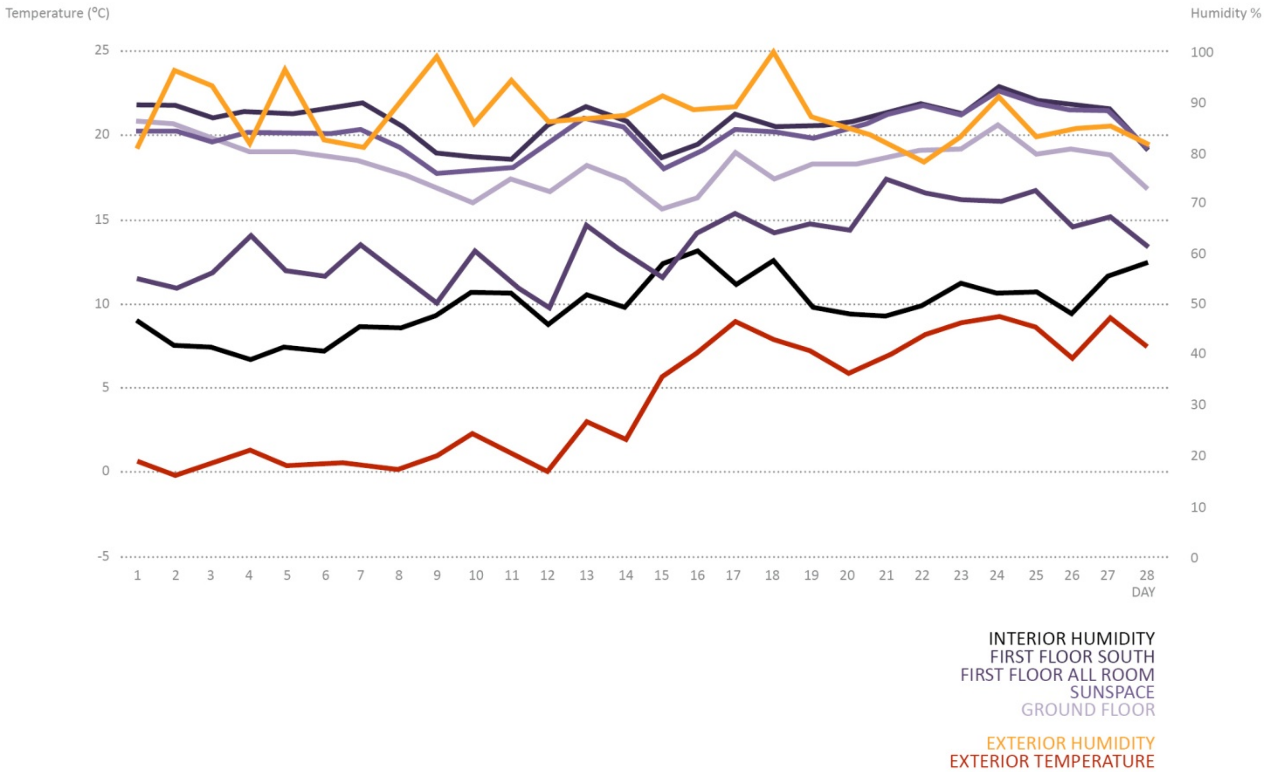


Figure 71 Average indoor temperatures and humidity for the BASF House in February 2009, first winter.

A second use of the GAHE was in the summer, when the indoor temperature surpassed 25°C. For a couple of days each season, as can be observed in the temperature graph in figure 72, the four first days of July and 20 July 2009 were very hot days, the GAHE was an excellent, effective, efficient and fast way of cooling down the BASF house when overheating occurred, especially at lunchtime.

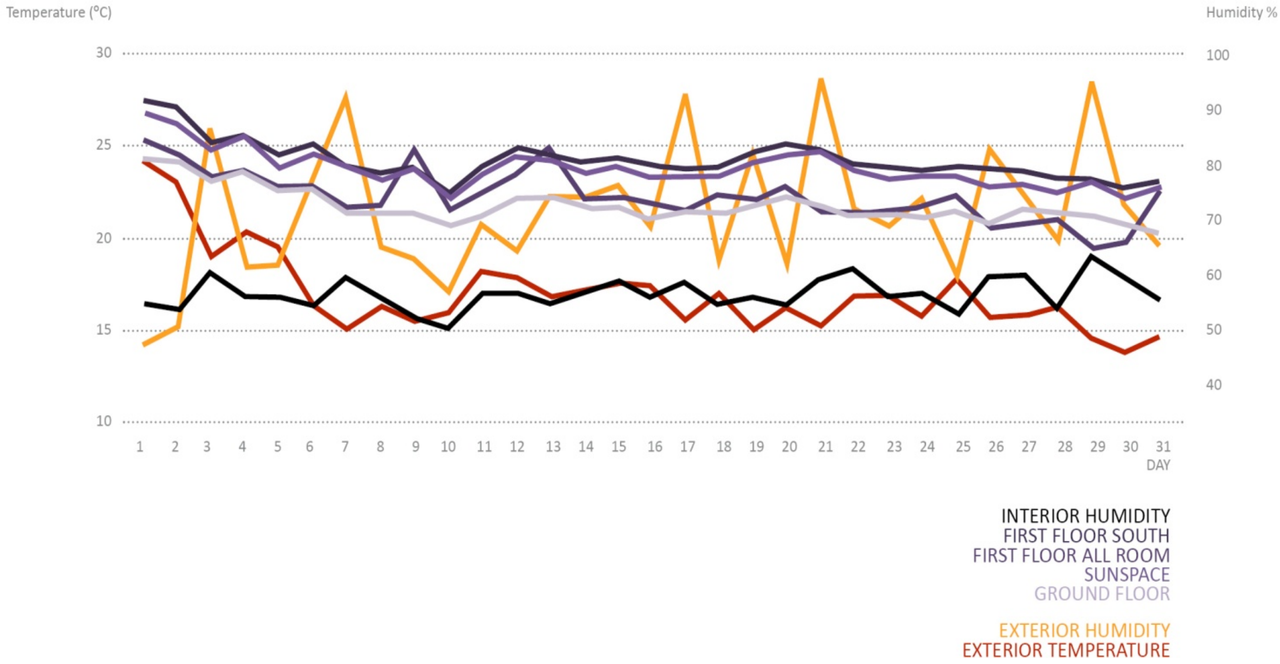


Figure 72 Average indoor temperatures and humidity for the BASF House in July 2009, first summer.

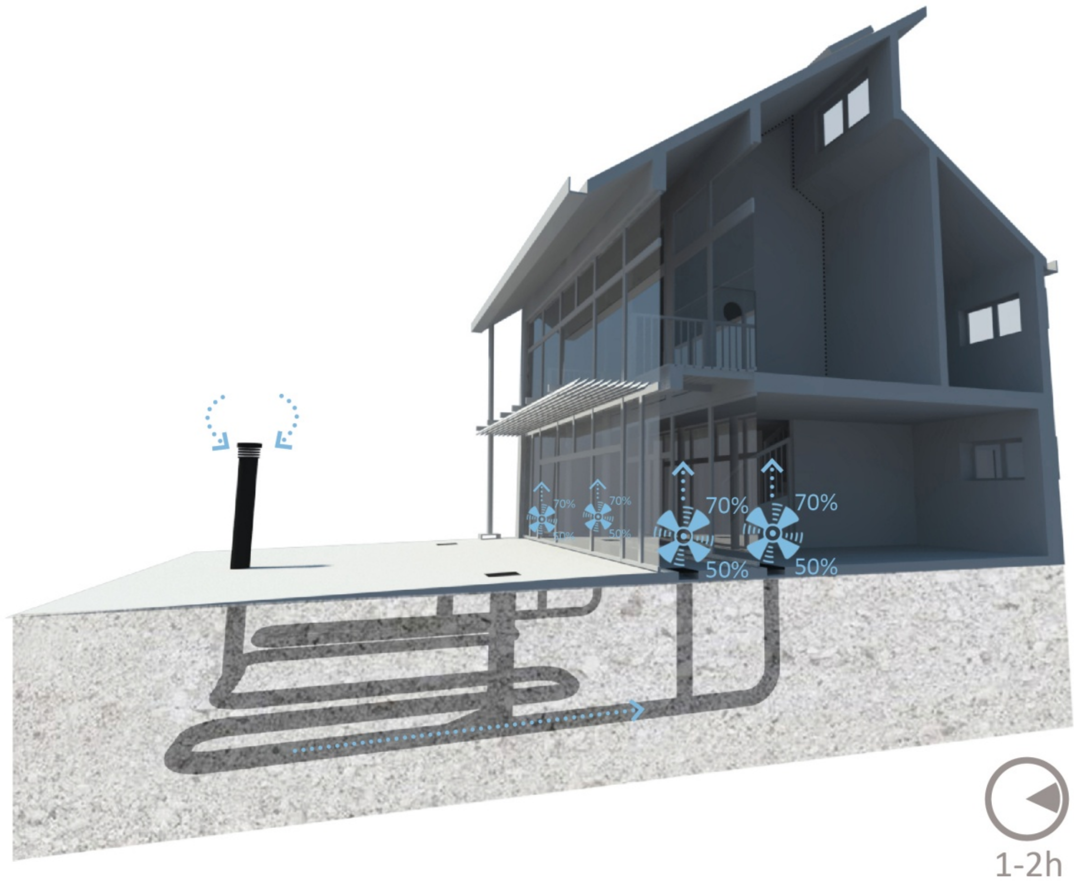


Figure 73 Scheme showing the GAHE operation to cool the house down in summer when overheating occurs.

Most and least favourite Passive Design Strategy (PDS) and Sustainable Energy Technology (SET)

This section presents the reply to the open questions answered by occupants. The transcription of the complete written answers is shown in appendix 12. Table 14 shows the answers to following instruction, which was given for the seven PDS and seven SET applied to the BASF house: Please select and rank by personal preference from one (most favourite feature) to seven (least favourite feature) and explain (below) why or describe any particular experience you had with it to like it or dislike it.

Table 14 Occupants' preferences among the PDS and SET implemented in the BASF house

OCCUPANT	MOST FAVOURITE PASSIVE DESIGN STRATEGY (PDS)	LEAST FAVOURITE PASSIVE DESIGN STRATEGY (PDS)	MOST FAVOURITE SUSTAINABLE ENERGY TECHNOLOGY (SET)	LEAST FAVOURITE SUSTAINABLE ENERGY TECHNOLOGY (SET)
1	High Ceiling	Reduced Window Size	Passive Solar System	Permeable Paving
2	Sun Orientation	Reduced Window Size	Water Conservation & Rain W Harvesting	Biomass Boiler
3	Sun Orientation	Airtightness	Ground Air Heat Exchange System	Biomass Boiler
4	Sunspace	Natural Ventilation Mechanism	Meters and Monitoring System	Biomass Boiler
5	High Thermal Insulation	High Ceiling	Passive Solar System	Biomass Boiler
6	Airtightness	Reduce Window Size	Meters and Monitoring System	Red Roof Coating
7	Sunspace	Airtightness	Passive Solar System	Biomass Boiler
8	Sunspace	Airtightness	Passive Solar System	Biomass Boiler

For the most favourite PDS: the sunspace obtained three votes, followed by the sun orientation with two votes.

For the least favourite PDS: the reduced window size on the north façade obtained three votes, followed by the airtightness with two votes.

These aspects of the BASF house are closely related to the lighting parameter. The sunspace and sun orientation are key features that influence the quality of natural light and they were the favourite feature, while the reduced window size of the north façade was the least preferred, because it affected the natural light quality of those rooms. A quick daylight factor test was pursued on a partially overcast day in winter, on 10 February 2012. Four spot measurements to determine the level of natural light in lux were taken at four different hours of the day in all the rooms of the BASF house and in two spots in the exterior, in the northern and southern areas adjacent to the house. The measurements were taken as indicated in the protocol; in the middle of each area at approximately table height (90 cm), for the kitchen, the measurements were taken at the work surface level at two points. The following plan views (figure 74) portray the measurements taken:

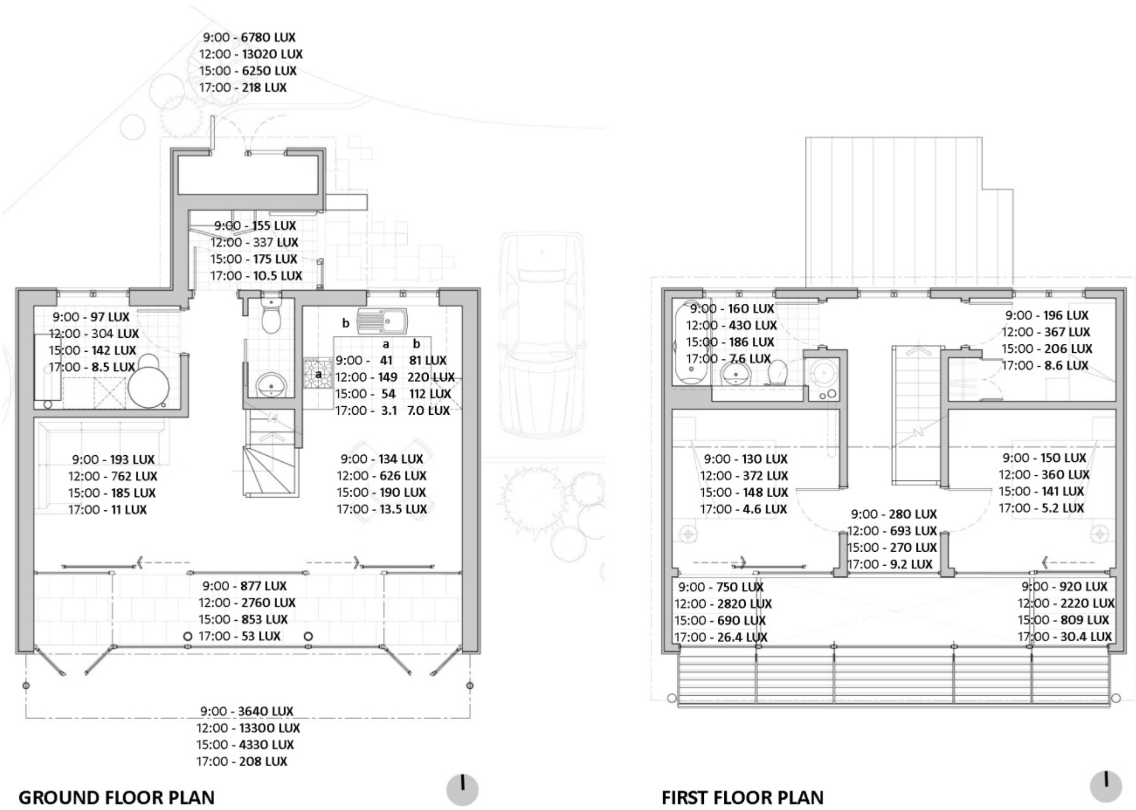


Figure 74 Luminance spot measurements for the 10/02/2012 taken four times a day.

It can be observed from the measurements that in wintertime, the amount of lux measured on the first floor in the north bedroom and in the main bathroom were higher than those measured in the two south bedrooms at any time; considering that the sunspace is in front of them. When contrasting these measurements with a daylight analysis generated by the Ecotect software for the winter solstice at noon on a clear day, the results obtained tended to be coherent with the measurement taken in February 2012. It is expected to have more daylight penetration in December, given the sun’s inclination. Therefore at noon in February (figure 74) the measurements on the ground floor are 2760 Lux in the sunspace, between 600-750 Lux in the living and dining rooms and between 150-220 in the kitchen, while in December when analysing the two ground floor views (axonometric and plan) of the daylight analysis, in the axonometric view (figure 75) indicates that the north parts of the living and dining rooms and the kitchen received in the range of 800 Lux, which are similar to the manual spot values measured in February with the lux meter. While in the plan view (figure 76) depicts over 1000 Lux in the sunspace, living and dining areas, while diminishing from 910 to 730 Lux in the kitchen.

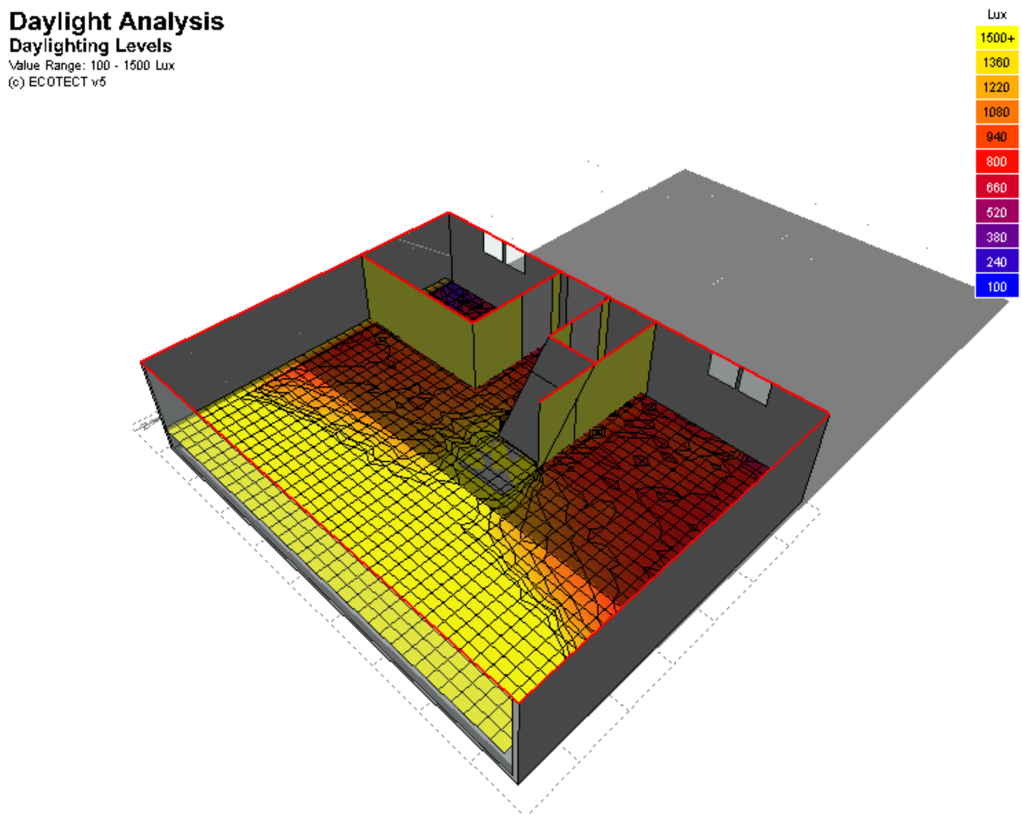


Figure 75 Ground floor axonometric of daylight Ecotect analysis for the 21st of December at noon for the BASF House.

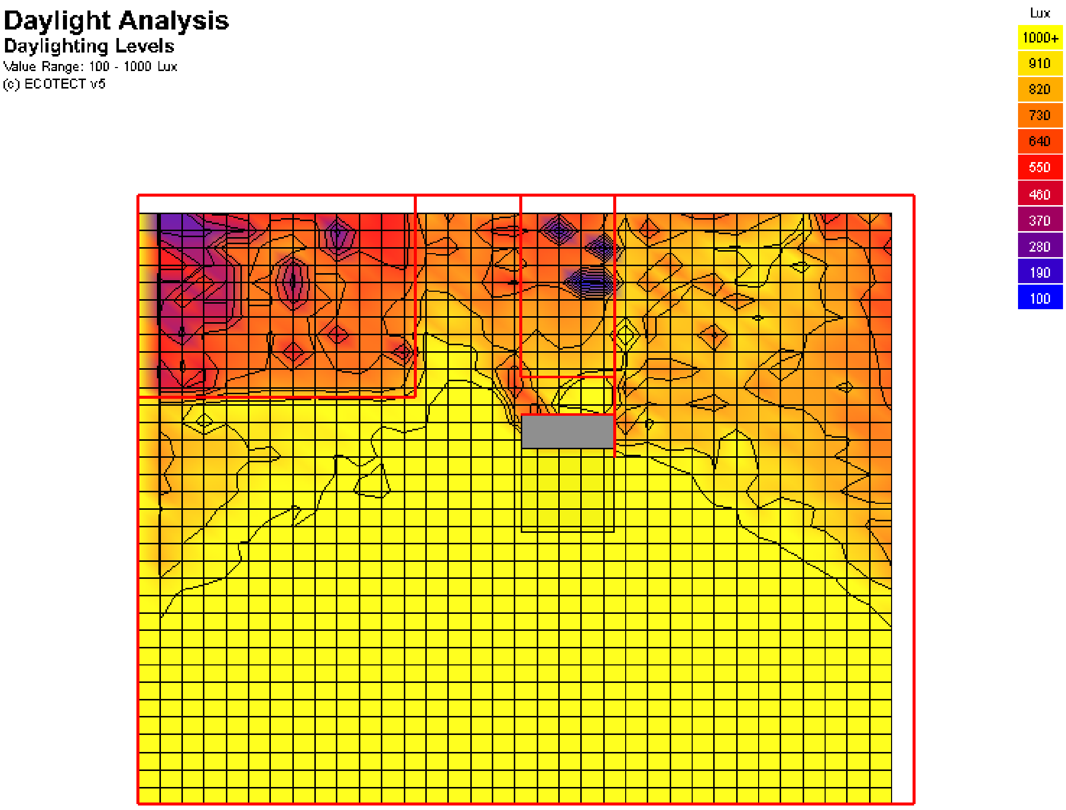


Figure 76 Ground floor plan view of daylight Ecotect analysis for the 21st of December at noon for the BASF House.

For the first floor in figure 77, the Ecotect calculation depicted a tendency of Lux to diminish over the two dates followed the same pattern for the bedrooms and stair landing, while for the bathroom and north bedroom, the daylight analysis for the winter solstice at noon showed lower measurements than the ones taken in February, about 400 Lux, while the Ecotect analysis depicted between 100 and 280 Lux at noon in December, which shows that the simulation is more limited when analysing rooms, for the longest day of the year the simulation should show a rather higher measurement that taken in situ (further daylight analysis with Ecotect are included in appendix 14).

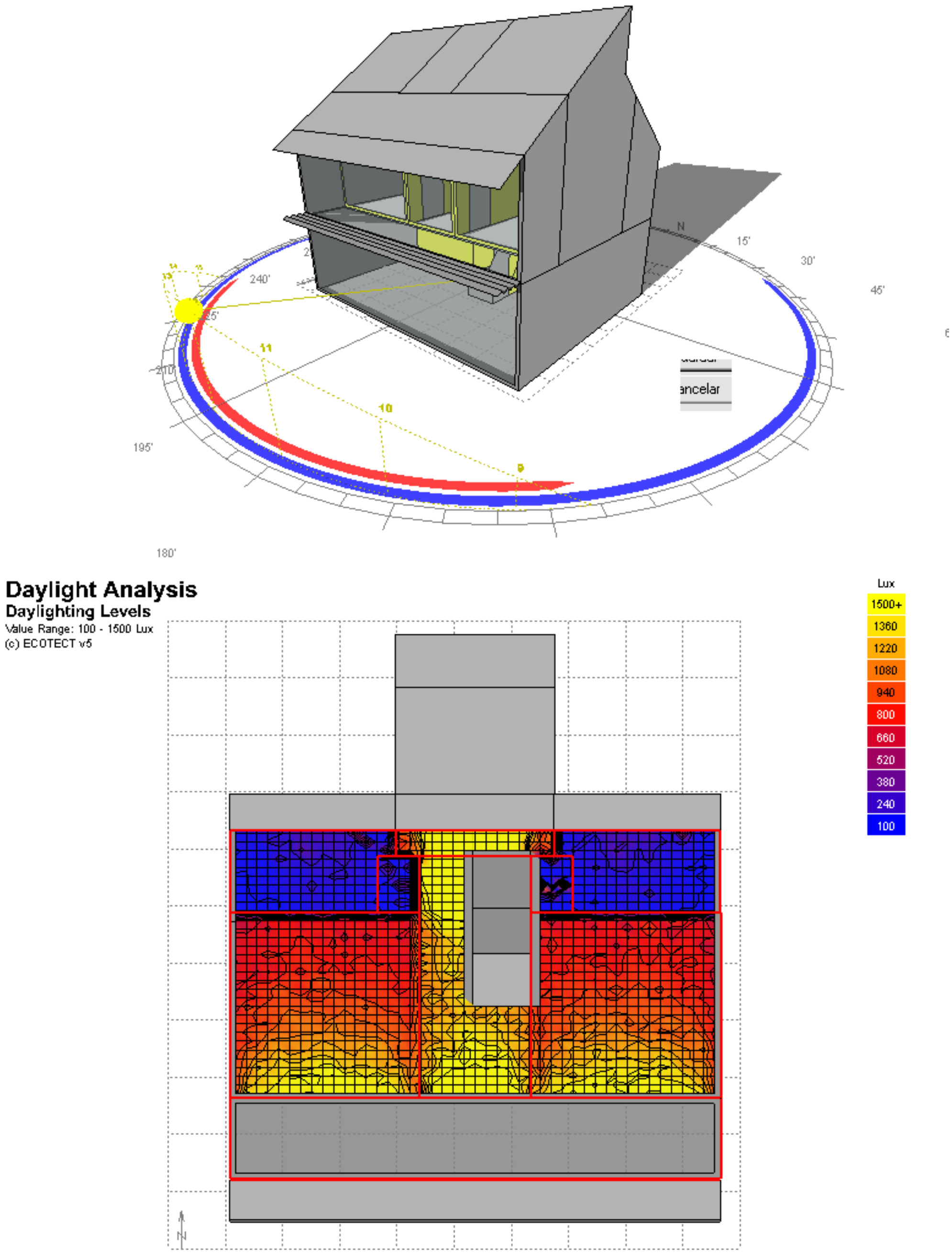


Figure 77 Axonometric with sunpath diagram and first floor daylight Ecotect analysis for 21 December at noon for the BASF House.

Author's observations as an occupant on the natural lighting

Many different variables were closely related to the natural light aspect of the BASF house, as for a dark climate this aspect is really important. The questionnaires, the experience of living in the house, the comments from the members of the public who visited the house were repeated, very common expressions from visitors were *"the sunspace makes the home nice and bright", "the light is great!", "it is very spacious and clear"*, however the results show that neither visitors nor occupants appreciated the size of the northern windows as a passive design strategy. This aspect should be carefully taken into consideration when designing areas of fenestration for the different façades based on the code allowances for sustainable homes. Sometimes, this could reach the extreme where new homes might become darker than expected or simulated and end up depending on a lot of artificial lighting. For a dark climate, like that of the UK, there must be effective compensation when reducing areas of fenestration, in order to draw natural light into interiors; if light wells are going to be used, they need to provide the same daylight quality as would be achieved through a window.

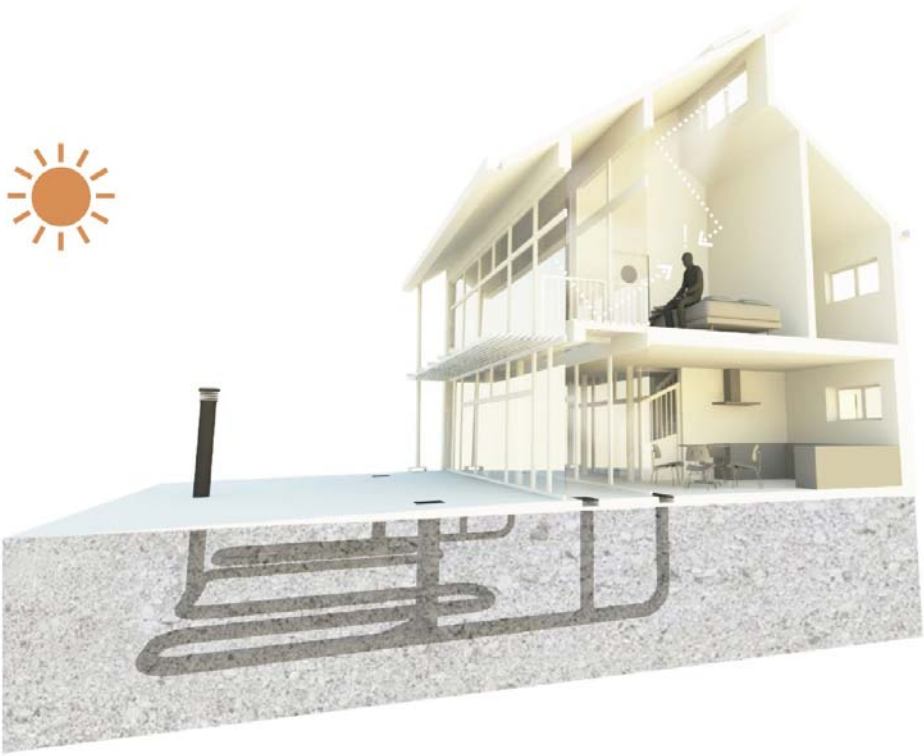


Figure 78 Scheme depicting the high reflection of natural light early in the morning on a summer day

The indoor reflection of light is also a factor that influences indoor light quality, so the selection of colour is an important factor. On the one hand, heavy use of white or light colours can be very positive in winter, but on the other, it could produce a negative effect in summer. Figure 78 depicts a typical situation that occurred in the BASF House on days around the summer solstice. The indoor has been painted white throughout. The curtains are also white and there is a high pitched ceiling. These factors combined to produce so much reflection that it woke up photosensitive occupants and they had to use eye shades during that season.

For the most favourite SET: the passive solar system obtained four votes, followed by the meters and monitoring system with two votes.

For the least favourite SET: the biomass boiler obtained six votes, followed by the permeable paving and roof coating with red pigments for solar heat management with one vote each.

In regard to the general questions, which are based on the visitors´ questionnaire, when occupants were asked the following two questions: “Was it a good experience for you to have visible readings of the energy consumption (W, kW-h)?” and, “Should all homes have visible energy meters showing consumption (W, kW-h) and cost (£)?” The answers were the same for both questions, 87.5% answered ‘Yes’, while just 12.5% marked the contrary. To the question: “How much extra are you willing to pay for a Zero Carbon Home?”, 66.7% of the occupants were willing to pay only 15% more for a zero carbon home while the rest were willing to pay more, between 15% and 25%. Therefore, 100% of the occupants said they would be willing to pay 10% extra. The final question was “If you were to refurbish your home to improve its energy performance, in how many years would you expect pay back?” The most popular choice was from 6 to 10 years, with 88.3%.

5.4. Results

By analysing the results of the questionnaire on the BASF House using the SPSS software, the most important results were:

5.4.1. Visitors’ Questionnaire

Awareness and preferences regarding passive design strategies (PDS) and sustainable energy technologies (SET)

There was no difference in regard to the knowledge and awareness of PDS between people related to the built environment (BE) and those with no such relationship (non-built environment, NBE).

People had general knowledge about PDS. The most well known aspect was sun orientation and the least known was high ceilings, 60%.

There was no general knowledge about SET. The least known aspect was the red pigment coating roof for solar management, as only 25.16% answered that they knew about it.

The most popular PDS were sun orientation and sunspace.

The least preferred PDS were the reduced window size on the north façade and airtightness.

The least preferred SET were the biomass boiler and red pigment coating roof for solar management

5.4.2. Occupants' Questionnaire

Interior space usage

Ground Floor: the most used space was the dining room and the least used were the sunspace, toilet, shed and plant room.

First Floor: In general the first floor was used more than the ground floor, because of sleeping patterns and the use of the main bathroom.

Space/room preferences

This section will list the ranking of preferences, going from the different spaces and rooms that occupants use the most to the one they use less.

Ground Floor (public spaces)

Kitchen · Dining room · Sunspace · Living room · Toilet · Plant room · First floor · Main bathroom · Balconies · Bedrooms 1 and 2 · North bedroom · Circulation areas · Landing · Stairs · Entrance porch · Shed

Specific design aspects of the spaces or rooms

Ground floor: For the kitchen as the most preferred space, the lighting was its best aspect and privacy its worst. For the plant room as the least preferred room, the temperature was its best and furniture its worst.

First floor: For the main bathroom as the most preferred space, the adequacy of space was its best aspect and storage space was its worst. For the north bedroom as the least preferred room, the acoustics/noise was its best aspect and flexibility of use was its worst.

Design and technology preferences

The characteristics of the architectural design in terms of adequacy and good quality that were well evaluated were: lighting in winter, quality of building materials, floor, ceilings and windows. And the badly evaluated aspects were: aesthetic quality of exterior, north façade, geometric form, adaptability and privacy.

Most favourite Passive Design Strategy (PDS): **sun orientation**

Least favourite PDS: **reduced window size on north façade**

Most favourite Sustainable Energy Technology (SET): **passive solar system**

Least favourite SET: **biomass boiler**

General Questions

87.5% of the occupants liked the experience with the meter and monitoring system and they also thought it was necessary for homes to have visible meters to read the cost and energy consumption.

66.7% of the occupants said they would be willing to pay between 10 to 15% extra for a Zero Carbon House.

88.3% of the occupants expected the payback after a refurbishment to improve energy performance to be within six to ten years.

5.5. Indications derived from the qualitative analysis

Biomass boiler as the heating system: The maintenance and operation of the biomass boiler is not user friendly at all. After this real-life experience, it is recommend that this type of technology or similar should not be operated by the occupants. This particular model is not automatic; it requires manual ignition whenever it goes out. This procedure requires expertise and in the case of a family with children, the safety issue is crucial. It also requires continuous maintenance due to the nature of the biofuel. Cleaning it involves the removal of 12 fire tubes that collect hard tar from the oil of the pellets, which then needs to be scraped off (see figures 79 and 39 in chapter 4). The cleaning was supposed to be done every 6 weeks, but actually had to be done every 17 days and took 4 person/hours to do. This process produces a great deal of particulate material from the fire ash, which remained in the nasal ducts for a couple of days after cleaning, so the person had the sensation of having breathed in polluted air. If a machine like this one but with a higher nominal output is going to serve a small group of houses, then specialised maintenance would need to be considered on a regular basis. When the biofuel type was changed, from rape seed oil to wood pellets, the smell, cleaning and smoke production issues almost disappeared. Therefore, not just the efficiency became better, but the user friendliness also improved.

Figure 79 Regular maintenance of the biomass boiler depicting the polluted dust, winter 2008.

As a general recommendation, the use of a biomass boiler of this type should be prohibited as a single device installation for a family home, particularly for families with small children. The biomass boiler should also be installed outside the living domain, as smoke is produced during ignition and occasionally during use, which generates a great deal of pollution.

The occupants interviewed all had the experience of living in the house during wintertime that is eight occupants plus the author. None of them had a high opinion of the heating system and the experience with the biomass boiler was quite traumatic for some of them. However the majority evaluated most of the other features of the house very highly. When the occupants received visitors (relatives) who stayed for longer periods (one to two months) in wintertime, none of them bothered to learn how the heating system worked, as they all found it difficult and uncomfortable to operate, and in every case, they continuously suggested using electrical heaters instead. They left the operation to the regular tenants and tended to the opinion expressed by one visitor *“why do tenants bother about this system when they could use another one?”*

For residential use, biomass boiler systems should always be located in an area detached from homes and should be operated automatically, as is the case with many systems currently in use in the UK. The negative aspect of this is that latent heat is produced when the system is running which goes to waste, when it has the potential to be used. All of this creates great potential for real-life research on the performance of biomass boiler systems for heating homes. In chapter six there are additional comments on this type of heating system, which were obtained through verbatim interviews carried out with occupants of the Upton homes in Northampton. However, as this technology is classified as one of the Low to Zero carbon technologies, it is quite important to find out the real performance of the biomass heating systems with regard to consumption, functioning, user friendliness, installation issues, pollution and so on.

This point in the discussion brings up a crucial aspect for the pre and post occupancy evaluation of low energy homes. For cold climates, the most hectic period in regard to energy demand is obviously wintertime; and it is therefore important to carry out a rigorous assessment at different stages for a new home. The newer sustainable energy technologies promoted for installation in homes should be tested before use and evaluated during use, in order to contrast the expected calculated performance, and to verify if the certification provided is actually merited, especially if the implementation of such technology is being promoted by codes, exhibited in many building construction fairs and widely offered by the market for the housing industry.

5.6. Chapter Conclusions

In addition to the physical performance analysed in chapter four, the in-use experience of the BASF House by its occupants is recognised as a valuable input to understand where some problems might occur when inhabiting sustainable homes. The learning from these new experiences in the housing sector provides much-needed feedback. The use of sustainable homes by occupants based on their lifestyles deserves great attention at the design stage to ensure they really achieve the energy conservation goals. The issues related to the control of the Sustainable Energy Technologies (SET) and the way sustainable behaviour and education could be influenced and promoted should be seriously considered.

- <u>Design</u> For the BASF House the **most appreciated** spaces/rooms were the **kitchen** and **dining room** followed by the sunspace, the preference of them was closely related to the **‘lighting’** quality, which also made the **north bedroom** the **least preferred** space/room. The ‘privacy’ aspect was the one that put the sunspace in third place in terms of preference. However an analysis of the written comments by occupants revealed that most of them would replicate this design feature for their own homes if they could, although the Passive Design Strategy (PDS) that occupants appreciated the most and would replicate in their own homes was the ‘sun orientation’ while their least favourite was the ‘reduced window size on the north façade and it was also the least preferred bedroom. The occupants’ experience and evaluation were very consistent with the visitors’ perceptions and it is clear that the importance of lighting in latitudes such as Nottingham make it a major design aspect. Most people know why the north orientation is crucial in the design of homes, which is less important in countries with milder climates and higher solar radiation; as is the case with most of Chile, for example. Another important aspect to point out in regard to the use of space is that places like conservatories are very intuitive in their use, which varies according to the season. Most people learn quickly through experience how to use them in their homes. The sun orientation and natural lighting are very important features related to home design in Nordic latitudes and they need to be carefully considered, as they are directly related to the thermal and lighting comfort for occupants.

- <u>SET</u> Engaging with technology is a complex issue within sustainable homes. The occupants need to adapt to both construction technologies and energy technologies. It is no trivial matter to gain an understanding of different types of SET that work with different sources of energy and which need to be used in specific ways in order to be efficient and able to perform as predicted. For the BASF House, when devices malfunctioned or were used incorrectly, it resulted in very low energy efficiency.

- <u>Functioning of SET</u> During the period of study at the BASF House, the problems with the heating system persisted over the three winters until the system had to be replaced, as it did not function in accordance with expectations. The basic functioning of the SET required to be provided by the code. The manuals and graphic schemes of use and operation were complicated to understand and of little or no help. The SET required specific settings and care to function properly. When problems occurred and the occupants called for them to be repaired, it was difficult to find the appropriate technicians and sometimes it took several visits before one would agree to take a look at it. For the BASF House, the biomass boiler was evaluated by the occupants as their ’least favourite’ SET within the category Passive Design Strategies (PDS) and they rated it as ‘poor’ for most of its features with very low rankings and written comments like

“… why would tenants bother about this system when they are able to use others instead?” (BASF House occupant).

It converted the wintertime quality of life of occupants of the BASF House into a very unpleasant experience. When the biofuel type was changed to wood pellets, the biomass boiler performed much better in regard to the comfort of the users; it no longer smelled, was easier to light, did not produce much smoke and the pellets moved in the hopper with greater ease.

In chapter 4, the biomass boiler data analysis suggested that this type of heating device should not be considered as a low to zero carbon (LZC) technology. It did not perform as expected nor as specified by the manufacturer; it had to be replaced three years afterwards. In this chapter, it has become clear that if a biomass boiler is going to be installed in a home, some important factors will need to be taken into consideration: for security reasons, it should be installed detached from the home, in a special space; for energy efficiency reasons, it should be the right size for the specific heating demand; to avoid pollution, it should use wood pellets for fuel; it should be automatically operated; for maintenance, suppliers and technicians should be specified.

- <u>Awareness of SET versus PDS</u> On one hand, it can be concluded that there is insufficient awareness and knowledge about SETs, among visitors and occupants alike, unless they work in this field, for instance mechanical engineers. On the other hand, both the general public and the occupants of the house had greater knowledge of the basic principles of passive design, regardless of whether or not they were involved in the built environment field.

- <u>Methodology: tools and techniques</u> **Questionnaires** are the most useful instruments for POE. The analysis of the data gathered from them offered multiple opportunities, especially when used with software like SPSS. However, if the researcher is not a specialist, as was the case of the author, there is a risk that he/she will get lost among the data and on applying the features offered by the computer programme to interpret results, could end up wasting time and not knowing what to do with so much data. Therefore, the design, process and analysis of questionnaires need to be done by specialist. For the PHO POE it is suggested that a sociologist or statistician be employed. For instance the Pearson correlation or analysis of dependence among variables and the predictive and segmentation model were both applied to give more validity to results, but as the statistical part of it was not fully understood, the author ended up using a great deal of time to obtain little and sometimes this took the author away from the focus of the research. However, one interesting result obtained by applying these SPSS features, was related to the respondents' dislike of the small windows on the north façade. Most people associated this feature with poor natural light rather than energy conservation, and it could be inferred that people's awareness of passive design features (PDS) was low. Although the interviewees knew the importance of southern orientation for fenestrations, they did not necessarily understand the flow of energy, and they were more concerned with the natural lighting aspect than thermal comfort. These insights suggest that education on sustainability in homes is needed. This, however, is a very general statement and further and deeper understanding is required. In the end, the most useful way to apply SPSS was for the descriptive analysis, which can also be done with a simple Excel spreadsheet.

The length and focus of questionnaires are very important features, as otherwise the conclusions are extremely general and difficult to sustain. For the occupants' questionnaire, the questions related to preference should have been within a typical Libert scale, of five options, otherwise many confusing steps need to be taken in order to obtain good results from the data. Cross-referencing with open questions complemented the results, but much of the data obtained for so many features of the BASH House were not useful.

The use of **tracking devices** was an attractive and interesting experiment, but ended up being a big distraction within this study. In the end, they did not address the associated research question, which could have been one whole piece of research in itself, and what was worst occupants did not feel comfortable with their use, so most of the data gathered with the tracking devices was not useful. An alternative reading of it was the length of time occupants spent in different zones, but in other to calculate the individual footprint for a given period of time, it was necessary to install the package in the whole house and ensure that the users were willing to participate. Otherwise it wastes too much time and money and the data is not useful. The data obtained as a result of the application of this tool is shown in appendix 12. It could have been obtained in a much simpler and cheaper way.

> **Observations, plans, specifications, photography, diary of events** and **simulations** are very useful tools for architects, and they help substantially to complement and shape the research, so they are typically used by architects. As textual/graphical data, they contribute to a better reading and a better explanation of the results obtained from numerical data. Sometimes a perception of the occupants was represented graphically, emphasising the findings.

Chapters 4 and 5 on the BASF House showed how difficult it is to work with a mixed methodology in which many tools and techniques from various disciplines are to be combined. Architecture is a very generalist discipline, so architects tend to borrow from many other disciplines to address a complex problem, but it does not imply the one person can be a specialist of many disciplines at the same time, Fitzpatrick et Al in 1992 wrote

> "Mixed Methodology (aka The Servant of Two Masters)...The basic difficulty with... is that you have to conduct two separate and distinct types of research, you have to write and write and research and research and analyzed and analyzed everything you do twice throughout..."

Rather than doing everything twice, what happened with this study is that a tremendous amount of data of different types and sources was gathered and it was very difficult to process and analyse. The main conclusion drawn therefore was the proposal to carry out a PHO POE, which proactively draws on the different disciplines and specialists around a main measurable parameter related to education on sustainability in homes; sustainability in homes is a multidisciplinary matter that architects cannot address alone.

Chapters six and seven are structured in the same way as chapters four and five. The first of the two chapters covers the analysis of numerical data, and the second covers the analysis of the textual data on the same case study, the BASF Home in chapters 4 and 5, the Upton Homes in chapters 6 and 7. The study of the real-life sustainable homes is not as in-depth as the one done for the BASF House. However, much of the learning from the first person research experience was crucial in focussing the Upton Homes study on some of the key issues related to the use of sustainable homes.

Chapter 6. Monitoring real-life case studies of sustainable homes under the Zero Carbon Era in the UK

This chapter comprises work on a large-scale residential development located in Upton Meadows, Northampton in the United Kingdom (figure 80). Since its beginnings, the Upton homes project was a real remarkable one. It captured much media attention and generated great expectation because it was one of the biggest urban "sustainable" development proposals at that time in the UK. This chapter looks at a piece of qualitative research called "smart meters – energy matters" which was carried out on the Upton homes project to address the research question of this thesis**, "are sustainable energy homes appropriate for any resident to live in?"** For this study, three tools were applied to collect data from human subjects: datalogging of power usage; questionnaires and verbatim interviews with occupants of the Upton homes. This chapter covers only the quantitative data analysis of the readings obtained from the Wattson energy meter.

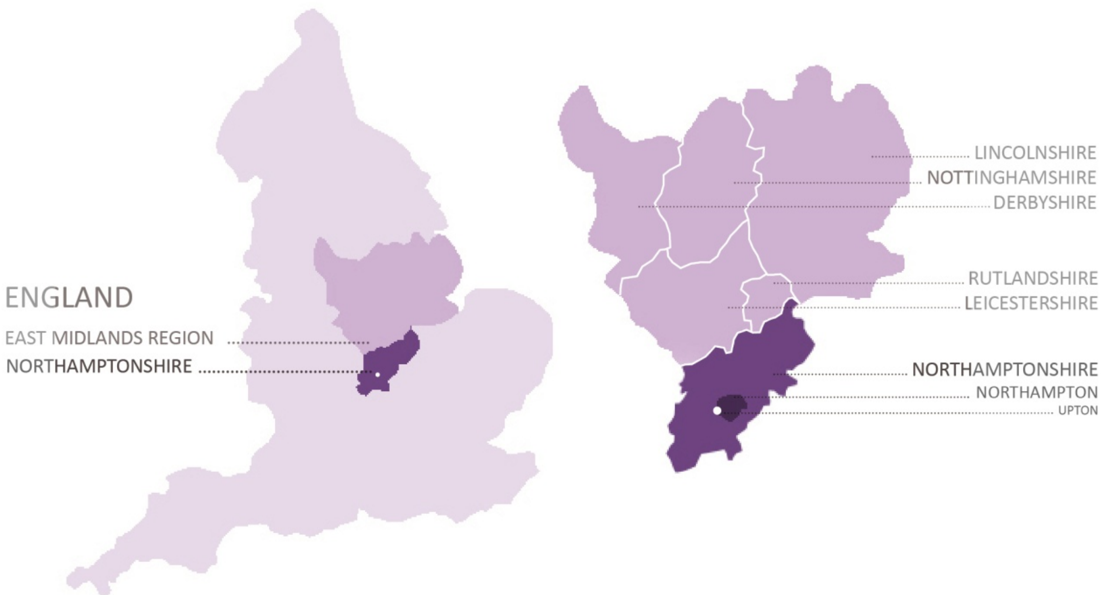


Figure 80 Map of England and East Midlands Region, highlighting Northampton and Upton

The research experience of the author as one of the occupants of the BASF house, helped much in shaping and focuses the qualitative research included in this chapter, given the complexity and problematic new sustainable home are portraying. However, this section is on a more macro level compare to the one done on the BASF house, the scale of definition of the data is bigger and less detailed, the set for the qualitative analysis is also smaller and it is focus on a specific study. Nonetheless, the information will add to contribute to comprehend and learn from the process towards energy efficiency in UK homes. The case studies were real-life commercial sustainable homes built under the Code for Sustainable Homes and being occupied for all type of occupants, mostly families, they consist of ten homes, eight terrace homes, one detached home and one flat. In this way, this chapter is a continuation on the research on occupied sustainable homes built after the CSH.

6.1. The Upton Homes – Real life sustainable homes

The Upton homes project (figure 80) became a great real-life laboratory for research; it presented a great opportunity to study and learn from recently built homes under the UK CSH. Given the rapid change in the issues related to sustainability in homes, this on-going development is an extremely interesting project to test, learn from and use to develop recommendations on housing issues at all levels. In projects like the Upton homes, many parties are involved, from the conception of the original proposal through to the end user; a number of these homes became case studies for different research projects and research groups.

Figure 81 Upton homes on “Scribers Drive”, winter 2010.

The Upton homes project included some demonstration homes, in which a monitoring system was installed, the data from which was to be analysed by the SHINE TRUE[15] project,

> "What is SHINE TRUE? SHINE TRUE is an East Midlands Region and European funded project to find out about how occupants interact with and use renewable technologies in their homes […]. The project also aims to understand how people use energy by looking at their energy behaviours. (Jackson, 2008)"

However, during the period of this study, it was very difficult to gain access to the monitoring system because of the commissioning procedure and, as time passed, the occupants moved in to their homes, so it became more difficult to access them. Nonetheless, ten homes (Figure 82), without a monitoring system installed, volunteered for the SHINE TRUE project presented in this chapter. They all were built under the CSH. They are located on two sites in the eight zones defined by the Upton Design Code, sites B and D1 (figure 83) facing Mill Pond Drive and Scribers Drive and one of them on Scribers Mews (Figure 81).

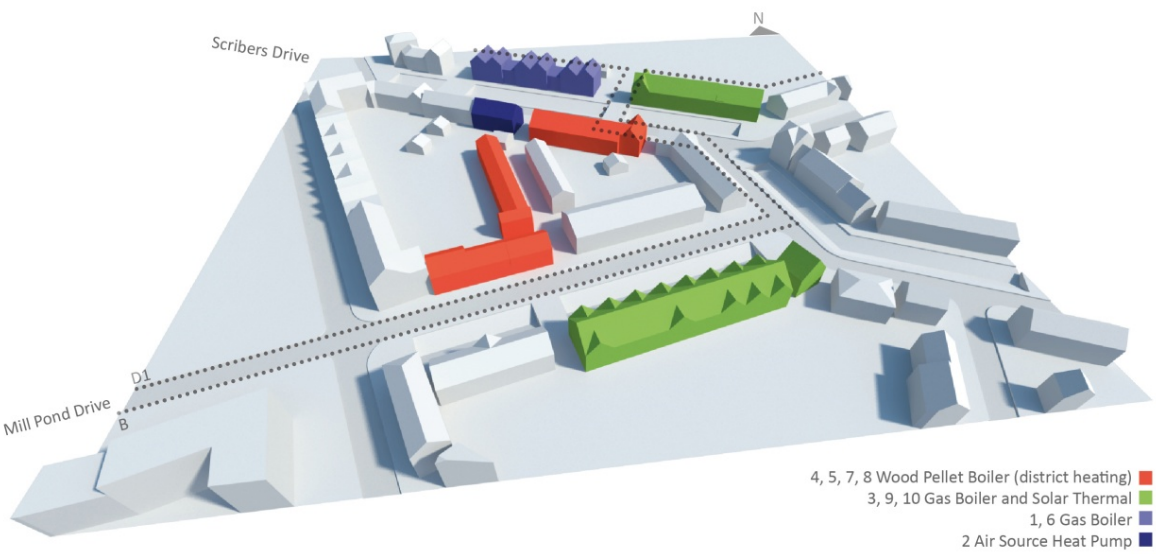


Figure 82 3D view showing the ten home and the user identification number; the colours identify the different heating systems

[15] SHINE TRUE "**S**ustainable **H**omes **I**nnovation **N**etwork of **E**xcellence - **T**ransdisciplinary **R**esearch into **U**ser **B**ehaviours"

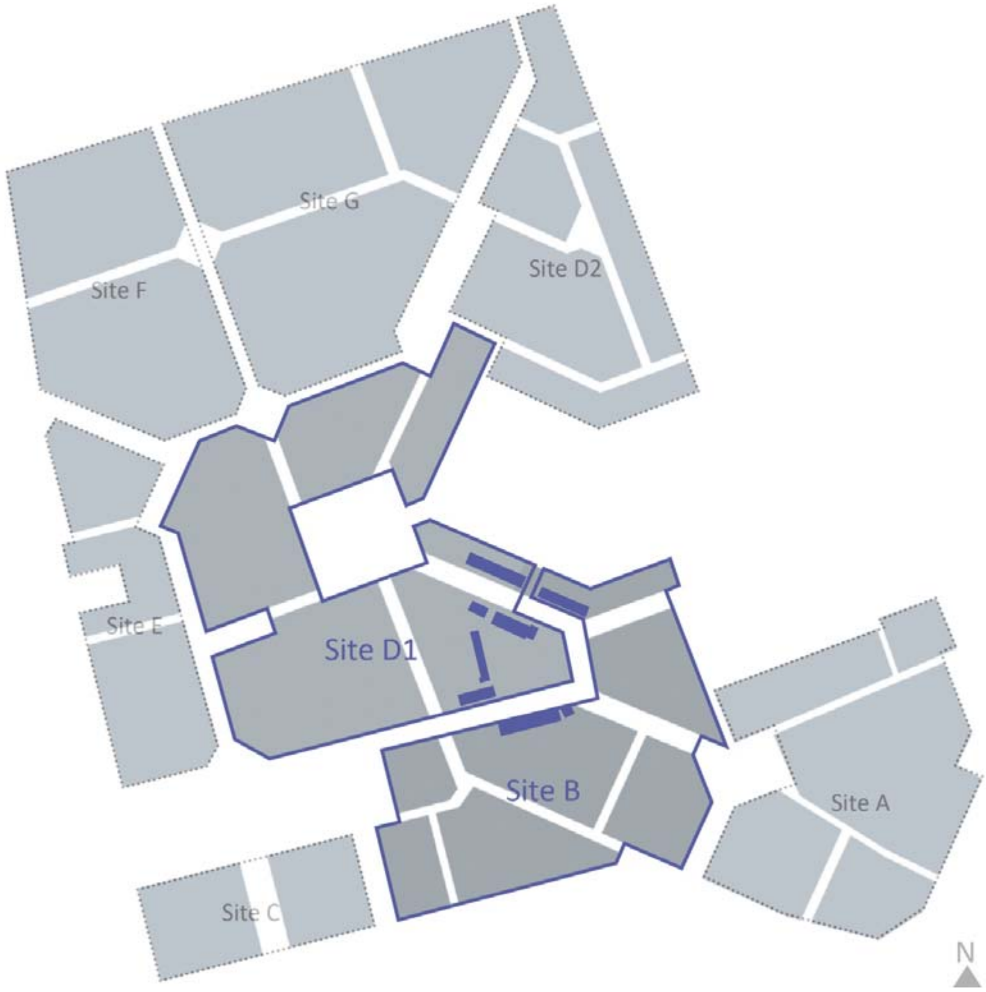


Figure 83 Scheme of the eight zones or development areas. The sites and the ten homes involved on this study are marked in darker purple.

Both sites, B and D1, included designs from various architecture firms; for site B, Cornhill Estates and Fairclough Homes were the selected developers, while for site D1, the developer was Metropolitan Housing Partnership. This site considered 345 dwellings of mixed townhouses and flats that needed to consider a number of advanced technologies, water recycling, PV and needed to be designed to comply with the Code for Sustainable Homes (CSH) and the Upton Design Code (UDC) and Zero Emission Design (ZED) standards were also applied to some of the homes.

> “[…] the Upton Scheme aims to promote the use of green technologies in a mainstream construction setting. The development sets new standards in volume house-building, giving developers an opportunity to design and build sustainable, energy-efficient homes with a conventional appearance.” (EST, 2006).

6.2. *Energy meters, energy matters*

On November 2006, one of the consultations proposed in the Energy Review report, "The Energy Challenge" (July 2006) was "Energy Billing and Metering. Changing customer behaviour" (BIS, 2006). One of the governmental considerations in this report related to the real time display of electricity consumption and cost was that if home residents were provided with effective means to keep track of their energy use, this might play a key role in aiding users to diminish their electricity bills. However they needed to test the assumptions made in regard to the positive impact on energy consumption reduction and the change in consumer behaviour. The consultation therefore asked, among many other related subjects, for the study to analyse the costs and benefits of introducing meters in homes (BIS, 2006).

Three years later, on December 2009, the UK Department for Energy and Climate Change (DECC) declared "the UK government had already announced that it wanted all UK homes to have smart meters by 2020" and "the Department of Energy and Climate Change wants to see 47 million meters in 26 million properties by 2020" (Moylan, BBC News, 2/12/2009).

It is proposed that the companies that supply gas and electricity should provide the meters for their customers, as they currently do. However, given the compulsory new measure for 2020, it is now possible to find on the market a vast range of real time display energy devices to monitor electricity consumption.

It is assumed that giving home residents a more complete picture of their electricity and gas consumption, both in real-time and historic usage will educate and inform people and therefore reduce energy demand in homes. However, little research to demonstrate the veracity of this assumption has been undertaken.

It is within this trend that SHINE TRUE has developed one of the aims of the project. For this particular study, a small trial was carried out on the use of monitoring technologies, such as energy meters, with real time display devices to test their **possible influence on behaviour among home users in regard to energy consumption in recently built sustainable homes**. Also, it was our intention to evaluate four different types of energy meter offered on the market, the prices of which varied from £35 to £90 approximately[16] (amazon.co.uk). In order

[16] www.amazon.com.uk

to understand **user acceptance of this type of device**, both of these aims from the SHINE TRUE project coincided with the general objectives of this study.

6.2.1. The real-time energy meters

The ten homes from the Upton homes development in Northampton become occupied in late 2007 and 2008. At the time of the study, most of the occupants had lived for more than a year in their homes and this was their first or second winter they had experienced in these homes. For the evaluation four different types of real-time energy meters were randomly chosen from the retail outlets where these devices are generally sold. The meters needed to have the basic features of a real-time display showing electricity consumption in kW-h or W-h and the cost in British Pounds (£). Prior to passing the energy meters to the ten families who volunteered to trial them for this study, a pilot trial was carried out, in which the four energy meters were given out to members of SHINE-TRUE team to test and evaluate. The author reviewed all of them and built up an evaluation comparing all the features, which can be seen in the tables in appendix 18. Some of the positive and negative comments from this initial test are listed below. The Wattson was the device rated highest by the author:

Table 15 Pictures, sizes and prices of the real time energy meters

Name and Pictures	WATTSON 	OWL CM119 	ENVI CC128 	EFERGY ELITE 
Sizes	11x8.4x2.6cm	7.8x11.3x4cm	12x7x3cm	Similar to Owl
Price	£ 90.- approx.	£ 30.- approx.	£ 50.- approx.	£ 40.- approx.

Comments about the Wattson (first from left in Table 10):

- It was very extremely intuitive to use
- The colour code indicated less or more electricity consumption, was easy to read and interpret; it might be a good educational device on energy consumption for children.
- It had a modern and attractive design, though it was a bit bulky.
- It stood out because of its simplicity

Comments about the Owl CM119 (second from left in Table 10):

- The display was difficult to read and confusing
- The reset buttons were difficult to access and they needed to be pressed during battery change

Comments about the Envi Current Cost (third from left in Table 10):

- It has outdoor usage for a transmitter + sensor
- The visual display of historical readings of three days or three times a day was good, it would help occupants be aware of peak hours of energy usage. However, too much information was displayed on the screen at any one time.

Comments regarding the Efergy Elite (to the right in Table 10):

- There was no control for the backlight
- The readings for low energy usage were not very accurate
- The reading of the daily average was confusing
- The diagram and history contradicted one another
- The same button needed to be used to set the time and switch the alarm on/off.

6.2.2. The ten volunteer homes

The list of volunteer families was drawn up following a previous study, when 100 questionnaires were distributed door-to-door. 50 of the questionnaires were completed and of those, 10 families volunteered for this real-time energy monitor trial period. For the study terraced houses were preferred to flats; nevertheless, one of the ten homes was a flat. The specific energy and environmental requirements for these two sites are listed in table 16.

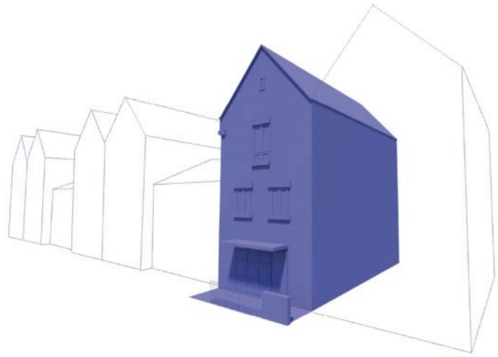
Table 16 Energy and environmental requirements established by Upton Design Code (UDC) prepared by EDAW

SITE	Nº UNIT	MANDATORY ACROSS WHOLE SITE	DEMONSTRATION PROJECTS/TECHNOLOGIES
B	3	BREEAM/EcoHomes Excellent National Home Energy Rating - NHER rating 10 Code for Sustainable Homes - CSH (2007 - voluntary) Northampton Design Code (NDC) Passive solar design Solar water heating Rainwater harvesting	Photovoltaic (PV) systems – min. 25 units Green roofs – min. 25 units
D1	7	BREEAM/EcoHomes Excellent NHER rating 10 CSH (2007 - voluntary) Northampton Design Code (NDC) ZED standards Passive solar design Solar water heating Insulation improvements High internal air quality	PV systems – min. 90 units Micro-combined heat and power (micro-CHP) – min. 60 units Rainwater harvesting – all freehold units without green roofs Green roofs (extensive) – min. 60 units

Figures 84 and 85 introduces the ten homes studied, including a brief profile and description for each of them. None of these homes was a demonstration home, so the special features, such as green roofs, or micro generation through wind turbines, among other renewable energy technologies, were not considered for these homes. Three of them included a rainwater-harvesting system with butts for water collection similar to the one at the RuralZED, but none of them has a PV system. Five of the ten homes have combined gas-fired heat power (CHP) systems and three of these five included solar thermal panels for water heating in warm weather. The flat has a an air source heat pump (ASHP) and the last four have their heating provided by a wood pellet boiler which heats 39 homes on site D of the Upton homes.

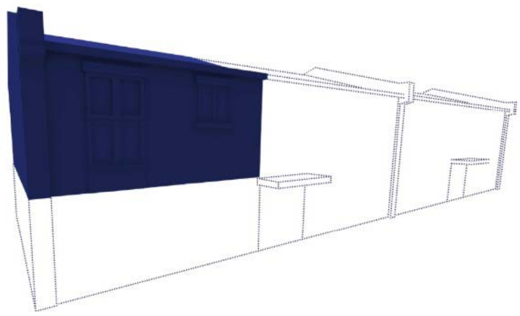
USER 1

Site: D1
Home Type: Terrace
Occupants: 2p
Storey: 2s
Area: 115.2m²
Bedrooms: 3b
Heating System: Gas Boiler



USER 2

Site: D1
Home Type: Flat
Occupants: 1p
Storey: 1s
Area: 43.9m²
Bedrooms: 1b
Heating System: Air Source Heat Pump

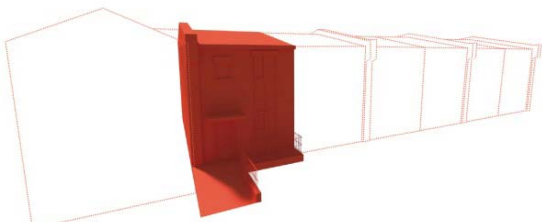


USER 3

Site: B
Home Type: Terrace
Occupants: 4p
Storey: 3s
Area: 120.7m²
Bedrooms: 4b
Heating System: Gas Boiler and Solar Thermal

USER 4

Site: D1
Home Type: Terrace
Occupants: 3p
Storey: 2s
Sqm: 94.4m²
Bedrooms: 3b
Heating System: Wood Pellet Boiler (district heating)



USER 5

Site: D1
Home Type: Terrace
Occupants: 4p
Storey: 2s
Sqm: 113.8m²
Bedrooms: 3b
Heating System: Wood Pellet Boiler (district heating)

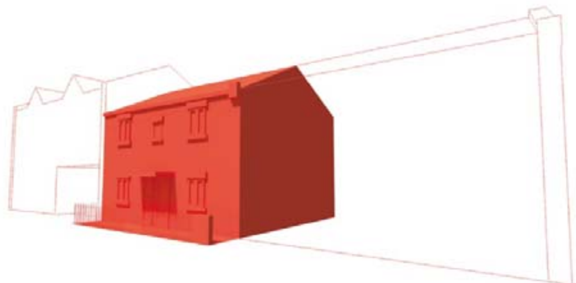


Figure 84 Five of the ten volunteer family homes in Upton which participated in the study “Energy meters, energy matters”: users 1, 2, 3, 4 and 5.

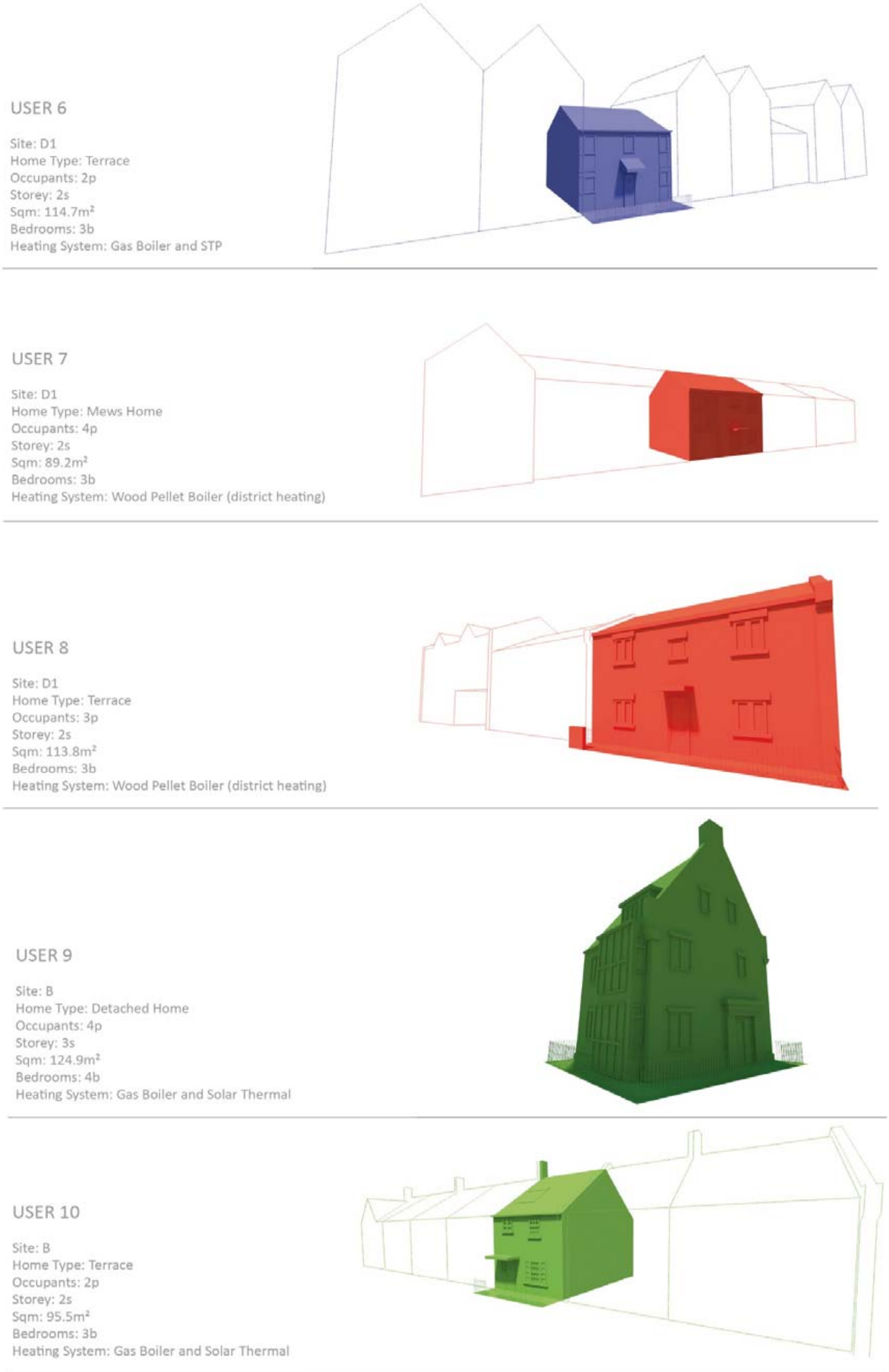


Figure 85 Five of the ten volunteer family homes in Upton that participated in the study "Energy meters, energy matters": users 6, 7, 8, 9 and 10.

Four of the five homes that were developed by the Metropolitan Housing Partnerships, users 4, 5, 7 and 8, relied on the HERZ wood pellet boiler system for their water and space heating. The other six homes, users 1, 2, 3, 6, 9 and 10, use a Combined Heat and Power (CHP) system for their water and space heating. For water heating in warm weather, three of these homes have solar thermal panels, users 3, 9 and 10 respectively, and when the solar radiation is not enough to heat water, they rely on their CHP system.

6.2.3. The trial period

Given the greatest energy demand in homes is during the winter, the experiment needed to be carried out over a period of at least four weeks, i.e. the whole month of February. However, in the end, it lasted six weeks, starting on 02/02/2010 and finishing on 16/03/2010. The approach was to leave one of the energy meters with the capacity to store data for the whole period of 6 weeks. The Wattson energy meter was chosen because of its simplicity of use. Each week, one of the remaining energy meters was given to each family to trial for a week (see table 17) and test it as they pleased. The data logged by the Wattson was downloaded during each of the weekly visit to users. To test it thoroughly and be able to evaluate the energy meter from the point of view of usability, each family received the package as new, as if they had just bought it themselves, and they were asked to discover and use it as they wished.

Table 17 The trial period for each energy meter

WEEK	DATE	ENERGY METER	LENGHTH OF TEST
1	02/02/2010	Wattson	To be kept for the whole measuring period, until 16/03/2010, to analyse the data logged.
2	09/02/2010	Wattson + Owl CM119	Owl CM119 to be kept and used for a week.
3	16/02/2010	Wattson + Envi C2	Envi C2 to be kept and used for a week.
4	23/02/2010	Wattson + Efergy Elite	Efergy Elite to be kept and used for a week.

After each week, the author distributed a short questionnaire of nine questions (see appendix 19) to evaluate its usability and features from the volunteer perspective. The questionnaires are analysed in the chapter 7. The question were the same for all of them, except if the energy meter had a particular feature that needed to be evaluated, then an additional question was added to the questionnaire.

At the end of the trial period, on 16/03/2010, a general energy meter questionnaire containing 13 questions was distributed, to compare the four different smart meters. At the same time, a short face-to-face interview pursued by the author with each volunteer was conducted and recorded to add more information to this study (transcriptions are included in appendix 20).

All the questionnaires and interviews focused on the central research question to be addressed by the study, which was to find out if the use of real time energy meters could influence in any way energy consumption and usage and also to find out the degree of awareness among volunteers about energy issues and sustainable homes.

6.2.4. What's going on with Upton homes? The data from the Wattson meter

Descriptive Analysis

The Wattson energy meters (figure 86) recorded data for a period of 42 winter days. A week after the ten energy meters had been installed, the situation was as follows: two meters did not work, as they were faulty, two of them recorded erroneous readings and the battery of a fifth was gone. Therefore for the subsequent weeks, the data from seven devices and for a reduced period was taken into consideration for the study.

Figure 86 The Wattson energy meter at one of the seven homes of Upton.

Figure 87 depicts examples of erroneous data readings after downloading the recorded data following the first week of measurements. The meters recorded periods with no data readings, as can be seen in columns (D, J and K), which are blank. The reasons were that the devices were faulty or the battery went flat. Another erroneous reading that became invalid was the jumping between one reading to the next one, in which one reading was recorded and then the following four were not, in a pattern that repeated for several hours before the device returned to a normal data reading, as can be seen in figure 87 in column I, user 6. A third type of invalid data was when for hours the device was read 0, as can be seen in column M to the right, for user 10.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2			Household	USER 1	USER 2	USER 3	USER 4	USER 5	USER 6	USER 7	USER 8	USER 9	USER 10
3			Home type	Terrace - 2 storeys	Flat	Terrace - 3 storeys	Terrace - 2 storeys	Terrace - 2 storeys	Terrace - 2 storeys	Terrace - 2 storeys	Terrace - 2 storeys	Terrace - 3 storeys	Terrace - 2 storeys
4			Household	2 adult, 3 dogs	1 adult	2 adults, 2 teenagers	1 adult, 2 children	2 adult, 2 children	2 adult, 1 baby	3 adult, 1 baby	1 adult, 2 teenagers	2 adult, 2 children	2 adults
5			Energy Monitor	SM ENVI	SM WATTSON 5776	SM WATTSON 5779	SM WATTSON 5791	SM WATTSON 5775	SM WATTSON 5773	SM ENVI	SM WATTSON 5777	SM WATTSON 5778	SM WATTSON 5772
6	DATE	TIME											
2198	09/02/2010	14:35			416	170	1005	390				246	0
2199	09/02/2010	14:40			406	183	282	1261				237	0
2200	09/02/2010	14:45			412	192	239	300				228	0
2201	09/02/2010	14:50			417	173	73	430				228	0
2202	09/02/2010	14:55			462	170	204	413	2149			229	0
2203	09/02/2010	15:00			675	167	2588	473				228	0
2204	09/02/2010	15:05			572	172	1467	472				228	0
2205	09/02/2010	15:10			445	203	602	469				227	0
2206	09/02/2010	15:15			427	171	207	421				227	0
2207	09/02/2010	15:20			413	200	193	400	136			228	0
2208	09/02/2010	15:25			452	213	96	408				227	0
2209	09/02/2010	15:30			441	210	72	405				227	0
2210	09/02/2010	15:35			447	275	177	404				247	0
2211	09/02/2010	15:40			460	257	170	407				245	0
2212	09/02/2010	15:45			448	215	71	406	142			247	0

data from 02-02 to 16-03 | SM Data 2010 02-02 to 15-03 | 730 AM | Graphs

QUALITY OF THE DATA READINGS FROM WATTSON ENERGY METER	NO DATA RECORDED	NORMAL DATA READING	INVALID DATA READING	NO DATA RECORDED	NORMAL DATA READING	INVALID DATA READING

Figure 87 Example of data readings from the Wattson energy meter.

When the data was invalid, those periods were not considered. However for the majority of weeks, the data seemed to be valid. The study is based on the data which recorded normally. Another important fact in regard to the datalogging, is that the energy meter did not take account of the power factor or of changes in voltage during the day; it merely gave an instant total power reading in watts.

Table 18 shows the profiles of the households, home typology and surface (m²), site location, heating and ventilation systems; highlighted are the seven homes with normal data readings. The number of inhabitants per home varied from one person, user 2, who also lived in the home with the smallest surface area (more than half that of all the other homes), a one-bedroom flat , to a maximum of four people, *users 3*, 5 and *9.* In between were two three-person families, *users 6* and *4* and *user 10* with 2 occupants.

Table 18 General features of the ten homes highlighting the seven households for the energy meter data analysis

USER	HOME TYPE / STOREYS	SITE	AREA	Nº OCCUPANT	Nº BEDROOMS	HEATING SYSTEM	VENTILATION SYSTEM	CONSTUCTION TYPE
1	Terrace – 2 st	D1	115.2	2p (2 adults)	3b	Gas Boiler	Mechanical Ventilation with Heat Recovery	Glulam Frame MMC
2	**Flat – 1 st**	**D1**	**43.9**	**1p (1 adult)**	**1b**	**Air Source Heat Pump**	**MV w/HR**	**Glulam Frame MMC**
3	**Terrace - 2 st**	**B**	**120.7**	**4p (2 adults, 2 teenagers)**	**4b**	**Gas Boiler and Solar Thermal**	**MV w/HR**	**Glulam Frame MMC**
4	**Terrace2 st**	**D1**	**94.4**	**3p (1 adult, 2 children)**	**3b**	**Wood Pellet Boiler (district heating)**	**MV w/HR**	**Glulam Frame MMC**
5	**Terrace - 2 st**	**D1**	**113.8**	**4p (2 adults, 2 children)**	**3b**	**Wood Pellet Boiler (district heating)**	**MV w/HR**	**Glulam Frame MMC**
6	**Terrace - 2 st**	**D1**	**114.7**	**2p (2 adults, 1 baby, 1 toddler)**	**3b**	**Gas Boiler and STP**	**MV w/HR**	**Glulam Frame MMC**
7	Mews Home - 2 st	D1	89.2	4p (3 adults, 1 baby)	3b	Wood Pellet Boiler (district heating)	MV w/HR	Glulam Frame MMC
8	Terrace - 2 st	D1	113.8	3p (1 adult, 2 teenagers)	3b	Wood Pellet Boiler (district heating)	MV w/HR	Glulam Frame MMC
9	**Detached Home - 3 st**	**B**	**124.9**	**4p (2 adults, 2 children)**	**4b**	**Gas Boiler and Solar Thermal**	**MV w/HR**	**Glulam Frame MMC**
10	**Terrace - 2 st**	**B**	**95.5**	**2p (2 adults)**	**3b**	**Gas Boiler and Solar Thermal**	**MV w/HR**	**Glulam Frame MMC**

As has been mentioned, the measurements taken were global readings of the instant power in use, which was given in Watts [W]. However the unit of measurement calculated for the analysis is the average energy value per day in kilowatt hours [kW-h], given that the other units of measurements used by this energy meter are, kW-h, cost in pounds [£] and CO_2 emissions [$kgCO_2$], which were calculated by the Wattson program from the instant reading in Watts [W].

Table 19 Descriptive statistics of the average energy values per day for the seven users of Upton homes

	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile 25	Third Quartile 75
USER 2	11.831	18.070	7.355	2.248	210.607	10.581	12.464
USER 3	15.250	20.676	12.549	2.585	278.322	13.233	16.728
USER 4	7.2891	11.956	4.261	1.802	135.294	6.185	7.982
USER 5	9.581	12.163	6.555	1.512	95.119	8.649	10.634
USER 6	27.712	34.674	19.044	4.927	1010.912	25.034	31.541
USER 9	11.146	16.587	5.857	2.448	249.705	9.848	12.489
USER 10	10.249	14.565	7.551	1.663	115.239	9.387	10.233

In the first instance, it was possible to determine from table 19 that the user who consumed the most energy during the measurement period was user 6. User 6 consisted of a family of 2 adults, one toddler and a newborn baby and they consumed three time more energy than user 4, a family of three, who can be seen to be the most “energy saving”. Both homes have boilers for their heating systems. In fact, the first quartile is roughly double the rest of users. An important feature of this household (user 6) is that one of the inhabitants is a baby. This fact may be associated with the rate of energy consumption in this house compared to the others. Of the families with 4 occupants, the one with the highest average rate of electricity consumption is still user 6, followed by user 3, a household of two adults and two teenagers.

The other users showed an energy consumption rate relatively close to 11.6 kW-h. They did not present unexpected levels of volatility in their electricity consumption and all of them were barely above and mostly below 2.4 kW-h, which is very comparable to *user 2*.

The above assumptions gain validity when the rates of electricity consumption by users are graphically compared; the higher usage of user 6, the lower levels used by user 4 and the homogeneity of all the others in regard to power consumption can be observed in graph in figure 88. The daily pattern was very repetitive and did not vary much from one day to the next.

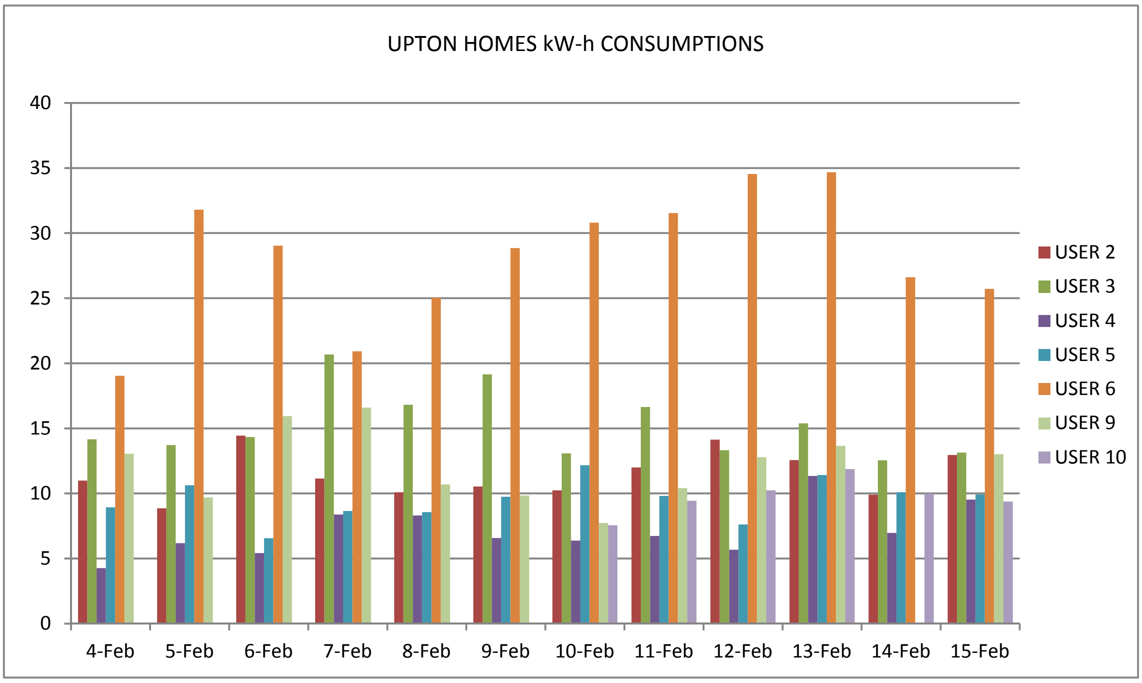


Figure 88 Graph of daily consumption in kW-h for the seven users of Upton homes, from 4/2/2010 to 15/2/2010.

In addition to the exploratory analysis, it is important to take into consideration the length of time in which the measurements were effective, for instance if the cumulative power consumption is presented by weeks or months, the picture will change slightly, as can be observed in figure 89, in which a graph shows the weekly power consumption by the seven households, with the exception of the first week, because of the invalid readings recorded, as has already been described.

In the graph in figure 89, *user 6* was still the one with the highest rate in regard to power consumption, but *user 4* stopped being the "energy saver", although this is the user who sustained a steady power consumption rate throughout the whole period, except for week 4. U*ser 2* (1 person flat with ASHP heating system) is the one with greatest rate of variations per week. Overall the weekly analysis showed the same trends already described. The analysis shows that the differences might be related to the profile of each household and the way in which each family used their appliances and lighting, as the heating was basically based on the same heating technologies, with all users except for user 2 having boilers (user 2 had heat pump technology).

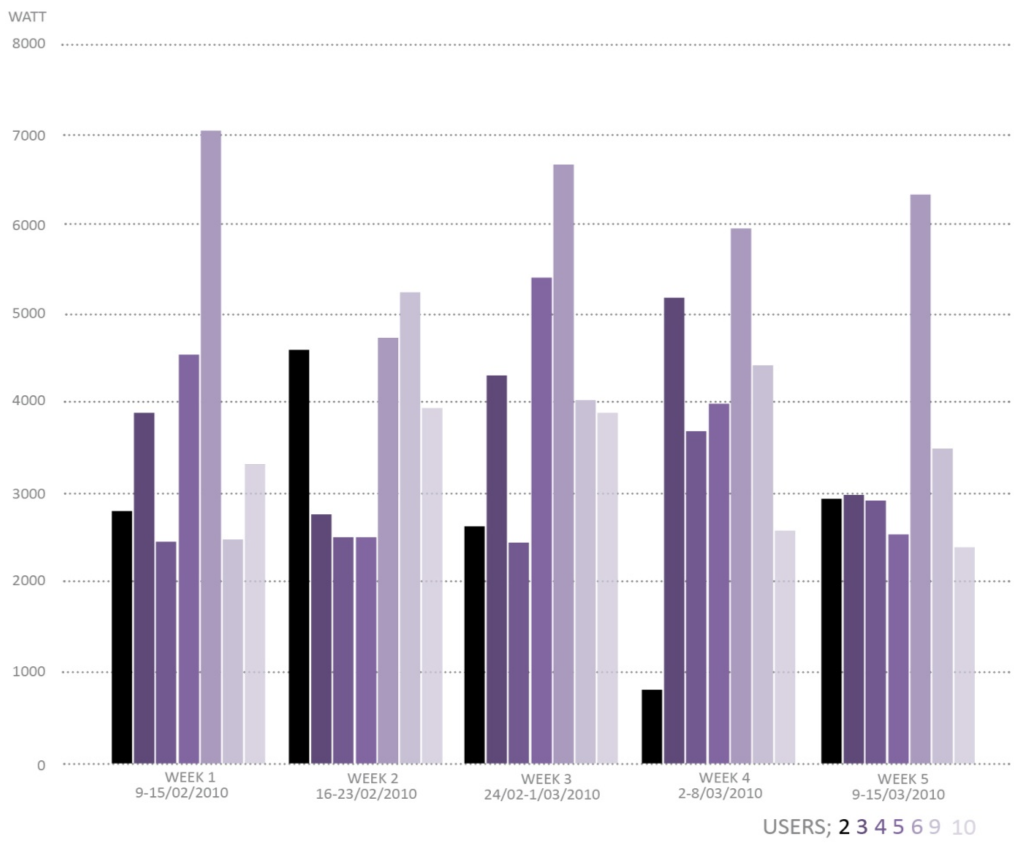


Figure 89 Graph of cumulative power consumption in Watts/week for the seven users of Upton homes

Association between variables: Pearson correlation and cluster analysis

The Pearson correlation as an association indicator did not help to understand the relationship among users, so a Clusters analysis was used instead. It was important to find correlations in order to help explain the results, as they could contribute towards confirm the fact that the household profiles and/or the type of appliances and lighting features could be the factors with greatest influence over power consumption differences. The energy meter readings by themselves could not provide this insight, unless an inventory of electrical devices and lighting had been made. A third attempt to understand power usage among the set was to pursue exactly the same procedure, starting with a descriptive analysis, followed by Cluster analysis at four defined hours of the day including peak hours such a waking up time at 7.30 a.m. and at 6 p.m., when the occupants came home.

6.3. Results

Results from the Upton homes

All the tables and figures obtained from the descriptive analysis are graphically shown in detail in appendix 21. Once the data had been analysed and first results obtained, mainly depicting the amount of electricity each household was consuming, further procedures were undertaken to obtain more results from the data and to established associations among variables in order to gain a better understanding of the numerical data collected. It was still difficult to visualise the levels of proximity among users based solely on such data. For example, the attempt to establish a relationship between the number and profiles of the occupants of homes with their power consumption by analysing one specific time of the day was an interesting approach to read data towards an expected result. However, it was still not possible to reach any robust conclusion in regard to energy consumption behaviour from the seven of the ten Upton homes. This step was therefore repeated for two other specific times during weekdays, obtaining more suggestive results, but it was already clear that the data was not robust enough even to conclude that user 6 was the highest power consumer and user 4 the lowest. Therefore the next step was to complement the numerical data with textual data. However, these results were interesting, as they brought to light new research questions, although they moved away from the main focus of the research. An example of this type of result is shown in figure 90 in next page.

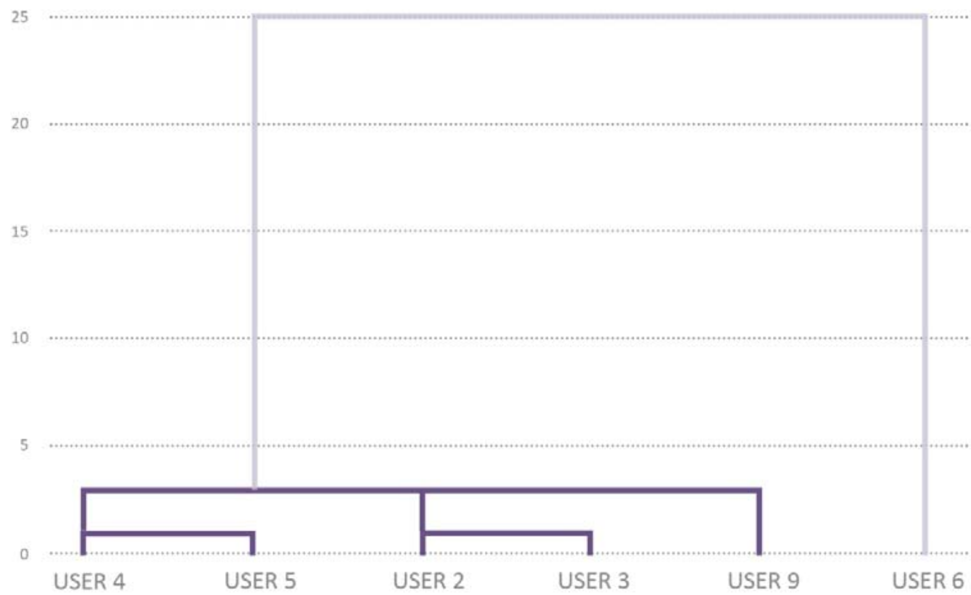


Figure 90 Single link dendrogram with Euclidean metric distance cluster combination for 9pm.

The cluster shown in the dendrogram figure 90 reveals a first cluster of spots formed by *users 4* and *5,* both homes with two children. By expanding the distance one step further, *user 9, also a family with* two children, becomes part of the same cluster. So an apparent correlation between child occupancy and energy consumption at certain hours of the day can be assumed. The energy consumption of *user 6* was quite different to that of the other users, as has already been pointed out in the analysis of the data. This result could be related to the presence of a baby. Therefore the typical Pearson correlation analysis finding was reaffirmed with this Cluster analysis of peak hours, although there was not enough data to establish this was indeed the cause for the consumption shown by this user.

6.4. Chapter Conclusions

The most relevant conclusion from this chapter is related to monitoring inhabited homes with sensors and data processing. For any datalogging system, the installation **must** be done before occupants move in to the homes and the system **must** be fully calibrated and tested prior to the defined measurement period. Sample data needs to be logged and analysed prior to the measurement period too, as otherwise it becomes very difficult to solve problems when they appear during the measuring period. The validity of the data needs to be proven before, not during the study, otherwise a great deal of erroneous data can be obtained, as was the case with the Wattson energy meter. In the end, it was hard to obtain good results and findings, and reach good conclusions. Indeed, good conclusions could not be obtained from the data, although a great deal of effort was put in to understanding it. However, in the end, the findings were not sufficiently robust. However, new interesting research questions arose related to family profiles, for instance does the age of children versus teenagers in a family imply higher or lower energy consumption? Does a household with a baby consume more energy? Two of the families in the Upton homes study had babies, but one of the energy meters did not function at all.

Home occupants do not appreciate intrusions into their privacy, so visits need to be reduced to the minimum and the period of time for which devices are going to be installed and measuring carried out should be a month or less, ideally during the coldest month of winter. When studies are realised in wintertime in a Nordic latitude like the UK, even if all the above details have been taken care of, such as the length of the measuring period, the dates, times and length of visits for installing sensors, downloading data, surveying, photographing, interviewing, etc., there is always a latent sense of intrusion, because the researcher has to meet the family after the adults have returned home and in wintertime it is already dark and the family are preparing or eating supper. The researcher therefore feels as though they are invading private family time at night. It is not easy to find volunteers for any type of study that involves human subjects, so once a group of volunteers has been obtained, it is very important to maintain a very cordial relationship between the subjects of the study and researchers, especially if the application of several tools to study a research a problem is planned. In fact, the SHINE TRUE project included carrying out measurements of occupied or soon to be occupied sustainable homes in three different locations within the East Midlands region, two homes in Colsterworth, two homes in West Bridgeford and two homes in Upton by RuralZED (see appendix 17), as well as demonstration homes in the Upton homes project. For these three cases, meters were installed, entailing money and time, which at the end of day was wasted. In the case of West Bridgeford, installation started when the homes were unoccupied, but was not complete when the occupants moved in. After some time, the occupants became very upset and stopped allowing the researchers to enter the homes. For the Rural ZED, the situation was even worst, because the whole installation of the monitoring system was done during the last stage of construction, but after the project was completed, it was extremely bureaucratic to access to those homes, and when the occupants moved in, they did not wanted any intrusion, so nobody volunteered.

A mixed methodology includes several tools needed for quantitative and qualitative research, for in-use homes both types of research are needed. However it is recommended that only those tools to those which are really needed to address the research question be used and that, as far as possible, tools be selected which cause the least intrusion into people's domestic routines. It is therefore essential to define at a very early stage the parameters to be studied. This study has clearly shown that carrying out research in in-use homes is very complex, so the research question and objectives need to be to the point, stick to the focus and it must be kept in mind throughout the whole process. The temptation to study other issues must be firmly withstood, regardless of how close they may be to the research question. They might be the subject of further studies.

Chapter 7. Upton Homes – Questionnaires and Verbatim Interviews

This chapter continues from chapter 6 and contains the results from the two analyses carried out with different tools for the same study. The first part of the chapter covers the results obtained from the questionnaires applied to the ten volunteers families at the Upton homes, utilising the software SPSS to carry out quantitative analysis. The second part shows the results obtained from the verbatim interviews held with seven of the volunteer occupants of the Upton homes, utilising the software NVivo to do the qualitative analysis. Finally, the results and analysis from Chapter 6 and the two sections of Chapter 7 set out to reach the conclusions stated at the end of this chapter.

7.1. Upton homes – 'smart meters, energy matters' questionnaires

The objective of the questionnaires was to understand which of the four meters used in the study was generally preferred by the residents and it was very important to test the possible influence of such meters on the energy consumption behaviour of the occupants of recently built sustainable homes. The survey began on 02/02/2010 and ended on 20/03/2010. This section covers the results obtained from the quantitative data analysis carried out on a survey of ten households of Upton homes, during the winter of 2010, between the months of February and March.

The study took place during a particularly cold winter period, in fact the coldest January and February in almost 30 years (appendix 6, in section "2010 Nottingham weather" illustrates as a reference for Northampton, the mean temperatures registered by the weather station of the Department of Architecture at the University of Nottingham for that particularly cold winter in 2010). The extremely cold weather, sometimes accompanied by rain, heavy wind or snow, and very dark days, might have affected attitudes towards the study. Nevertheless, on most occasions, the residents let the researchers into their homes in order to avoid spending time in the cold. The weather is very likely to be one of the most influential parameters in regard to the way energy is used, particularly lighting and heating.

7.1.1. Quantitative Analysis results

For the first part of the survey, of a total of 40 questionnaires to evaluate the energy meters, 25 were completed. Some of the questionnaires were not answered for the reasons explained above, such as the disengagement of the occupants. Other reasons cited for not replying to questionnaires were the malfunctioning of the devices, some written comments on questionnaires without **full** answers **such as** "*couldn't use as clamp was too big to fit onto wire in meter box…"* or *"did not work"* or *"could not get it to connect with meter + display, tried many times".* After the first week, the author found out that some occupants failed to set up the meters. Some occupants explained *"it was too difficult", "I give up on trying",* and *"I'm not sure about which cable should the clamp be attached to, it could be dangerous".* As a result, these occupants had to ask for help to install the devices. It was therefore decided that all the meters would be working on the remaining weeks before the author left the home, regardless of the initial idea that occupants should go through each stage of installation and usage from the opening of the package onwards. Taking into account the above, seven completed questionnaires were received for the Wattson, Owl and Envi CC128 and four questionnaires for the Efergy Elite energy meters. For the general questionnaire, seven out of the ten distributed to the occupants were collected.

In regard to the question *"How would you evaluate the Smart Meter your family tested?"*, occupants were asked to evaluate the energy meters in regard to preferences based on their perceptions and experience with regard to 18 attributes within a 'Livert Scale' that ranged from 1 for dislike to 5 for like. The mean value between 1 and 5 was used to show occupants' preferences. Table 20 in the top of next page shows the mean values of the choices occupants made regarding each of the four energy meters and a total mean value for all of them as a set for each of the 18 attributes being evaluated. Some of the attributes were not common to all of the devices, for instance the Wattson was the only one with a colour signal.

As can be seen in table 21 in the bottom of next page, the energy meter ranked lowest was the Owl energy meter, which shows mean values below those of the rest of the devices most of the time. The average score for the 15 attributes evaluated for the Owl is 2.2, i.e. less than the score of 3 which on the Livert scale indicates 'like'. The energy meter that receives the best evaluation is the Wattson, which obtained an average of 4.1 across the 14 attributes that were evaluated, followed by the Envi CC128 with an average of 3.8 and the Efergy Elite with 3.6. However it should be borne in mind that the latter was the energy meter for which only four questionnaires were completed.

Table 20 Mean values for the evaluation of 18 attributes of the four energy meters

5	Evaluated Attribute	6 Mean Values				
		Watson	Owl	Envi cc 128	Efergy Elite	Total mean
1	Setup	4.7	2.3	4.4	4.5	3.98
2	User Manual	4.4	1.7	4.0	3.8	3.47
3	Clamp	4.3	2.6	4.6	4.3	3.92
4	Safety	4.9	2.9	4.6	3.3	3.88
5	Transmitter	4.1	2.4	4.7	4.3	3.88
6	Clarity of the Display	5.0	2.3	4.0	4.5	3.95
7	Energy Display (kWh)	4.4	2.6	4.1	4.3	3.85
8	Cost Display (£)	4.7	2.6	3.7	3.3	3.56
9	Design	4.7	2.3	3.6	3.8	3.58
10	Size	4.7	2.3	4.1	4.0	3.79
11	Mobility	4.4	2.9	3.4	4.5	3.80
12	Historical Reading	1.1	1.3	2.6	2.0	1.75
13	PC Connection	1.0	-	1.0	-	1.00
14	Colour Signal	4.9	-	-	-	4.86
15	CO2 display	-	2.4	-	3.0	2.71
16	Temperature display	-	2.0	4.1	-	3.07
17	Alarm	-	1.1	-	2.0	1.57
18	Backlight	-	-	-	3.0	3.00

Table 21 Percentage distribution for the evaluation of 18 attributes of four energy meters

Energy Meter	Wattson Total=7					Owl Total=7					Envi CC 128 Total=7					Efergy Elite Total=4				
Attribute Evaluation	5, like	4	3	2	1, dislk	5, like	4	3	2	1, dislk	5, like	4	3	2	1, dislk	5, like	4	3	2	1, dislk
Setup	71% (5)	29% (2)	0% (0)	0% (0)	0% (0)	14% (1)	0% (0)	29% (2)	14% (1)	43% (3)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	43% (3)	0% (0)	14% (1)	0% (0)	0% (0)
User Manual	57% (4)	29% (2)	14% (1)	0% (0)	0% (0)	0% (0)	0% (0)	29% (2)	14% (1)	57% (4)	57% (4)	29% (2)	14% (1)	0% (0)	0% (0)	29% (2)	0% (0)	14% (1)	14% (1)	0% (0)
Clamp	57% (4)	29% (2)	0% (0)	14% (1)	0% (0)	29% (2)	0% (0)	29% (2)	0% (0)	29% (2)	29% (2)	43% (3)	29% (2)	0% (0)	0% (0)	29% (2)	14% (1)	14% (1)	0% (0)	0% (0)
Safety	86% (6)	14% (1)	0% (0)	0% (0)	0% (0)	43% (3)	14% (1)	0% (0)	0% (0)	14% (1)	71% (5)	14% (1)	14% (1)	0% (0)	0% (0)	14% (1)	14% (1)	14% (1)	0% (0)	14% (1)
Transmitter	57% (4)	14% (1)	14% (1)	14% (1)	0% (0)	14% (1)	14% (1)	29% (2)	14% (1)	0% (0)	57% (4)	43% (3)	0% (0)	0% (0)	0% (0)	29% (2)	14% (1)	14% (1)	0% (0)	0% (0)
Clarity of the Display	100 (7)	0% (0)	0% (0)	0% (0)	0% (0)	14% (1)	0% (0)	43% (3)	14% (1)	0% (0)	71% (5)	29% (2)	0% (0)	0% (0)	0% (0)	43% (3)	0% (0)	14% (1)	0% (0)	0% (0)
Energy Display - kWh	86% (6)	0% (0)	0% (0)	0% (0)	14% (1)	14% (1)	14% (1)	43% (3)	0% (0)	0% (0)	57% (4)	14% (1)	14% (1)	0% (0)	14% (1)	29% (2)	14% (1)	14% (1)	0% (0)	0% (0)
Cost Display (£)	86% (6)	0% (0)	14% (1)	0% (0)	0% (0)	14% (1)	14% (1)	43% (3)	0% (0)	0% (0)	57% (4)	29% (2)	0% (0)	0% (0)	14% (1)	14% (1)	14% (1)	14% (1)	0% (0)	14% (1)
Design	71% (5)	29% (2)	0% (0)	0% (0)	0% (0)	14% (1)	0% (0)	43% (3)	0% (0)	29% (2)	29% (2)	43% (3)	14% (1)	0% (0)	14% (1)	0% (0)	43% (3)	14% (1)	0% (0)	0% (0)
Size	71% (5)	29% (2)	0% (0)	0% (0)	0% (0)	14% (1)	0% (0)	43% (3)	0% (0)	29% (2)	14% (1)	43% (3)	29% (2)	14% (1)	0% (0)	14% (1)	29% (2)	14% (1)	0% (0)	0% (0)
Mobility	71% (5)	14% (1)	0% (0)	14% (1)	0% (0)	14% (1)	43% (2)	14% (1)	0% (0)	0% (0)	29% (2)	57% (4)	14% (1)	0% (0)	0% (0)	29% (2)	29% (2)	0% (0)	0% (0)	0% (0)
Historical Reading	14% (1)	0% (0)	14% (1)	0% (0)	0% (0)	0% (0)	0% (0)	43% (3)	0% (0)	0% (0)	14% (1)	57% (4)	0% (0)	14% (1)	14% (1)	0% (0)	14% (1)	14% (1)	0% (0)	14% (1)
PC Connection	0% (0)	14% (1)	14% (1)	0% (0)	0% (0)	-	-	-	-	-	0% (0)	43% (3)	14% (1)	14% (1)	14% (1)	-	-	-	-	-
Colour Signal	86% (6)	14% (1)	0% (0)	0% (0)	0% (0)	-	-	-	-	-	0% (0)	14% (1)	14% (1)	0% (0)	0% (0)	-	-	-	-	-
CO2 display	-	-	-	-	-	14% (1)	0% (0)	57% (4)	0% (0)	0% (0)	-	-	-	-	-	0% (0)	29% (2)	14% (1)	0% (0)	14% (1)
Temperature display	-	-	-	-	-	0% (0)	0% (0)	57% (4)	14% (1)	0% (0)	-	-	-	-	-	-	-	-	-	-
Alarm	-	-	-	-	-	14% (1)	0% (0)	0% (0)	14% (1)	14% (1)	57% (4)	14% (1)	14% (1)	14% (1)	0% (0)	0% (0)	14% (1)	14% (1)	0% (0)	14% (1)

Table 21 reveals:

Regarding the Wattson: The attributes which scored highest among the seven analysed questionnaires are Clarity of display, Energy Display (W), Cost display (£), Colour signal, while the PC connection was the attribute least preferred.

With regard to the Owl: The best evaluated attribute was Safety and 43% of interviewees 'liked' this attribute, followed by Clamp with 29% for 'like', while the worst evaluated attribute was User manual with 57% of occupants indicating 'dislike'.

With regard to the Envi CC128: The attributes Safety and Clarity of the display were highly evaluated and 71% of interviewees said they 'liked' it, while none of the attributes of this device was categorised with a low evaluation, i.e. no respondent indicated a 'dislike' for any of its attributes.

For the Efergy Elite: The attribute with the highest score was Setup with 43%, followed by the attributes Transmitter and Mobility, scoring29% 'like'.

After occupants had used the four energy meters, where possible, in the "General smart meter questionnaire", the fifth questionnaire was delivered to the ten households and seven completed questionnaires were collected. These were fully completed, and asked about preferences and for the features of the different devices to be compared. This questionnaire had open questions; and respondents were instructed to write their comments regarding their preferences and to compare the features of the different devices. Table 22 below lists the written comments occupants made when they were asked to compare the features of the four Smart Meters (the 'solidus' (/) indicates a comment made by a different occupant):

Table 22 Transcription of written comments to compare the four energy meters after the trial period

	Favourite feature	**Least favourite feature**	**Feature that would like to add**
Wattson 	*"Visibility, big display, doesn't require effort to see energy use / Looks / Easy to read (2) clear understanding / Display /*	*Too big / Size*	*More information / Longer battery life /*
Owl CM 119 	*Neat compact / Small*	*Rubbish / Usage not clear / All / Difficult to use / Complicated to use /*	*Colours to indicate high and low usage / Less complex display*

Envi CC 128 	*Lots of on screen info, good clip / Lots of information, wall mountable / Easy to read display (2) /*	*Not very visible, so doesn't make an impact / Battery only no mains feed / Had to be permanently plugged in / Too complicated / Not clear instructions*	*Would've like daily and weekly average cost / More mobility*
Efergy Elite 	*Small (2), night light / Good amount of information / Small / Mobile, didn't need a socket / Easy to read display /*	*Would've been better without back light / Too much info on display / Took me ages to find the light*	*Ability to download to PC"*

Table 22 makes it possible to identify the features that were more recurrent and important to highlight on an energy meter. The majority of the features pointed out by the occupants were related to the display unit. *Visibility* and *legibility* are correlated in meaning, and the occupants' tended to cite them as a 'favourite feature' for those devices that they considered had them. When this feature was not present, its lack was also identified and written down as one of the least favourite features. Another feature that appeared to be very important was the *size* of the energy meter; compactness was preferred over less compact. In fact, when analysing the comments for the Wattson, the only least favourite feature cited twice was its size, 10.5x17.0x5.5 cm, while the only positively evaluated feature of the heavily criticised Owl was its size, 10.7x11.7x3. Other features that appeared to be particularly considered by the occupants were the characteristics and the amount of information the energy meters displayed, where opinions were more divided; however the Wattson was the meter that gave least information and it seemed to be well evaluated for the ease with which the data provided by the energy meter could be read, and the way it displayed it (i.e. colour code). Also the features related to the way the devices function and the level of difficulty in installing them, for example when the instructions for the energy meter were not intuitive or easy to use, were rated *'complicated'* or *'difficult'.*

The energy meter was most frequently located in the kitchen. Of the 25 questionnaires, the kitchen was cited 15 times as the location for the energy meters, followed by five mentions each for the dining and living rooms. Only a few were located in the circulation area, as can be observed in table 23 below.

Table 23 Frequency of locations of the energy meter at the different rooms in the homes

Location of the energy meter	Watson Total=7	Owl Total=7	Envi CC 128 Total=7	Efergy Elite=4	Total times in location 25 answers
Kitchen	**71% (5)**	43% (3)	**57% (5)**	**75% (3)**	**16**
Dining Room	14% (1)	14% (1)	29% (2)	25% (1)	**5**
Living Room	14% (1)	14% (1)	14% (1)	50% (2)	**5**
Circulation Area	0% (0)	14% (1)	0% (0)	25% (1)	**2**
Bedroom	0% (0)	0% (0)	0% (0)	25% (1)	**1**
Bathroom	0% (0)	0% (0)	7 0 % (0)	8 0 % (0)	9 0
Study Room	0% (0)	0% (0)	0% (0)	25% (1)	**1**
Other Room	0% (0)	0% (0)	0% (0)	0% (0)	**0**

There was one energy meter, the Efergy Elite that was moved into different bedrooms within the home by one of the occupants. However, the occupants tended to keep all of them in the same place from the beginning, usually one of the public spaces of the home, where all the family normally gathered. The meters were never installed in the bathrooms or other rooms. Therefore, in answer to the question about the visibility of the energy meter for each member of the family, three of the energy meters, the Wattson, Envi CC128 and Efergy Elite, were located in a clearly visible place for the duration of the study. Strangely the Owl was the only energy meter that was on occasion located in a place where it was not visible to every member of the family.

For the question on whether occupants used the different features of each energy meter, the majority responded that they did not. The energy meter that attracted or invited most curiosity in regard to its features was the Envi CC128, with 43% of usage by occupants, while the other three, obtained over 70% ‘no’ responses in regard to the use of the features of the energy meter. None of the attributes of the Owl, for instance, was ever manipulated. A few of the attributes of the Wattson and the Efergy Elite were occasionally used. Nonetheless, when analysing the results related to the question: *How often did you look at your consumption display on the Smart Meter per day?*, the majority of the answers were mostly located within ‘occasionally’, ‘often’ and ‘all the time’, where the Wattson and the Envi CC128 tended to attract more attention than the others from the occupants. The other two, the Owl and the Efergy Elite, however, attracted less attention with their display of information, as can be observed in table 24 in next page.

Table 24 Frequency with which occupants looked at the information displayed by the energy meter

	Watson Total=7	Owl Total=7	Envi cc 128 Total=7	Efergy Elite Total=4
all the time	**43% (3)**	0% (0)	14% (1)	0% (0)
often	**57% (4)**	0% (0)	43% (3)	25% (1)
occasionally	0% (0)	57% (4)	43% (3)	50% (2)
one/twice	0% (0)	14% (1)	0% (0)	0% (0)
never	0% (0)	14% (1)	0% (0)	25% (1)

In addition to the above question, there was a similar question that slightly changed the instruction: *Did you look at your consumption display on the Smart Meter every day?*. When looking at the results of this question, the energy meter that was looked at on a daily basis was the Wattson, with 71% responding 'all the time'. The distribution changes when comparing the results for these two questions, as can be observed in table 25**,** except for the Wattson where 100% of positive answers fell between 'all the time' and 'often'. On the contrary, the Owl received the highest ranking among the negative responses 'Occasionally', 'one/twice' and 'never', with 100%, which implied the need to be more attentive regarding what was occurring with the energy consumption of those households. The Envi CC128 and Efergy Elite energy meters concentrated the responses within the three middle options, 87% and 100% within 'often', 'occasionally' and 'one/twice' respectively..

Table 25 Frequency with which occupants looked at the information displayed by the energy meter on a daily basis

	Watson Total=7	Owl Total=7	Envi cc 128 Total=7	Efergy Elite Total=4
all the time	**71% (5)**	0% (0)	14% (1)	0% (0)
Often	29% (2)	0% (0)	29% (2)	50% (2)
Occasionally	0% (0)	43% (3)	29% (2)	25% (1)
one/twice	0% (0)	14% (1)	29% (2)	25% (1)
Never	0% (0)	14% (1)	0% (0)	0% (0)

In addition to the results obtained in regard to the frequency with which occupants paid attention to the information displayed by the energy meters, more than 70% of the occupants never utilised the historical readings. Also, for the two energy meters with the option of being connected to the computer to obtain analysis of the recorded data, the Wattson and Envi CC128, only one occupant connected to the Wattson.

For the general questionnaire, the idea was to determine the occupants' level of awareness of the energy meter legislation planned for 2020. At the time of writing, many homes have already received free British Gas energy meters, the result of an energy consumption campaign by the company during winter 2010-2011, in which meters were given to anybody who wanted them. Figure 91 shows one of the energy meters given by the gas company installed in a household that uses the CHP-gas system in Beeston. However, the majority of the interviewees, 86%, at the time of the study were unaware of this legislation, so it can be assumed that occupants did not have any pre-conceptions in regard to this analysis.

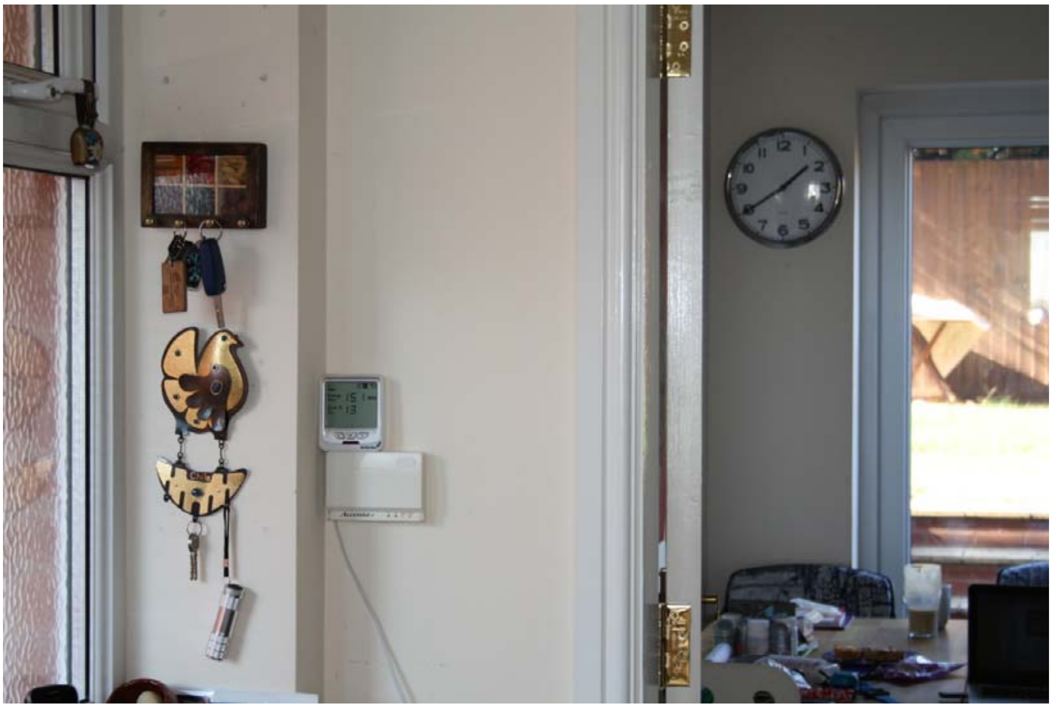


Figure 91 Photograph of a typical energy meter from British Gas currently installed in a home.

In regard to energy consumption behaviour and the expectation that using an energy meter should produce a change in attitude regarding the way energy is used by the household, table 32 below depicts the percentage distribution of the answers given by the users:

Table 26 Distribution of the answers to five questions related to the expectation of behavioural changes among households after using the energy meters

Do you think the use of Smart Meter could:					
	influence energy consumption?	**change lifestyle**?	change **awareness on use** of energy?	help you **save money**?	help to **decrease** energy consumption
Highly agree	28.6	28.6	**57.1**	28.6	28.6
Agree	**71.4**	**57.1**	42.9	**57.1**	**57.1**
Indifferent	0	14.3	0	14.3	14.3
Disagree	0	0	0	0	0
Highly disagree	0	0	0	0	0

The majority of the occupants that replied to the five questions presented above tended to 'agree' and 'highly agree' that the use of the energy meter could influence their energy consumption, change their lifestyles, raise their awareness of the way energy is used, help them to save money and decrease their energy consumption. However 14.3% were 'indifferent' with regard to lifestyle change, money saving and decreasing their energy consumption.

Table 27 Distribution of the answers to four questions related to the expectations regarding energy meters among households after using them

Do you think the use of Smart Meter could help:				
	identify how the electricity is being used in your home?	identify which appliance consumes more energy?	obtain more accurate bills?	identify the changes of energy usage throughout the seasons?
Highly agree	**57.1**	**71.4**	14.3	28.6
Agree	42.9	28.6	42.9	**71.4**
Indifferent	0	0	28.6	0
Disagree	0	0	14.3	0
Highly disagree	0	0	0	0

Based on their experience with the energy meter, the majority of the occupants that replied to the four questions presented in table 33 above, which are related to information they could obtain by using the devices, tended to 'agree' and 'highly agree' that the use of the energy meter could help them to identify how the electricity was being used in their homes, which appliance consumed most energy and how energy usage changed in different seasons. However, they were more sceptical about the idea that the energy meters could help them to obtain more accurate bills, 14.3% indicated 'disagree' and 28.6 indicated 'indifferent' in response to this question.

Table 28 Distribution of the answers to two similar questions related to the possession of energy meters in occupants' homes

Possession of an energy meter	Would you like keep an energy meter in your home?	How important is it to have an energy meter in your home?
Highly agree	71.4	14.3
Agree	28.6	57.1
Indifferent	0	28.6
Disagree	0	0
Highly disagree	0	0

The majority of the interviewees 'highly agreed' that they would like to keep an energy meter in their homes at, 71.4% and nobody was 'indifferent' to this question. However, when the occupants were asked almost the same question but in a slightly different way, emphasising the importance for them of having an energy meter in their homes, the percentage distribution changes, only 14.3% selected 'highly agree', 57.1% selected the 'agree' choice and 28.6 % selected the choice 'indifferent', as it can be observed in table 34.

7.2. Upton Homes – Verbatim Interviews

This section presents the face-to-face interviews undertaken by the author. Four open questions were put to the seven out of the ten occupants of the Upton homes who were available and who agreed to be recorded. The conversations took place during different days in the month of April 2010. The conversations were based around the following topics:

- The possible influence of the energy meters on their energy consumption habits and energy usage awareness.
- The importance of having one energy meter at home. The interviewee tried to find out if they were willing to buy one.
- The limitations of the energy meters and any possible improvements.
- Their experience with the meters during the trial period, in terms of helpfulness, recommendations, family wise, etc.

7.2.1. Qualitative Analysis results

The results of the verbatim interviews held with the occupants from Upton homes generated a phenomenon that can be graphically represented by the scheme shown in figure 94:

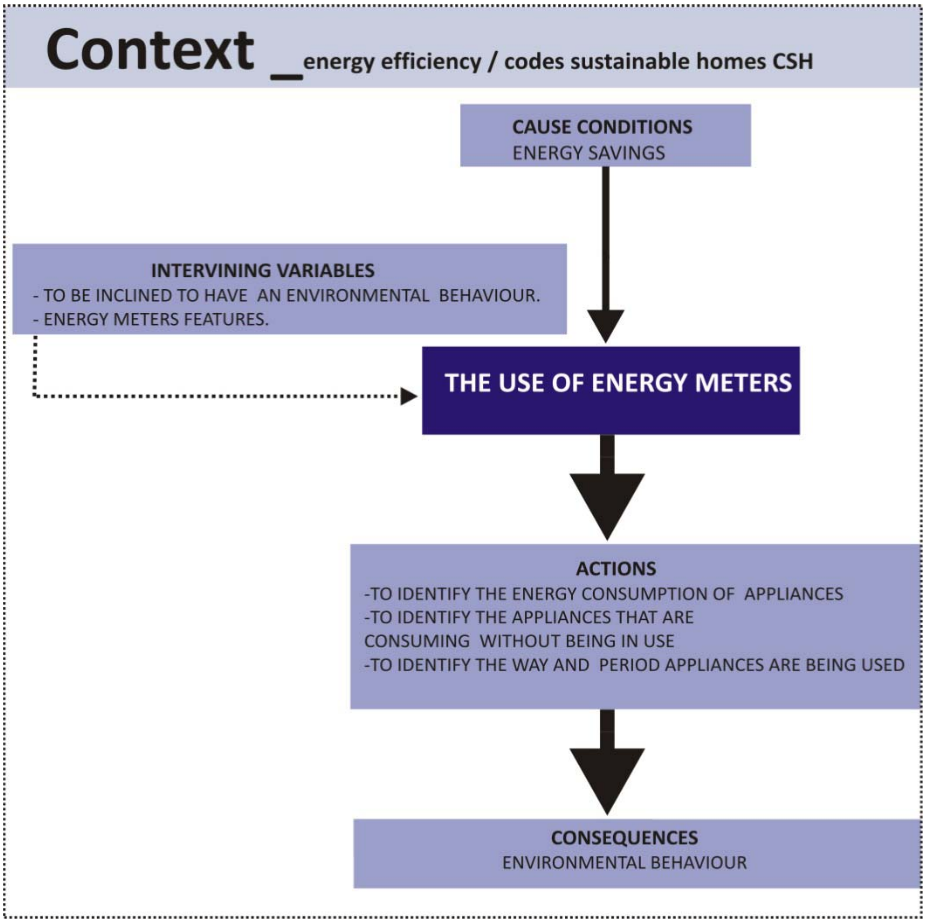


Figure 92 Scheme of the main phenomenon: the use of energy meters.

The main phenomenon was that the researcher used the energy meters for a longer period than had originally been planned during the trial period. The users who declared they would buy an energy meter are those for whom the use of the energy meter during the trial period allowed them to understand their families' energy consumption and who consequently could see the potential to save energy.

The energy meter was used to find out how the electricity was being consumed, what appliances were consuming the most and during which hours of the day the consumption was most expensive. Also, the energy meter showed the consumption of some appliances on standby, thereby generating constant energy expenditure. As user 4 stated:

> "…clear on what you're using and what uses more because obviously as soon as you put the kettle on it goes sky high, so you realise what uses more electricity"

In this way, the energy meter works as an educational tool through which the users realise and learn how they are using electricity in their homes.

> “It wouldn’t make any difference. It was a good educational piece, now we know not to leave things on standby and the difference that really makes“ (User 9)

The interviewees’ increased awareness of their electricity usage in general terms turned the use of the energy meters into a positive experience and they described it as worthwhile.

> “The testing period has been helpful because we’re aware of what appliances have an energy demand” (User 9)

In addition, the experience enabled their eyes to be opened and to realise that the different appliances utilise different amount of electricity and that their energy consumption is not necessarily constant.

> “It’s been a bit of an eye opener, for instance, the oven; when the oven was on, I just assumed that the moment you turn the oven on, it was using power, I didn’t realise that it preheats it to a temperature and when it gets to that temperature, it stops using power” (User 2)

In this way, the energy meters become an informational tool that allows people to become more aware of their electricity usage, leading to them taking actions that tend improve this usage.

> “I like to know how much I’m using, like many; I reckon you said before you would buy the Watson.” (User 4)

The main benefit associated with the use of energy meters is the opportunity to save. The possibility of saving money through using energy more efficiently is more important than saving energy.

> “…That would be the thing, saving money is important, not necessarily saving energy, but saving money …” (User 1)

> “Oh my lord, we could probably get £ 10,000 worth of electricity”. (User 9)

Although the entire group acknowledged saving as the main aspect to promote the use of energy meters, for savings to actually occur, people must already be inclined towards using energy efficiently. In other words, for those people who already displayed energy-saving behaviour and/or were inclined to have more sustainable environmental behaviour, the energy meters reaffirmed their actions.

> “But to be fair, we are always pretty good anyways. If we are making tea, we only pour enough for a couple of cups of tea – what is needed?” (User 5)

For those users, however, who did not behave in a sustainable environmental manner with regard to the efficient use of energy, the energy meter did not necessarily change their attitude and the experience ended up being anecdotic.

> “Unless it was so simple, you plug in and go with it, but it’s not something that attracts me personally, I’m not into energy consumption mode yet” (User 1)

Another important aspect when thinking about using an energy meter is related to the features associated with the device. In general terms, the users recognised several limitations on the use and information possessed by the energy meters used for this study. In fact, the interviews showed that none of the energy meters tested was optimal. Nevertheless, the users concurred in identifying the Wattson meter as the one that best suited their needs.

Among their expectations in terms of the features an energy meter should have, the first was that the display should be easy to read. For the Wattson meter, the users spoke of the colours used by this meter to communicate the real-time use of energy. The colours were striking and easy to read, and they clearly indicated when high-energy consumption was occurring. Also, the colours allowed the information to be easily decoded or interpreted by different types of users. The colour emission by the meter was also visible at almost any location within the home.

> “Information about the Wattson is like that, easy to use, it uses colours” (User 1)
>
> “It’s very good, I like the red light, everything on it and the style… “ (User 3)
>
> “…you can walk to the kitchen, everyone can see it –the kids can see it, I can see it- and when it’s glowing anything other than blue. It makes you think” (User 9)

To be easy to read, or possess intelligible language, was a feature appreciated by the users. It allowed for the correct use of the meter and it made it easy even for people with glasses to decode or interpret the information.

The use of colours was graphic and striking, it made data immediately noticeable and warned when there was high-energy consumption. This tended to produce an instant reaction from the user, to find out the cause of the consumption and reduce it if it was related to misuse or a waste of energy.

> “It gives you much greater awareness of what you’re using, especially the, the one that’s coloured, the Wattson, because it went red. It attracts you straight to order, as you knew when it was blue, you knew it was running well and the energy was down. On the red you knew, one of the kit switch sign on it was costing you a fortune, so that one, definitely, it just makes you so aware of what you’re using and where you can make cut backs…” (User 3)

Another feature that was well evaluated for an energy meter was its size and transportability (ability to be carried or moved from one place to other). Small meter size was a highly evaluated attribute and one which the Wattson meter did not meet.

Its transportability was also important so that the meter could be placed where it was most visible, easy to read and easy to plug in; when it was not cordless, and this feature gives the energy meter itself autonomy.

> "In fact I can use that, I like it just for the fact that I might want to move it at some point, so I don't have to keep it in the right socket" (User 2)

> "You can take it around the home and the batteries keep… last for a long time" (User 7)

The information the energy meter displayed was also a feature that was analysed by users, they wanted detailed information about energy consumption. In fact, one of the greatest weaknesses observed regarding the meters was related to this feature. None of the energy meters used for this study displayed detailed information on the daily or monthly consumption or disaggregated readings by appliance in an instant manner. They had to be connected to a computer and the accumulated data downloaded to obtain an overall picture of a period. This aspect was perceived as unhelpful.

> "It displayed a lot of information and some of the information was very good; it showed what was going up and down. But the basic thing that I would think would appeal to most people is knowing how much you spent last week, or how much this month or last month" (User 5)

Users also did not appreciate that the information that was given by some of the meters was an annual projection of cost presuming that overall electricity usage was based on current electricity usage.

> "Speaking in terms of the Wattson one, the limitations were, it didn't tell you very much. Although it was very bright and it told you very clearly what you wanted to know, it literally only told you yearly power usage and yearly price, I think it was yearly" (User 2)

It was also perceived that the information given was not always the most useful. The occupants highlighted that they would appreciate the possibility of getting savings projections and information on the money saved. In this way, the energy meter could contribute towards the decision to change certain appliances in order to generate more savings.

> "And for me I would rather to see just the physical data, how much I save in kW by switching off something or changing the electricity plug and I did actually save 40% by switching to… those smart plugs when you switch off the TV, switch off the computer and everything is shut down, from it was 30 to 17" (User 7)

“That would get more people thinking about what they are using than kilowatts or whatever it says up, down” (User 7)

Another aspect that was not appreciated by users of the energy meters was the complexity of the user manual.

“…the instructions in one of them. I couldn’t find any indications of how to change, for instance, the date or the time and that’s a simple, straightforward thing for everybody to have…” (User 1)

In the interviews, the topic of the heating systems, although not directly related to the study, was a common factor that was raised when issues related energy were being studied. As with the use of the heating systems, it can be inferred that for meters, it is also important to have systems that are well tested and checked to confirm they are functioning well. Otherwise, people tend to prefer traditional systems that are proven to work better even if they are not necessarily energy efficient.

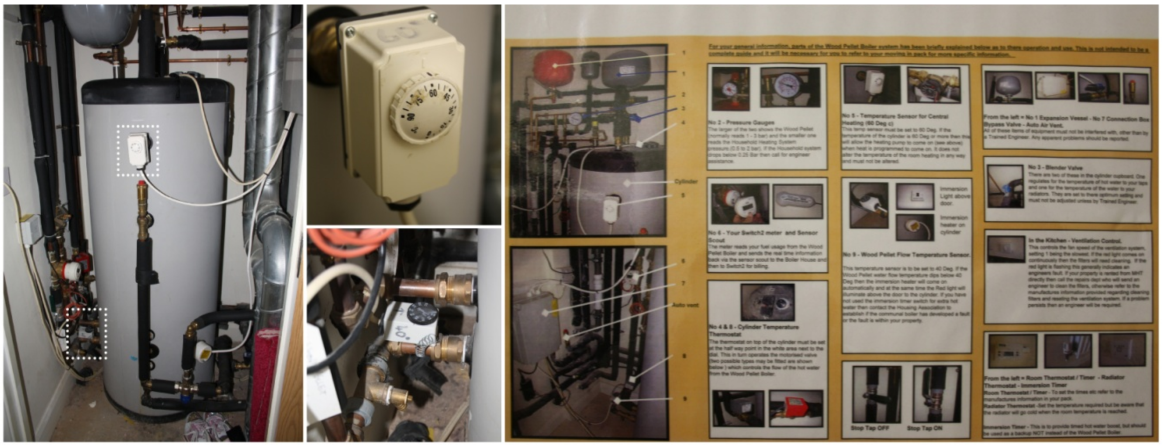


Figure 93 A typical cupboard and poster with the user manual in Upton Homes, boiler connected to the communal heating with biomass.

In order to operate the sustainable energy technology, it was necessary to study the manuals and graphic schemes showing how to use and operate them, but they were unintelligible for lay people, as can be seen in figure 93, where even the very cupboard containing the boiler was complicated to look at. Redundant information was provided, for instance the poster explained that the dial for the water temperature should be set to 60^{o}C, but ‘60^{o}’ was also marked on the dial, even thought there were other temperatures available. This represents a clear duplication of information without educating the user why this is a key temperature related to energy efficient good practice. It also provided pictures to explain the functioning, which were equally difficult to read.

When problems occurred and the occupants needed someone to repair it, it was difficult for them to find the appropriate technicians and, in some cases, three different technicians needed to come before a solution could be found. In the case of heating systems, it could be observed that the lack of knowledge and familiarisation with the new technologies, the lack of being able to personalise their use and the complexity of the systems are all aspects that inhibit their use and make users opt for better-known technologies. This could ultimately badly affect the prestige of sustainable homes.

> "Yes, it is a brilliant system, it is, but, right now it is we got the Grandville, the Gretville, whatever it is called…? Gledhill... it's a very good system, it's a top of the range system, but it's too complicated, it's just, you know, you look at it and it's like, it looks like a tardis, it has so many displays on it, just you know, it's too complicated" (User 3)

It is hoped that when it becomes mandatory for all energy companies to distribute energy meters to their clients, set for 2020, the users will not be "Guinea pigs". The implementation of this policy should be serious, proved and tested, so users do not become depositories for the negative consequences of a national policy.

> "And I suppose it does in anything with meters, and with you in Nottingham, it just feels like you are a Guinea pig, but it should be ready. It should be trialed and tested. You know we've bought a house. I've paid a lot of money for this house for a system that doesn't work" (User 3)

It is also important for the good practice and use of energy meters that there is a group of technicians and professionals trained in how the systems work and who can respond to concerns and queries and give technical support to clients.

> And they will need a special team to deal with the problems. They will need that, because as it stands at the moment, it's not going to work. (User 1)

It is therefore crucial for the energy companies to be able to provide fast, efficient and easy to use meters.

> "So the energy companies are going to want to be able to provide the simplest, easiest, quickest machine, because otherwise they are going to get a lot of inquiries from people saying: "this isn't working, what do I do?, and blah blah blah blah" (User 1)

Users expect that the energy provider companies are the one that should give the meters to their clients, as is normally is the case.

> "The companies that provide energy need to provide the energy meters" (User 1)

Despite the limitations of the devices, the main outcome from the experience of the trial period of using the energy meters was that users were able to achieve actions responsive to sustainable environmental behaviour.

The use of the energy meters and the information they displayed permitted the users to be more alert in regard to the way they utilised and consumed energy, which generated several habit changes such as:

· Turning off lights

> "I would certainly be more conscious of leaving the lights on" (User 5)

· Switching offs appliances or devices that were not in use

> "And the kid's TVs once they finish watching a film, I would make sure they are turned off at the switch on the wall. Whereas normally I'd just leave them running" (User 4)

· Switching off appliances or devices that were used a few times a day, because the users realised although they were on stand-by, they were consuming energy anyway.

> "We started switching them off at night because it's just a waste of money"(User 9)

· Cutting down the use of lights at night, avoiding leaving lights on unnecessarily at night.

> "But also it's good to know that if we leave a light on for the kids, it makes hardly any difference because it's an energy saving one and that gave us peace of mind on that one, so we are not just throwing money away… "

· Replacing normal bulbs with low-consumption ones.

> "Also I have changed some of the light switches, like in here and in the front room. I had one light switch which turned both lights on and now I have changed them over so they are independents switches" (User 5)

· Replacing shared switches for individual ones; to turn on individual lights.

These consequences are limited mainly to electricity consumption; an impact on other areas of energy consumption, like gas or water was not observed. The context of the use of these energy meters is within the mandatory measure that will be implemented in 2020 in the UK. In regard to this, the users felt that more information would be necessary, as well as a more explicit policy stating what the objectives of this initiative are.

> "I think they need to try to do something, push more literature, make us aware of it rather just setting a device. For the moment I wouldn't buy one, so literature, information needs to be passed out to us. Ok we need to do it by 2020, it said" (User 1)

Likewise, users who tended towards sustainable environmental behaviour responded on an individual basis rather than a family or group response.

> “No, no it’s just me, my husband is away… and he is the one who volunteered for this and then he left…” (User 1)

7.3. Chapter conclusions

From the quantitative and qualitative results obtained and analysed with different tools, it is possible to conclude that the use of energy meters generated responsive behaviour among users. The energy meters enabled users to see the way power was consumed and how much it cost.

This increased awareness connected with a familiar way of saving. These types of users favour the saving of money over the attitude that requires a change of habits to contribute towards sustainable and responsible use of energy consumption. In fact, it can be stated that as soon as the use of energy meters implies an effort from the user´s perspective, such as reading and comprehending the way the meter functions or using it to obtain more thorough information by using a computer, people tend to not want to bother and only minority of people goes further in exploring the device and it potential.

To connect with this dimension, it is necessary to use energy meters to develop the possibility of rationalising energy consumption, to make it more efficient and effective to generate changes in behaviour and good practices which favour energy saving.

As this saving materialises in practice, the change in habit should become more plausible, since it connects with a dimension highly appreciated by these users when interviewed and answering the questionnaires. Nonetheless, the energy meters need to be simple to use, easy to read and of a suitable size.

The energy meter promotes conscious habits in people and this is the first step to changing their behaviour. The willingness they reported to receive a free energy meter invites them to start this process. This is the reason why the information and data displayed by the energy meters is very valuable. The way this data is shown to people is extremely important at the beginning of the process, and in a way, the Wattson offers an attractive alternative, as it is easy for the whole family to read and interpret, with the colour code it uses to report energy consumption.

For the policy to be effective, however, it is important to consider certain criteria:

- First, it is important to go from individual to more collective use. How is the use of the energy meter spread and shared within the family? In general the users indicated individual use of the energy meter and in order to generate a change over time, it is crucial to go from individual conduct to family conduct, where every member of the family becomes involved in the responsible and sustainable consumption of energy. In this way, the individual footprint improves and, by involving all members of the households, the footprint is reduced.
- As the consumer becomes more sophisticated, he or she will demand a more complete device with more information with the objective of generating more actions towards reducing their energy consumption. For this reason, it is important to rely on an accessible support system to back up possible issues.
- It is important to take into consideration that the study looked at sustainable homes, where it could be assumed that the occupants would have more sustainable environmental behaviour. Their actions might not necessarily be the same as the actions of users of traditional homes where energy efficiency features are not considered or where important changes towards decarbonisation have not yet been made. It will therefore be important to use different strategies to motivate energy saving activities and promote real use of energy meters among all types of occupants.
- Upton Homes received much media attention in regard to its green features and the residents are aware of the type of home they live in. However, when expectations are not met or when residents feel that living a more sustainable lifestyle requires too much effort on their part, they are not going to bother. However, it is likely that changes in behaviour will certainly take place when the household budget starts to be affected.

Chapter 8. Conclusions and Recommendations

This final chapter includes the overall conclusions presented in three sections, demonstrating the achievement of the original objective of this study. The first section discusses the situation in the UK and Europe with regard to the energy performance of homes, which was covered in the introduction chapter, focussing on the status quo and future trends. The second section looks at the inclusion and appropriateness of the technology installed in sustainable buildings, their application, operation and relationship with the occupants of newly built sustainable homes, topics which were covered in chapters four to seven, while the evidence of the study is presented in the appendices. The third section is the point of departure for the proposal, now in its first stage of development, which has arisen as a result of this study and was introduced in the executive summary. The First Home Occupant (FHO) POE contemplates a series of recommendations for developing a model for testing and applying this research as a continuation, an important objective of this FHO POE is to be an instrumental tool for environmental education starting “in the home”.

The most important results and findings obtained from the evidence are presented and reflected as contributions directed to every party involved in the process of producing sustainable homes, a category which should include all homes, both those newly built and older homes that need to be retrofitted to improve their performance. Also the findings could contribute towards the education of future professionals involved in housing developments, especially in countries like Chile.

Overall this study contains a contribution to the bank of reports and information from the various programmes that are being developed in the UK on the matter of feedback from real homes on the route towards achieving national goals and in the search for the zero carbon home era in the UK. During the last five years, many new sustainable homes have been produced in the UK and these homes are expected to comply with the standards contained within the three upper levels of the Code for Sustainable Homes, so it seemed very logical to study and research this new generation of homes and learn from the findings, given the many changes that are occurring in this area at a very fast pace.

Energy efficiency measures for achieving sustainable energy homes do not necessarily take into account the satisfaction and comfort of the occupant and, over time, these considerations could even jeopardise the occupant’s psycho-physiological wellbeing.

8.1. The UK and European situation

The different stages, scales and processes involved in the production and functioning of the built environment as a whole demand a great amount of energy and materials. In many countries, the existing housing stock alone accounts for 25% of total carbon emissions. This fact is receiving increasing attention from different governments, resulting in many initiatives, especially in developed nations. However, many non-OECD countries have also given priority to climate initiatives, especially in political discourse, although they lag far behind in regard to policies and legislation. There are many reasons why governments put this issue on their agenda; the two most forceful ones are without question political and economic reasons, over and above the fundamental reasons, which are climate change and the urgent need for energy savings. This last goal is vital for European countries, as energy security is being strongly impacted by the supply and sources of energy. Although the interests and reasons for energy conservation might differ from the agreed ultimate goal, it is important to recognise that the issue has found its way onto the agenda of many government administrations, which is very positive. In addition to this, it can be seen that to achieve world climate targets, massive decarbonisation and major energy savings within the building industry will have to occur. Energy efficiency is certainly a route to reaching these goals and currently the energy efficiency strategies are the ones establishing the best way to reduce emissions to the lowest possible cost.

An analysis of the European Union initiatives and policies revealed the evident broad differences in crucial aspects related to the development of each country. The way the different EU members adopt and implement energy efficiency policies and programmes regarding the different initiatives varies widely as well. However, the majority of the EU members are going in the same direction. At the moment, the focus of many programmes is placed on the existing housing stock. In the UK, this consists of some 27 million dwellings. A major number of existing homes are still relying on types of technology other than energy efficiency ones, design and construction (passive) and installations (active). While the policies include and enforce the continuous revision of local codes and certification procedures for new homes, the response to the issue of existing dwellings is still very poor. In the latest EU Initiative, this problem has been especially acknowledged and many EU members have started to develop new programmes in response.

In the research “The Regulatory Assistant Project” prepared for the Department of Energy and Climate Change UK in February 2010, Hamilton and several other authors identified the lack of **people participation and savings** as a vital issue to be dealt with, showing that the different actions in themselves are not sufficient to reach the level of energy savings widely agreed in the emission reduction goals. It is therefore suggested that public investment in existing homes should increase and specific energy efficiency policies be developed urgently and made mandatory. Closely linked to the above issue is the issue of public funds and financial aid, along with the economic incentives mechanism, given the undeniably high cost involved in any energy efficiency improvement. The way some countries have found to promote energy efficiency refurbishment programmes is through subsidies and different types of financing to reduce the economic burden for people who are interested in converting their homes. The cost problem is even more extreme for developing and third world nations. Considering both the issues mentioned above, there needs to be a sea change in the public’s lack of interest and involvement and the high cost of retrofitting homes is a very most significant disincentive. Some EU countries have developed many attractive retrofit programmes with varying levels of public funding. Some of them are highly beneficial for consumers but nonetheless many programmes have still failed to attract interest, so a major revision oriented towards capturing the interest of consumers and motivating a cultural change in attitude towards the current environmental situation is needed. This task should be dealt with as a priority.

In addition to the lack of consumer participation, funding programmes have not considered the long-term. Refurbishments involve a major investment; just the first stage of improving the quality of a thermal envelope could represent a substantial economic and physical problem for any family, for instance regular loans do not even consider some economic incentives designed for retrofitting homes. There are great differences between the different EU members with regard to the funds and programmes designed to make energy efficiency improvements to homes. However, the existing programmes are likely to be insufficient to achieve the expected savings and agreed goals. Probably the only way to effectively reach them resides in newly designed subsidies based on public funds. The use of public funds and the allocation of subsidies bring up issues related to the **administration of energy efficiency programmes**, for which the management, responsibility and accountability need to be appropriate and well managed. Transparency and clarity between the subsidy processes and applications and selections are therefore sensitive features for customers. This report analysed as a key issue **the implementation of refurbishment**. Retrofit work can be done in stages, which is better than not at all. However, it is far better to look at energy efficiency refurbishment in a holistic way rather than implementing one measure here and another there, because, whilst while each individual measure could be cheaper in the short-term, in the long-term the cost may be much higher than if a comprehensive approach had been taken to the problem. For example, it would be wrong to start refurbishing a house by changing the heating system, because the most important measure is improving the thermal envelope. This is because once the thermal envelope has been improved, the heating system installed will be oversized for the now better insulated home, so the occupants will have to change the system again or use it inefficiently. The implementation of programmes goes along with the **quality of refurbishment**, which includes two aspects, the passive design of specifications for improving the thermal quality of the envelope (opaque components such as doors, walls, roof and floors and transparent components, such as windows, doors, conservatories and skylights) and the quality of replacement installations with new forms of sustainable energy technology prescribed for the specific refurbishment project; this second aspect will be covered in the next section. As already mentioned, there is a significant difference in the treatment given to new homes versus that for existing homes and the **energy efficiency requirements and regulations for existing homes** have been neglected in comparison to those for new homes, for which so much has been done in regard to codes and certification. This delay in focussing on energy efficiency legislation for all types of existing buildings is without doubt a major issue that needs to be promptly addressed if better results in terms of energy savings and emission reduction targets are to be seen sooner rather than later.

The **measures** implemented by different countries vary widely. Even though they are based on the same widely agreed goals (Kyoto Protocol, EU Initiatives, 20-20-20 among others), they respond to development and cultural issues, latitudes and other local concerns and urgencies and these differences sometimes respond more to the current local administration than these ultimate shared goals, converting the energy efficiency measures into political propaganda rather than real actions. This is particularly the case in less developed nations, given their different levels of development. When first world countries act in developing nations, energy conservation agreements tend to be inconsistent with their international economic interests. An aspect that tends to be left behind is the issue of **fuel poverty;** energy efficiency in existing social, public or low-income homes has received almost no attention from successive governments. Some administrations have given it very low-priority, while others have had a few programmes; undoubtedly this issue is another one that needs to be addressed. Thus, all types of existing homes and all existing non-domestic buildings need further development in terms of energy efficiency initiatives, strategies, policies, legislation, programmes and actions.

The UK has been a global pioneer of many initiatives and strategies for the development of excellent legislative instruments and programmes related to energy efficiency in buildings. The collaborative work within the code and certification institutions and how the different instruments have actively contributed to the evolution of the Code for Sustainable Homes are quite remarkable. In this way, they have avoided the need to have two powerful instruments for procurement, one public and the other private, as is the case in Germany, where they have the EnEv, the German Energy Saving Ordinance or Germany Energy Conservation Regulations for Buildings, which is mandatory, as well as a certification package like PassivHaus. PassivHaus is one of the world's top standards and a certification package that is aggressive in offering its services around the world, creating joint ventures with local firms and government agencies in order to sell their product. It is hard to be critical and take a stance against this type of certification, but it is important to keep in mind that, while they are supposed to be not-for-profit "green" organisations, in reality profit is important for these certification companies and they sell "green prestige" to big private companies. In fact, many fantastic green initiatives fall into this profit-nonprofits dichotomy, where the ultimate goal can sometimes become blurry. There must be a balance between profit and ultimate goals.

8.2. Sustainable Homes and Sustainable Energy Technologies in the UK

EU initiatives and local standards in the UK are designed to promote and enforce the use of passive and mechanical systems that feature energy efficiency and sustainability for all new or refurbished buildings. These systems need to provide comfortable homes to their occupants and consume the least amount of energy possible so as to reduce carbon emissions to zero. These forms of technology are supposed to operate when comfort cannot be passively achieved, mainly through sustainable design, materials and construction. Moreover, these systems should rely mostly on renewable energy resources. For this study, all the research was concentrated in wintertime, as this is the period when the highest energy consumption occurs in most homes in the UK.

Energy performance in sustainable homes

To conclude that the BASF House is quite close to meeting expectations for both the EPC estimated calculation and the PassivHaus standard for heating and cooling is a very positive outcome. The UK EPC SAP calculation estimated that the house would consume 104 kWh/m²/year of energy, but in actual fact the house used a total of **80.97 kWh/m²/year**, 78% of the estimated calculation. However, at 17.22 kWh/m²/year, it was 15% over the PassivHaus standards of 15 kWh/m²/year for heating and cooling the house.

- <u>BASF House Envelope</u> Evidence has shown that the BASF House has a low demand for space heating, thanks to the good thermo-physical quality of the fabric and its airtightness characteristics. The low U values, high levels of insulation and the homogeneity of its envelope performed well for the latitude, where the passive design of the sunspace contributes greatly in wintertime to the continuity of the envelope becoming a monolithic component as the southern wall. The sunspace provides an excellent buffer zone to control heat flow between exterior and interior temperatures. The main demand for energy to heat up the water and space is concentrated into just a quarter of the year. In regard to airtightness, if pure PassivHaus standards were to be applied in the UK, many further studies of real cases would need to be done, as the first signs of airtightness-related problems such as mould, leaks and the smell of damp are just beginning to appear in the BASF house. Therefore well insulated, breathable walls need to be carefully considered and inspected some time after homes are occupied.
- <u>Biomass Boiler</u> For this research, the in-depth experimental case study of the BASF House, the post-construction measurements demonstrated that the energy performance came close to meeting the expectations for Level 4 in the Code for Sustainable Homes and also the 15 kWh/m² year for ventilation and cooling demand established by the PassivHaus standards. The total energy delivered to heat the space for the winter period was **1,421 kWh** and to cool was almost negligible at **0.02 kWh/m² year**. These figures result in a total heating/cooling demand over a fully monitored winter of 1,421+1.9 kWh/ 82.6 m² = **17.22 kWh/m² year.** However, these excellent results were lessened by the performance of the biomass boiler, which uses Low or Zero Carbon (LZC) technology. Although there is great motivation to install LZC technology in UK homes, this device performed at very low efficiency during the first winter, at a monthly average of 13%. It improved considerably during the second winter with a monthly average of 72.5 %, but the manufacturer claims that it should be between 87% and 90%. The improvement between the first and second years was due to the change in the type of pellets, from rapeseed oil to wood, as well as better

operation. In the beginning, 80 kilos lasted for four days (pellet consumption was 20 kilos per day), which implies that the hopper needed to be loaded more often. The energy yield was 17 MJ/kg and, as the boiler was running continuously, the biofuel consumption was reaching 9 kg per day. As this is an experimental home, a new heating system was installed to replace the existing one for the 2010-2011 winter, one which was more suitable for the thermal characteristics of this home. Winter 2011-2012 was the first year to be monitored in order to analyse its performance.

- Electricity and Appliances The total energy consumption for all electrical devices, including water heating, lighting and all the appliances in the BASF House was **63.75 kWh/m² year**.
- Power consumption For the real life case studies, the Upton homes, the energy performance was poorly analysed because of various difficulties: the instruments were not appropriate for this analysis; the coordination with people involved a great deal of work and the cost of these types of studies is very high. Therefore the physical measurements, which just concentrated on the energy use of all the electrical devices and which excluded the heating systems, because none of them relied on power, were not robust enough. The data confirmed that the inherent differences and variability in households, such as size, family profile, routines and types of appliances, among other factors, tended to make the results confusing and difficult to read and interpret. Furthermore, disentangling the energy consumption data required significant processing. Finally, The most relevant conclusion from this chapter is related to monitoring inhabited homes with sensors and data processing. For any datalogging system, the installation **must** be done before occupants move in to the homes and the system **must** be fully calibrated and tested prior to the defined measurement period. Sample data needs to be logged and analysed prior to the measurement period too, as otherwise it becomes very difficult to solve problems when they appear during the measuring period. The validity of the data needs to be proven before, not during the study, otherwise a great deal of erroneous data can be obtained, as was the case with the Wattson energy meter. In the end, it was hard to obtain good results and findings, and reach good conclusions. Indeed, good conclusions could not be obtained from the data, although a great deal of effort was put into understanding it. The findings were not sufficiently robust. However, the analysis suggested that the apparent correlation between children's occupancy and energy consumption at certain hours of the day produces high peaks in consumption. Closer analysis revealed that the age of children

also influenced energy consumption, as the presence of babies and teenagers can have an important impact on energy consumption in homes. New interesting research questions arose related to family profiles, for instance does the age of children or the presence of teenagers in a family imply higher or lower energy consumption? Does a household with a baby consume more energy? Two of the families in the Upton homes study had babies, but one of the energy meters did not function at all.

- Hot water system: As the measurements of the solar system never worked well, it is only thanks to the first-hand experience of living in the BASF House that there is evidence that when it is not overcast, the solar system heated water very effectively; a few hours of solar radiation produced enough energy to warm up sufficient water to meet domestic hot water demand. However, during the short days of winter, the weather is mostly overcast, so the normal option was to use the biomass boiler with 15kW output. This was very effective at heating the water but very inefficient. The alternative option, especially once the biomass boiler was off for the season or when it was not running properly, was to use the immersion heater of the solar system with 3kW output. Although it was very efficient, it cannot be specifically classified as a LZC technology. The most sustainable way to use it was for two hours (5 kWh approximately) per day on colder days, which provided sufficient hot water to meet daily demand, while on less cold days, one hour per day was enough. The system's water tank stratifies the water and is highly insulated. This was the recurrent option for hot water during non-winter days when there was insufficient sun radiation.
- The mechanical ventilation and cooling system, the ground air heat exchanger (GAHE) in the BASF House was shown to be complex and the technology used was complicated to use and over-dimensioned for the house; in Nottingham cooling is really only needed for two to five days per year. This system was difficult to use during the course of daily domestic activities, and while it was intended to be both user-friendly and intuitive (similar to traditional window ventilation), this did not prove to be the case. In fact, there were 4,096 possible settings that combined opening and closing the inlets and seven opening positions for each of the vents to draw the fresh cool air indoors. Each of the combinations that required mechanical air movement was subject to the purpose, season, weather, time, etc; and to add more options, the setting could be combined with the opening of certain windows.

- Natural ventilation mechanism For the BASF House, different sets of windows worked very well during all seasons. This worked intuitively and effectively, especially when a draught was needed to quickly remove cooking smells or the smoke from the biomass boiler. The windows are located at different levels in the core of the house, connecting the exterior with the interior through the conservatory and at the top of the stairs. This passive design feature proved to be very useful but it was counter-productive to use it to remove the smoke from the biomass boiler, because it makes the home lose heat, so this particular issue revealed the truth in the hypothesis of this thesis, namely that the SET really could harm the wellbeing of the occupants. The decision to install a biomass boiler in the BASF House was taken because such boilers are specified as LZC technology, in order to achieve success in terms of energy efficient design but this decision did not take into consideration the psycho-physiological wellbeing of its occupants.

Relationship between occupants and their sustainable homes

In addition to the physical performance, the in-use experience of sustainable homes by their occupants is extremely important to the success of predictions, expectations and agreed goals. The learning from these new experiences in the housing sector provides much-needed feedback. People's lifestyles and the use occupants make of sustainable homes need to be given attention in the design of sustainable homes in order that energy conservation goals can be achieved. The issues related to the control of sustainable energy technologies (SET) and the way that sustainable behaviour and education could be influenced and promoted should be seriously considered.

- Design The parts of the BASF House which were most appreciated were the kitchen and dining room, followed by the sunspace. This preference was closely related to the 'lighting' quality, which made the north-facing bedroom the least preferred space/room. It was the 'privacy' aspect which led to the sunspace being ranked third. The Passive Design Strategy (PDS) that occupants appreciated the most and which they would replicate in their own homes was the 'sun orientation', while their least favourite was the 'reduced window size on the northern façade' and the north-facing bedroom was also their least favourite. The occupants' experience and evaluation are very consistent with the perceptions of visitors to the house; the importance of lighting in latitudes such as that of Nottingham make it a major design aspect. Most people in the UK know why a northerly orientation is crucial in the design of homes; this is of lesser importance in countries with milder climates and higher solar radiation, as is the case with most of the Chilean territory. Another important aspect with regard to the use of space is that places like conservatories are very intuitive in their use, which depends on the season. Most people learn quickly through experience how to use them in homes.

- Sustainable Energy Technologies - SET Engaging with technology is a complex issue within sustainable homes; the occupants need to adapt to different types of construction and energy technology. It is no minor matter to understand different types of SET, each of which works with different sources of energy and needs to be used in specific ways in order to perform efficiently. This was an issue both for the BASF House and the Upton homes. As has already been mentioned, the malfunctioning or the wrong prescription of devices has a significant impact on energy efficiency.

"… it's a very good system, a top of the range system, but it's too complicated, it's just, you know, you look at it and it's like, one looks like a Tardis, it has so many displays on it, just, you know, it's too complicated"

- Installation of SET In both the Upton homes and the BASF House, most of the families had problems at some time or other with their heating systems, when the functioning of their devices did not meet expectations. To operate the SET meant studying the manuals and graphic schemes of use and operation, but they were unintelligible for lay people, as can be seen in figure 120 in the previous chapter, where even the very cupboard containing the boiler is complicated to look at. It provided redundant written information on the different setting buttons, for instance, the poster was explained that the dial for the water temperature should be set at 60^{o}C, then on the dial itself, the number '60^{o}' was written, even though there were other temperatures on the dial. This just duplicated the information, without educating the user about why this is a key temperature related to good energy efficiency practice. It also provided pictures to explain the functioning, but these were equally difficult to read. When problems occurred with the boiler and the occupants called for someone to repair it, it was difficult to find appropriate technicians and, in some cases, three different technicians needed to come before a solution could be found. This could ultimately badly affect the prestige of sustainable homes.

"… it just feels like you are a Guinea pig, but it should be ready. It should be trialed and tested. You know we've bought a house. I've paid a lot of money for this house for a system that doesn't work" (User 3),

"And, they will need a special team to deal with the problems. They will need that, because as it stands at the moment, it's not going to work" (User 1)

For the BASF House, the biomass boiler was evaluated by the occupants as the 'least favourite' SET within the category Passive Design Strategies (PDS). They rated it as 'poor' for most of the features and gave it very low rankings and written comments like

"… why tenants bother themselves with this system, being able to use others instead" (BASF House occupant).

It converted the winter quality of life of the occupants of the BASF House into a very unpleasant experience. When the biofuel type was changed to wood pellets, the biomass boiler performed much better in regard to user comfort; it no longer smelled, was easier to light, did not produce much smoke and the pellets moved more easily in the hopper.

8.3. General recommendations

It is important to highlight that there are solutions for most of the problems encountered within this study. The evidence and analysis of issues discovered helps with developing solutions, so the general recommendation is based on education and adaption. Many of the recommendations coincide with those from other similar studies, such as "Lessons from Elm Tree Mews", a report produced in 2010 regarding a housing development in York. This provided evidence of the results of implementing major changes to respond to very ambitious carbon emission reduction targets in the UK's housing sector, which is characterised by a very traditional culture and capabilities and currently needs to adapt to many new requirements.

In addition to this evidence, in November 2010, research carried out by Bell et Al identified nine issues which could be the source of the problems. These issues are related to **designers' knowledge** and the **detailed design for low energy solutions**, where a key aspect is the thermal performance calculation (TPC) process. Other issues include the reluctance to develop the skills needed to carry out TPC effectively, the accuracy of information for the TPC, the manufacturer's responsibility for performance, the addressing of thermal bridges, the complex geometry TPC, the detailed design of SET, especially for LZC systems for space and water, the services and installations for the LZC technologies. For designers these technologies are difficult to integrate, use and test within and during the design process.

> "Detailed design is a difficult, and often unacknowledged, part of the design. […]To undertake it fully is costly and involves a high level of expertise on the part of the designer." (Bell et Al, 2010, p 97)

As mentioned in the previous section, these nine issues are coherent with the findings in this study, which has indicated that to ensure the quality of SET, the assessment, installation and maintenance of products need to be part of this process, for which **trained and certified technicians** and an institution to evaluate them should be considered. There is also an important opportunity with regard to the **occupants' interaction with SET**; SET could be an instructive and educational tool if it were possible to operate them in a more intuitive manner, without feeling that one needs to have a degree in mechanics to be able to use them. Another aspect that needs revision and attention is related to the **appropriateness of the SET chosen.** In the UK, the codes and assessments are exhaustive in terms of prescribing what to do and in providing instruments to evaluate performance. There are design incentives for certain types of Low to Zero Carbon technology (LZC) to be installed in a housing project. These measures are pertinent and they probably motivate and promote the use of one type of LZC technology rather than another. However at times there is an inconsistency between the prescribed heating systems and the thermal performance required for a home, which can result in installations which are inefficient due to oversized technology being provided for a super insulated home with high airtightness, that probably requires a completely different system. Changes have been occurring at a very fast pace in recent decades and it seems that there is not enough time to evolve all the aspects in parallel, such as the development and adaption of technology for these new homes so as to achieve the expected energy savings. This fast pace of change in developed nations is quite influential on developing nations, such as Chile, where energy is currently one of the four main areas of development on the national agenda, so a great deal of attention and resources are being allocated to it. A proposal like PHO POE could therefore have a good opportunity for development and implementation and, in fact, a PHO POE is currently being tested in social housing for elderly.

Beside the four aspects related to SET already identified, the **excessive application of technology** is another problem. Much has been discussed and exemplified in this study about the way that excessive levels of sustainable forms of technology are installed in sustainable homes without reflection being given to whether they are really needed. For instance, the RuralZED in Upton, which were also demonstration homes, raised the question about what else could be applied to homes. The homes already had a system, which was removed and never replaced, so the question needs to be asked: were those wind turbines really necessary? Excessive SET places an additional burden on the occupants in terms of effort and understanding and may also entail more expense in terms of revision and maintenance. The operation of a sustainable home should be as intuitive as possible. For instance, it goes against human nature to prohibit someone from opening a window so they can feel that natural contrast in temperatures between a warm indoor environment and the coolness outside and tell them they must instead press a button to cool and change the air in an invisible fashion, without them being able to really enjoy the sensation of a contrast in temperatures.

Another issue indirectly related to the use of SET, is the use of **other types of technology in homes:** all sort of appliances, computers, games and toys. They are highly dependent on power - almost everything today functions with electricity - and many of them are heat producers. When calculations and simulations for homes are prepared, the group of small devices and appliances tends to be generalised, but households are currently changing very rapidly. For instance a family of four can have four computers, four mobile phones, two to four televisions, music players, battery chargers, cameras, plus a whole range of other typical appliances, so it is hard to estimate without there being significant discrepancies. For example, during a late summer period in 2009 in the BASF house, the two occupants needed to move their offices to the house, because of renovation work in the building where their regular offices were located. As a result, for a period of two and a half months, computers and electricity consumption during working hours were added to the energy load. The results were extreme and completely unexpected, as can be seen in the tables in appendix 6 for the particular period. When analysing the annual data for energy consumption, and comparing month to month, leaving out the winter months, the months of august and september of 2009 showed a peak of a third more than the other months in the same year for "lighting+sockets+network" readings, 598 kW-h (aug+sep). In July 2010 for the same months, the power consumption was 170 kW-h (aug+sep), more than two thirds lower. This difference corresponded to nine weeks with two computers plugged into the sockets 24/7, plus the general usage by the occupants while working at home. The occupants did not anticipate this increase in power consumption. Computers are so much part of home life today, so this became “a real alert”, as many of us would never have imagined that the use of a couple of computers could be as high as a third or more of total monthly power consumption.

The electricity consumption in the two subsequent months, August and September 2009 was three times higher than that the following summer, purely because of this one factor.

With regard to methodology, tools and techniques, **questionnaires** are the most useful instruments for POE. The analysis of the data gathered from them offers multiple opportunities, especially when used with software like SPSS. However, if the researcher is not a specialist, as was the case of the author, there is a risk that he/she will get lost among the data and on applying the features offered by the computer programme to interpret results, could end up wasting time and not knowing what to do with so much information. Therefore, the design, process and analysis of questionnaires need to be done by a specialist. For PHO POE, it is suggested that a sociologist or statistician be employed.

For instance the Pearson correlation or analysis of dependence among variables and the predictive and segmentation model were both applied to give more validity to results, but as the statistical part of it was not fully understood, the author ended up using a great deal of time to obtain little and sometimes this took the author away from the focus of the research. However, one interesting result obtained by applying these SPSS features, was related to the respondents’ dislike of the small windows on the north façade. Most people associated this feature with poor natural light rather than energy conservation, and it could be inferred that people’s awareness of passive design features (PDS) was low. Although the interviewees knew the importance of southern orientation for fenestrations, they did not necessarily understand the flow of energy, and they were more concerned with the natural lighting aspect than thermal comfort. These insights suggest that education on sustainability in homes is needed. This, however, is a very general statement and further and deeper understanding is required. In the end, the most useful way to apply SPSS was for the descriptive analysis, which can also be done with a simple Excel spreadsheet.

The length and focus of questionnaires are very important features, as otherwise the conclusions are extremely general and difficult to sustain. For the occupants’ questionnaire, the questions related to preference should have been within a typical Libert scale, of five options, otherwise many confusing steps need to be taken in order to obtain good results from the data. Cross-referencing with open questions complemented the results, but much of the data obtained for so many features of the BASH House was not useful.

The use of **tracking devices** was an attractive and interesting experiment, but ended up being a major distraction within this study. In the end, they did not address the associated research question, which could have been one whole piece of research in itself, and what was worse, the occupants did not feel comfortable with their use, so most of the data gathered with the tracking devices was not useful. An alternative reading of it was the length of time occupants spent in different zones, but in other to calculate the individual footprint for a given period of time, it would be necessary to install the package in the whole house and ensure that the users were willing to participate. Otherwise it wastes too much time and money and the data is not useful. The data obtained as a result of the application of this tool is shown in appendix 12. It could have been obtained in a much simpler and cheaper way.

The **study of human subjects**, home occupants do not appreciate intrusions into their privacy, so visits need to be reduced to the minimum and the period of time for which devices are going to be installed and measuring carried out should be a month or less, ideally during the coldest month of winter. When studies are realised in wintertime in a Nordic latitude like the UK, even if all the above details have been taken care of, such as the length of the measuring period, the dates, times and length of visits for installing sensors, downloading data, surveying, photographing, interviewing, etc., there is always a latent sense of intrusion, because the researcher has to meet the family after the adults have returned home and in wintertime it is already dark and the family are preparing or eating supper. The researcher therefore feels as though he/she is invading private family time at night. It is not easy to find volunteers for any type of study that involves human subjects, so once a group of volunteers has been obtained, it is very important to maintain a very cordial relationship between the subjects of the study and researchers, especially if the application of several tools to study or research a problem is planned. In fact, the SHINE TRUE project included carrying out measurements of occupied or soon to be occupied sustainable homes in three different locations within the East Midlands region, two homes in Colsterworth, two homes in West Bridgeford and two homes in Upton by RuralZED (see appendix 17), as well as demonstration homes in the Upton homes project. For these three cases, meters were installed, entailing money and time, which at the end of day was wasted. In the case of West Bridgeford, installation started when the homes were unoccupied, but was not complete when the occupants moved in. After some time, the occupants became very upset and stopped allowing the researchers to enter the homes. For the Rural ZED, the situation was even worst, because the whole installation of the monitoring system was done during the last stage of construction, but after the project was completed, it was extremely bureaucratic to gain access to those homes, and when the occupants moved in, they did not wanted any intrusion, so nobody volunteered.

Observations (graphical and textual), plans, specifications, photography and **computer simulations** are very useful tools for architects, and they help substantially to complement and shape the research, so they are typically used by architects. As graphical/textual data, they contribute to a better reading and a better explanation of the results obtained from numerical data. Sometimes a perception of the occupants was represented graphically, emphasising the findings, which enhance the understanding of the issue.

A mixed methodology includes several tools needed for quantitative and qualitative research, for in-use homes, both types of research are needed. However it is recommended that only those tools which are really needed to address the research question be used and that, as far as possible, tools be selected which cause the least intrusion into people's domestic routines. It is therefore essential to define at a very early stage the parameters to be studied. This study has clearly shown that carrying out research in in-use homes is very complex, so the research question and objectives need to be to the point, stick to the focus and must be kept in mind throughout the whole process. The temptation to study other issues must be firmly withstood, regardless of how close they may be to the research question. They might be the subject of further studies.

Architecture is a very generalist discipline, so architects tend to borrow from many other disciplines to address a complex problem, but this does not imply that one person can be a specialist of many disciplines at the same time, Fitzpatrick et Al in 1992 wrote

> "Mixed Methodology (aka The Servant of Two Masters)...The basic difficulty with... is that you have to conduct two separate and distinct types of research, you have to write and write and research and research and analyzed and analyzed everything you do twice throughout..."

Rather than doing everything twice, what happened with this study is that a tremendous amount of data of different types and sources was gathered and it was very difficult to process and analyse. The main conclusion drawn therefore was the proposal to carry out a PHO POE, which proactively relies on the different disciplines and specialists around a main measurable parameter related to education on sustainability in homes; sustainability in homes is a multidisciplinary matter that architects cannot address alone. Again, it might seem evident that this proposal should define what, how and when; however, data processing from in-use homes is rather complex, time-consuming and very costly. There is an endless list of parameters which can be measured and, when this quantitative, numerical data needs to be combined with qualitative, textual data to reach a more complete evaluation, the purpose of the POE needs to be even more precisely defined.

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Appendixes

Appendix 1 BASF House summary of transcription of occupant's observations from diary of events

Summary of occupant's observations annotated on the diary of events from the BASF House. The users' annotations were partially transcribed and they were taken from the period starting on 30/01/2009 until 26/02/2009. These were the weekly relevant events that corresponded to the last columns of spread sheet included on Appendix 2 where all the quantitative data was plotted in four major rows, each representing a week.

WEEK	WEEKLY BIOMASS BOILER ENERGY DELIVERED	WEEKLY BIOMASS BOILER ENERGY CONSUMED	WEEKLY OTHER ELECTRICAL ENERGY CONSUMPTION	WEEKLY BIOMASS-FUEL CONSUMPTION (Oil seed rape pellets)	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON' PER WEEK	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK	WEEKLY AVERAGE OUTDOOR TEMPERATURE	WEEKLY AVERAGE INDOOR TEMPERATURE
units	**kW-h**	**kW-h**	**kW-h**	**kg**	**h**	**%**	**ºC**	**ºC**
observations	Week 1. 30/01/09 to 05/02/2009: This was the first week the logging system was generating reliable data. Also the bmb needed to be fixed due to the wrong set up. BAXI recommended for the bmb to be "on" at all times (24/7) and to set it at 65ºC as the maximum temperature. The hopper was fed at noon on the first day with 69.5 k of biofuel made of rape seed oil pellets (new supply from Masstock), which was fully consumed by the seventh day, at 4 pm the bmb was turned off. Biofuel consumption rate 9.7 k per day							
1	**52.73**	**412.8**	**0.00**	**63**	**156**	**12.77**	**1.14**	**21.31**
observations	Week 2. 06/02/09 to 12/02/2009: this was the coldest week of the month, there was no biofuel to feed the bmb, therefore the use of the immersion and electrical heaters were needed for water and space heating. The heating produced by the bmb for space and water lasted for 1.5 days after it was turned off. The biofuel supply arrived at the 6th day of the week. After cleaning the bmb it was lit at 6 pm and the hopper was fed with 80 k of pellets (Biofuel consumption rate: 15 k per day).							
2	**15.32**	**135.6**	**81.03**	**30**	**48**	**11.30**	**0.53**	**19.15**
observations	Week 3. 13/02/09 to 19/02/2009: the external temperature increased much so the bmb was turned on and off as demanded, almost every night for 10 hours approx. Therefore some days the use of immersion and electrical heaters was needed, due the temperatures will be very low at nights, especially the fourth and fifth day of this week. This irregular situation made the efficiency of the bmb go lower than the first and second weeks and the consumption of biofuel was higher (15 k per day).							
3	**13.98**	**133.3**	**23.60**	**28**	**44**	**10.49**	**5.79**	**19.82**
observations	Week 4. 20/02/09 to 26/02/2009, the external temperatures increased much so the bmb was lit at nights solely to secure warm water for the morning showers when there was not sun during the day, soon it was realised when the temperature of water reached over 40ºC, it lasted for two days or more if we had a sunny day. The demand of the bmb started to diminished then. At this point we realised as well that we have never turned the bmb in a "lockout" mode, therefore it was always consuming electrical energy.							
4	**29.50**	**165.8**	**9.55**	**36**	**58**	**17.79**	**7.64**	**21.29**

Appendix 2 BASF house summary of processed data from first winter

Summary of daily energy consumption from all the heating systems (space and water) installed in the BASF House for the first winter starting on 30/01/2009 until 26/02/2009. Each row is the daily consumption calculated from the raw data logged by the WebBrick monitoring system. Two columns show the fuel consumption in kilos at the day the hopper was fed and the amount of hours per day the boiler was 'on'.

DATE	TIME	BEDROOM SOCKETS	LIVING & DINING ROOM SOCKETS	DAILY ELECTRICITY CONS. SPECIFIC SOCKETS	DAILY ELECTRICITY CONS. WITHOUT ELECTRIC HEATERS	DAILY ELECTRIC HEATER CONS. Space Heating	IMMERSION HEATER	DAILY IMMERSION HEATER CONS. FOR Water Heating	BIOMASS BOILER ELECTRICITY CONSUMPTION	DAILY BIOMASS BOILER ELECTRICITY CONSUMPTION	HOPPER FEEDING DAY & AMOUNT OF BIOFUEL	HOURS OF BIOMASS BOILER ON	BIOMASS BOILER ENERGY CONSUMED FROM BIOFUEL	BIOMASS BOILER ENERGY DELIVERED	BIOMASS BOILER ENERGY CONSUMED	OTHER ELECTRICAL ENERGY CONSUMPTION	DAILY ENERGY DELIVERED Water+Space Heating kW-h	DAILY ENERGY CONSUMPTION (Electricity+Biofuel) FOR Water+Space Heating
	day	W-h	W-h	kW-h	kW-h	kW-h	W-h	kW-h	W-h	kW-h	kg	h	kW-h	kW-h	kW-h	kW-h	kW-h	kW-h
30/01/2009	day 1	52.5	2444.5	2.50	**2.50**	**0**	**0**	**0**	**4112**	**4.1**	**69.5**	**12**	**29.6**	**9.8**	**33.8**	**0**	**9.84**	**33.75**
31/01/2009	day 2	112	4776	4.89	**4.89**	**0**	**0**	**0**	**4093.5**	**4.09**		**24**	**59.3**	**8.5**	**63.4**	**0**	**8.47**	**63.37**
01/02/2009	day 3	70.5	3911	3.98	**3.98**	**0**	**0**	**0**	**4085.5**	**4.09**		**24**	**59.3**	**8.7**	**63.4**	**0**	**8.75**	**63.36**
02/02/2009	day 4	38	4397.5	4.44	**4.44**	**0**	**0**	**0**	**4017**	**4.02**		**24**	**59.3**	**8.7**	**63.3**	**0**	**8.70**	**63.29**
03/02/2009	day 5	15	5000	5.02	**5.02**	**0**	**0**	**0**	**3951**	**3.95**		**24**	**59.3**	**9.0**	**63.2**	**0**	**9.03**	**63.23**
04/02/2009	day 6	15	4373	4.39	**4.39**	**0**	**0**	**0**	**3606.5**	**3.61**		**24**	**59.3**	**3.7**	**62.9**	**0**	**3.68**	**62.88**
05/02/2009	day 7	0.043	5066.5	5.07	**5.07**	**0**	**0**	**0**	**3674.5**	**3.67**		**24**	**59.3**	**4.3**	**63.0**	**0**	**4.25**	**62.95**
06/02/2009	day 8	0.043	4683	4.68	**4.68**	**0**	**0**	**0**	**3730.5**	**3.73**		**16**	**39.5**	**4.8**	**43.2**	**0**	**4.84**	**43.25**
07/02/2009	day 9	6857.5	4902	11.76	**4.47**	**7.29**	**0**	**0**	**3621**	**3.62**		**0**	**0.0**	**0.8**	**3.6**	**7.3**	**8.06**	**10.92**
08/02/2009	day 10	4504	14685.5	19.19	**4.47**	**14.72**	**4055.5**	**4.06**	**1951**	**1.95**		**0**	**0**	**0**	**2.0**	**18.8**	**18.78**	**20.73**
09/02/2009	day 11	6637	15365	22.00	**4.47**	**17.54**	**2625**	**2.63**	**1914.5**	**1.91**		**0**	**0**	**0**	**1.9**	**20.2**	**20.16**	**22.08**
10/02/2009	day 12	1141.5	11461	12.60	**4.47**	**8.14**	**8055**	**8.06**	**1928**	**1.93**		**0**	**0**	**0**	**1.9**	**16.2**	**16.19**	**18.12**
11/02/2009	day 13	2285	15353	17.64	**4.47**	**13.17**	**5431**	**5.43**	**2411**	**2.41**	**80**	**8**	**19.8**	**2.5**	**22.2**	**18.6**	**21.07**	**40.77**
12/02/2009	day 14	3142.5	1619	4.76	**4.76**	**0**	**0**	**0.00**	**1455**	**1.46**		**24**	**59.3**	**7.2**	**60.7**	**0**	**7.24**	**60.73**
13/02/2009	day 15	209	2787.5	3.00	3.00	0	0	0	2117	2.12		24	59.3	0.9	61.4	0	0.87	61.39
14/02/2009	day 16	85.5	4273	4.36	**4.36**	**0**	**5532.5**	**5.53**	**3655**	**3.66**		**6**	**14.8**	**0.9**	**18.5**	**5.5**	**6.43**	**24.01**
15/02/2009	day 17	3052	4154	7.21	**4.47**	**2.74**	**5287**	**5.29**	**3654.5**	**3.65**		**0**	**0.0**	**1.3**	**3.7**	**8.0**	**9.30**	**11.68**
16/02/2009	day 18	3517	4509	8.03	**4.47**	**3.56**	**2665**	**2.67**	**3653**	**3.65**		**6**	**14.8**	**2.1**	**18.5**	**6.2**	**8.29**	**24.70**
17/02/2009	day 19	376.5	4699.5	5.08	**5.08**	**0**	**0**	**0**	**3759**	**3.76**		**0**	**0.0**	**4.0**	**3.8**	**0**	**4.02**	**3.76**
18/02/2009	day 20	356	4442	4.80	**4.80**	**0**	**0**	**0**	**3656.5**	**3.66**		**8**	**19.8**	**0**	**23.4**	**0**	**0**	**23.42**
19/02/2009	day 21	1558	4109.5	5.67	**4.47**	**1.20**	**2612**	**2.61**	**4097**	**4.10**		**0**	**0.0**	**4.9**	**4.1**	**3.8**	**8.67**	**7.91**
20/02/2009	day 22	403.5	4322.5	4.73	**4.73**	**0.26**	**0**	**0**	**3976**	**3.98**		**10**	**24.7**	**4.7**	**28.7**	**0.3**	**4.97**	**28.94**
21/02/2009	day 23	968	4295.5	5.26	**4.47**	**0.80**	**0**	**0**	**3884**	**3.88**		**10**	**24.7**	**5.1**	**28.6**	**0.8**	**5.88**	**29.38**
22/02/2009	day 24	326.5	6128	6.45	**4.47**	**1.99**	**2770.5**	**2.77**	**3401.5**	**3.40**		**10**	**24.7**	**3.0**	**28.1**	**4.8**	**7.73**	**32.86**
23/02/2009	day 25	775	4738.5	5.51	**4.47**	**1.05**	**0**	**0**	**2260.5**	**2.26**	**40**	**0**	**0**	**2.7**	**2.3**	**1.0**	**3.74**	**3.31**
24/02/2009	day 26	669.5	4306.5	4.98	**4.98**	**0**	**0**	**0**	**3098.5**	**3.10**		**0**	**0**	**5.1**	**3.1**	**0**	**5.12**	**3.10**
25/02/2009	day 27	350.5	4353.5	4.70	**4.70**	**0**	**2686**	**2.69**	**2092.5**	**2.09**		**10**	**25**	**0**	**26.8**	**2.7**	**2.69**	**29.48**
26/02/2009	day 28	155	4400	4.56	**4.56**	**0**	**0**	**0**	**3870**	**3.87**		**18**	**44**	**8.9**	**48.3**	**0.0**	**8.94**	**48.33**

Appendix 3 BAFS House summary of processed data from second winter

Results of calculations obtained from the readings of the WebBrick monitoring system of the BASF House for the second winter, beginning on 01/12/2009 to 29/03/2010. Weekly heating system performance and indoor and outdoor temperature averages.

	WEEK	BIOMASS BOILER ENERGY DELIVERED	BIOMASS BOILER ENERGY CONSUMPTION	ELECTRICAL HEATER ENERGY CONSUMP FOR SH	IMMERSION HEATER ENERGY CONSUMP FOR WH	ELECTRICAL + IMMERSION HEATER ENERGY CONSUMPTION	BIOMASS-FUEL CONSUMP (wood pellets)	TOTAL AMOUNT OF HOURS BIOMASS BOILER 'ON'	ENERGY EFICIENCY OF BIOMASS BOILER BASED ON A WEEK	TOTAL AMOUNT OF HOURS OF ELECTRICAL HEATER 'ON'	TOTAL AMOUNT OF HOURS OF IMMERSION HEATER 'ON'	WEEKLY AVERAGE OUTDOOR T°	WEEKLY AVERAGE SUNSPACE T°	WEEKLY AVERAGE INDOOR T°	TOTAL AMOUNT OF HOURS OF ELECTRICAL + IMMERSION HEATER 'ON'	WEEKLY AVERAGE OUTDOOR T°	WEEKLY AVERAGE SUNSPACE T°	WEEKLY AVERAGE INDOOR T°
		kW-h	kW-h	kW-h	kW-h	kW-h	kg	h	%	h	h	°C	°C	°C	h	°C	°C	°C
Dec-09	Week 1. 01-07/12/2009	**94**	**295**	**0**	**0**	**0**	**80**	**168**	**32**	**33**	**0**	**6.26**	**13.89**	**18.73**	**33**	**6.26**	**13.89**	**18.73**
	Week 2. 08- 14/12/2009	**86**	**182**	**18**	**20**	**38**	**0**	**96**	**47**	**61**	**7**	**5.55**	**13.55**	**17.68**	**68**	**5.55**	**13.55**	**17.68**
	Week 3. 15-21/12/2009	**49**	**71**	**170**	**45**	**215**	**0**	**28**	**69**	**1**	**16**	**0.60**	**11.22**	**16.78**	**17**	**0.60**	**11.22**	**16.78**
	Week 4. 22-28/12/2009	**11**	**27**	**3**	**0**	**3**	**0**	**0**	**39**	**32**	**0**	**1.73**	**8.12**	**10.42**	**32.44**	**1.73**	**8.12**	**10.42**
	monthly totals	**239**	**576**	**191**	**65**	**256**	**80**	**12**	**46.71**	**127**	**23**	**3.53**	**11.69**	**15.91**	**150.00**			
Jan-10	Week 5. 29/12/2009 to 04/01/2010	**10**	**48**	**91**	**11**	**102**	**0**	**13**	**20**	**117**	**4**	**0.74**	**6.88**	**8.95**	**121**	**0.74**	**6.88**	**8.95**
	Week 6. 05-11/01/2010	**6**	**10**	**327**	**56**	**382**	**0**	**0**	**62**	**93**	**20**	**-0.42**	**10.98**	**16.70**	**113**	**-0.42**	**10.98**	**16.70**
	Week 7. 12-18/01/2010	**68**	**102**	**261**	**66**	**327**	**80**	**24**	**67**	**0**	**24**	**2.73**	**11.76**	**17.19**	**24**	**2.73**	**11.76**	**17.19**
	Week 8. 19-25/01/2010	**487**	**728**	**0**	**6**	**6**	**80**	**168**	**67**	**0**	**2**	**4.18**	**12.77**	**19.38**	**2**	**4.18**	**12.77**	**19.38**
	Week 9. 26/01/2010 to 01/02/2010	**252**	**527**	**0**	**6**	**6**	**160**	**168**	**48**	**0**	**2**	**2.18**	**13.65**	**19.17**	**2**	**2.18**	**13.65**	**19.17**
	monthly totals	**822**	**1414**	**678**	**145**	**823**	**320**	**16**	**52.82**	**210**	**52**	**1.88**	**11.21**	**16.28**	**262**			
Feb-10	Week 10. 02-08/02/2010	**302**	**394**	**0**	**0**	**0**	**80**	**168**	**77**	**0**	**0**	**3.35**	**12.20**	**18.41**	**0**	**3.35**	**12.20**	**18.41**
	Week 11. 09-15/02/2010	**238**	**450**	**0**	**0**	**0**	**80**	**168**	**53**	**0**	**0**	**2.42**	**13.61**	**18.57**	**0**	**2.42**	**13.61**	**18.57**
	Week 12. 16-22/02/2010	**269**	**338**	**0**	**0**	**0**	**0**	**168**	**80**	**0**	**0**	**1.59**	**12.98**	**18.05**	**0**	**1.59**	**12.98**	**18.05**
	Week 13. 3/02/2010 to 1/03/2010	**194**	**243**	**0**	**0**	**0**	**80**	**168**	**80**	**3**	**0**	**4.24**	**12.00**	**17.05**	**3**	**4.24**	**12.00**	**17.05**
	monthly totals	**1004**	**1425**	**0**	**0**	**0**	**240**	**28**	**72.25**	**3**	**0**	**2.90**	**12.70**	**18.02**	**3**			
Mar-10	Week 14. 02-08/03/2010	**41**	**248**	**9**	**3**	**12**	**40**	**168**	**17**	**7**	**1**	**2.75**	**15.69**	**18.26**	**8**	**2.75**	**15.69**	**18.26**
	Week 15. 09- 15/03/2010	**107**	**195**	**20**	**0**	**20**	**0**	**108**	**55**	**5**	**0**	**5.63**	**16.02**	**19.17**	**5**	**5.63**	**16.02**	**19.17**
	Week 16. 16- 22/03/2010	**0**	**0**	**13**	**6**	**19**	**0**	**0**	**0**	**1**	**2**	**9.04**	**21.85**	**19.69**	**3**	**9.04**	**21.85**	**19.69**
	Week 17. 23-29/03/2010	**0**	**0**	**3**	**9**	**12**	**0**	**0**	**0**	**0**	**3**	**9.31**	**16.34**	**18.34**	**3**	**9.31**	**16.34**	**18.34**
	monthly totals	**149**	**443**	**45**	**18**	**63**	**40**	**12**		**13**	**6**	**6.68**	**17.48**	**18.87**	**19**			

Appendix 4 Biomass boiler water and space heating chart

Totals for BIOMASS BOILER usage, WATER and SPACE HEATING separated winter 2009-2010

WINTER 2 PERIOD	TOTAL OF HOUR BMB 'ON'	TOTAL OF DAYS BMB 'ON'	TOTAL FUEL USED k	% USAGE SH+WH	% USAGE SH	% USAGE WH
26/11/2009 to 17/12/2009	399	16.6	160	26.7	15.0	11.7
18/01/2010 to 31/01/2010	373	15.5	80	27.5	15.1	12.4
01/02/2010 to 28/02/2010	672	28.0	320	32.0	19.4	12.6
TOTALS	**1444**	**60.2**	**560**	**28.7**	**16.5**	**12.3**

Fuel per day oil seed rape	9.6 k
Fuel per day wood pellets	9.2 k

	BIOMASS BOILER 'ON' days	ELECTRICAL HEATER 'ON' hour	IMMERSION HEATER 'ON' hour
dic-09	**12**	**127**	**23**
ene-10	**16**	**210**	**52**
feb-10	**28**	**3**	**0**
mar-10	**12**	**13**	**6**

Appendix 5 BASF House manual record transcription

Manual records from system readings to disaggregate space heating (SH) and water heating (WH) of the BASF House, second winter (November 2009 - February 2010)

DATE	TIME	MANUAL READING of THE ELECTRICITY METER	MANUAL READING of THE WATER METER	PERSONS AT HOME	DAYS	WConsump PER PERSON	BIOMASS BOILER USAGE, MANUAL READING TO DISAGGREGATE WATER FROM SPACE HEATING									OBSERVATIONS
	hr	kW-h	m³	N°	N°	m³	hr ON	hr OFF	hr CH ON	hr CH OFF	total hrs	hr WH ON	hr WH OFF	total hrs	kg pellets	
08-10-2009		3337.9														
29-10-2009			0													
NOVEMBER 2009																
03-11-2009	10:25	3610	1310	3	5	262.0										
05-11-2009	10:30	3623.9	1517	1	2	104										
08-11-2009	9:40	3647.2	2003	2	3	162										
10-11-2009	13:30	3683.7	3020	4	2	509										
16-11-2009	10:30	3768.6	4844	4	6	304										
18-11-2009	15:10	3793.4	5245	2	2	201										
20-11-2009	12:30	3818.6	5703	2	2	229										
22-11-2009	19:00	3846.4	6188	2	2	243										
26-11-2009	12:15	3884	6514	4	4	81.5	1:00		2:15			4:20	7:15	2:55	80	
27-11-2009				2						12:40	10:25					
28-11-2009				2					10:50	15:25	4:35					
29-11-2009				2					19:05			8:25	10:25	2:00		
30-11-2009				2						8:40	13:35					
DECEMBER 2009																
01-12-2009	9:30	3955.3	7764	2	5										43	
02-12-2009				2												
03-12-2009	11:00	3976.8	8058	2					18:10	23:40	5:30	8:00	8:50	0:50	40	
04-12-2009				3					19:50	20:50	1:00	23:45	12:45	13:00		Extra heating needed: electrical heater on SW bedroom from 23:45 to 1:20 hours.
05-12-2009		4029.9	9510	4					0:00	0:45	0:45	12:45	20:30	8:45		
06-12-2009				4												
07-12-2009				4				12:00	10:55	12:00	1:05					The boiler shut off, after 12 days of having the boiler 'on' continuosly
08-12-2009				3												
09-12-2009				3												Three days without boiler.
10-12-2009				3												
11-12-2009				3			3:00		5:00	17:00	12:00	17:00	19:00	2:00		
12-12-2009				3												Five days with boiler 'on' continously
13-12-2009				3								11:45	0:30	12:45		
14-12-2009				3				6:47	0:30	6:50	6:20					
15-12-2009				3					7:00	11:30	4:30	7:00	11:30	4:30		
16-12-2009				3			20:00	0:00								no more biofuel, 4 hrs. con bmb
17-12-2009	15:30	4232.4	1302	3												
18-12-2009				3												
19-12-2009				3												
20-12-2009				2												
21-12-2009				1												rape seed oil pellets

DATE	TIME	MANUAL READING of THE ELECTRICITY METER	MANUAL READING of THE WATER METER	PERSONS AT HOME	DAYS	WConsump PER PERSON	BIOMASS BOILER USAGE, MANUAL READING TO DISAGGREGATE WATER FROM SPACE HEATING									OBSERVATIONS
	hr	kW-h	m^3	N°	N°	m^3	hr ON	hr OFF	hr CH ON	hr CH OFF	total hrs	hr WH ON	hr WH OFF	total hrs	kg pellets	
							JANUARY 2010 CHRISTMAS BRAKE (NOBODY AT HOME)									
03-01-2010	0.4	8058	3977	1			8:00	21:00				13				Return after Chrismas break. Imm. H 17:00 hrs
04-01-2010				1												Two weeks without BMB for heating. Water Heating (WH) with the Immersion Heater on for 2 hrs every day. Space Heating (SH) with electrical heaters every day.
05-01-2010				1												
06-01-2010				2												
07-01-2010	0.951	15810		3												
08-01-2010				4												
09-01-2010				3												
10-01-2010	0.59	17014		4												
11-01-2010				3												
12-01-2010	0.417	17692		3												
13-01-2010				3												
14-01-2010		18655		3												
15-01-2010				3												
16-01-2010				3												
17-01-2010	0.917	19962		3												
18-01-2010				3			18:00								80	Change of fuel type, from rape seed to
19-01-2010				3				11:00	14:51	17:00	2:09					wood pellets
20-01-2010				3			11:45		11:45	12:30	0:45	12:30	20:30	8:00		
21-01-2010	0.542	21517		3					13:00	20:30	7:30					
22-01-2010									0:30	9:00	8:30				80	
23-01-2010											0:00	12:00	14:05	2:05		
24-01-2010									12:00	13:00	1:00					
									16:41							
25-01-2010										8:30	8:11	8:30	14:45	6:15		
									20:30							
26-01-2010	0.646	23446		6			2:05		15:15	21:00	5:45	21:00			80	
27-01-2010									2:30	6:00	3:30		2:00	6:00		
28-01-2010									17:00							
29-01-2010												0:00	18:00	18:00		
30-01-2010									18:00							
31-01-2010										13:00	19:00				20	bmb on/off all day. Change of fuel type, from rape seed to wood pellets

DATE	TIME	MANUAL READING of THE ELECTRICITY METER	MANUAL READING of THE WATER METER	PERSONS AT HOME	DAYS	WConsump PER PERSON	BIOMASS BOILER USAGE, MANUAL READING TO DISAGGREGATE WATER FROM SPACE HEATING									OBSERVATIONS
	hr	kW-h	m^3	N°	N°	m^3	hr ON	hr OFF	hr CH ON	hr CH OFF	total hrs	hr WH ON	hr WH OFF	total hrs	kg pellets	
FEBRUARY 2010																wood pellets
01-02-2010	0.51	26636		3					12:30	22:45	**10:15**	22:45			60	bmb went off at night, lit at noon. Very smoky
02-02-2010									10:00		**20:45**		9:00	**10:15**		2
03-02-2010										6:45						3
									16:15	21:30	**5:15**					
04-02-2010																4
05-02-2010										9:00		1:00	7:00	**6:00**		5
06-02-2010	0.583	28863		3												6
07-02-2010									7:00	11:00	**4:00**	11:00				7
08-02-2010									11:00	13:30	**2:30**		7:45	**8:45**	80	8
									16:30	19:10	**2:40**	19:10	23:45	**4:35**		
09-02-2010									8:30	13:00	**4:30**					9
10-02-2010									21:50			20:50	21:50	**1:00**		10
11-02-2010										8:55	**11:05**					11
12-02-2010	0.688	32096		5					12:00	14:00	**2:00**	1:00	9:45	**8:45**		12
									19:40	23:45	**4:05**	23:45				
13-02-2010													8:45	**9:45**		13
14-02-2010												7:00	12:45	**5:45**	80	14
15-02-2010	0.646	33409		4					12:50	14:15	**1:25**					15
16-02-2010																16
17-02-2010									12:30			10:30	12:30	**2:00**		17
18-02-2010										8:30	**20:00**	8:30	20:30	**12:00**		18
									20:30							
19-02-2010										9:00	**12:30**					19
20-02-2010																20
21-02-2010																21
									14:30	16:30	**2:00**					
									20:00	22:45	**2:45**	22:45	23:50	**1:05**		
22-02-2010									9:15	15:50	**6:35**	7:30	8:15	**0:45**	80	22
23-02-2010									18:50	23:00	**4:10**	23:15				23
24-02-2010													2:00	**2:15**		24
25-02-2010									2:40							25
										11:35	**8:55**					
26-02-2010									12:00	13:45	**1:45**	9:00	13:45	**4:45**		26
27-02-2010									9:00	16:00	**7:00**	17:00	20:00	**3:00**		27
28-02-2010									1:50	10:20	**8:30**					bmb off for the season at 23:00
												18:50	23:00	**4:10**		

Appendix 6 BASF House data of 2009 and 2010 from the monitoring system

Energy consumption

Indoor climate

Nottingham weather.

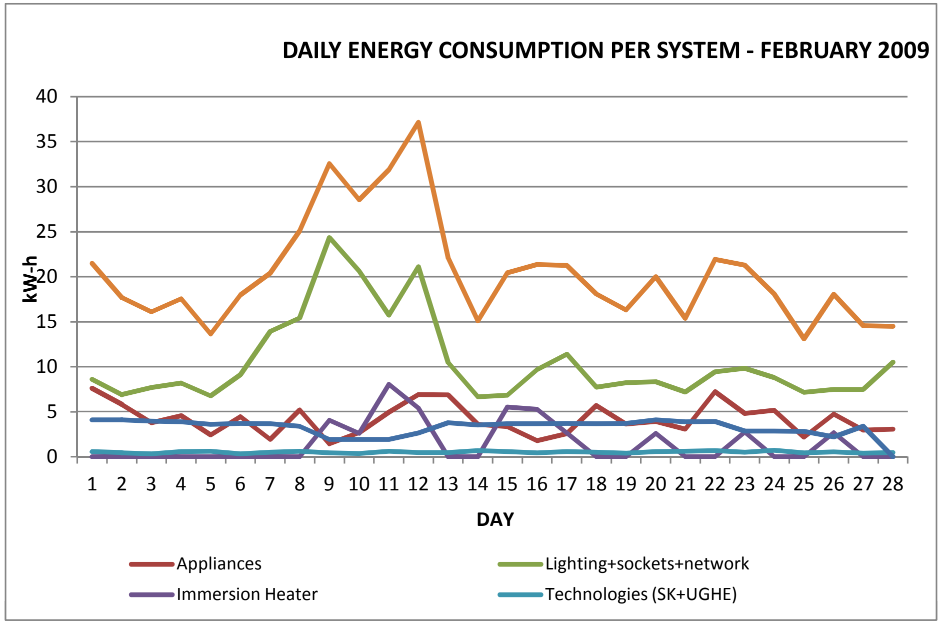
Power consumption comparison in three months in the BASF House, July, August and September of late summer and early spring of years 2009 and 2010

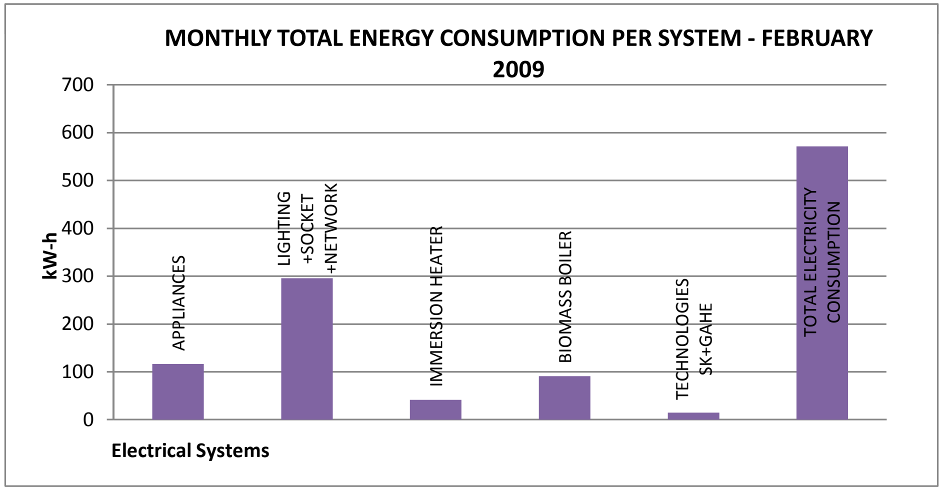
Month/ Year	2009		2010	
	Lighting/Sockets /Network	Month Total	Lighting/Sockets /Network	Month Total
	kW-h			
July	196.89	304.20	88.17	193.66
August	**301.75**	454.81	92.39	199.92
September	**296.26**	407.16	77.52	186.34

Numerical processed data from 2009-2010 of the BASF House organised by energy consumption, indoor climate and Nottingham weather

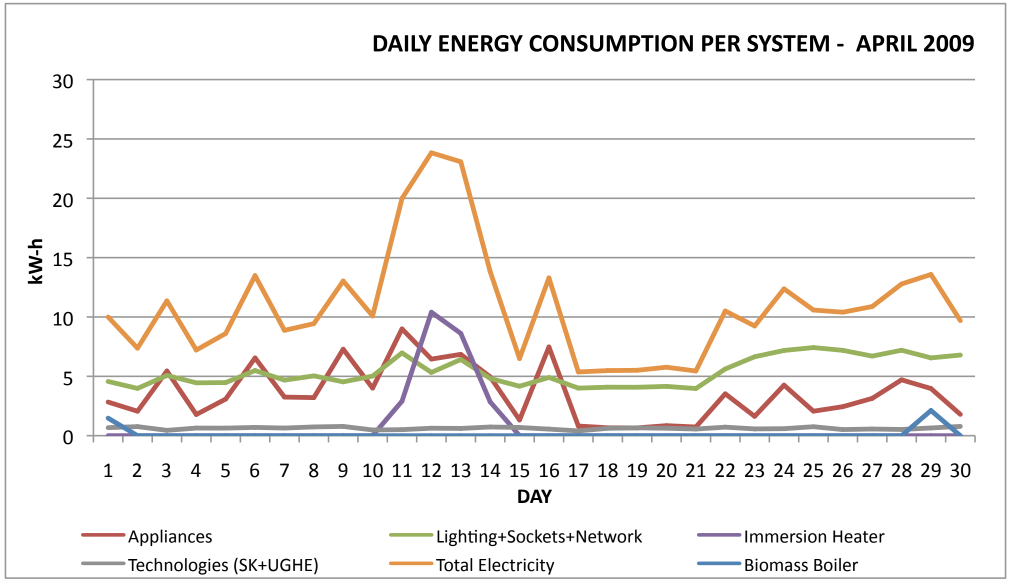
BASF HOUSE ELECTRICITY CONSUMPTION FROM ALL ELECTRICAL SYSTEMS FOR 2009

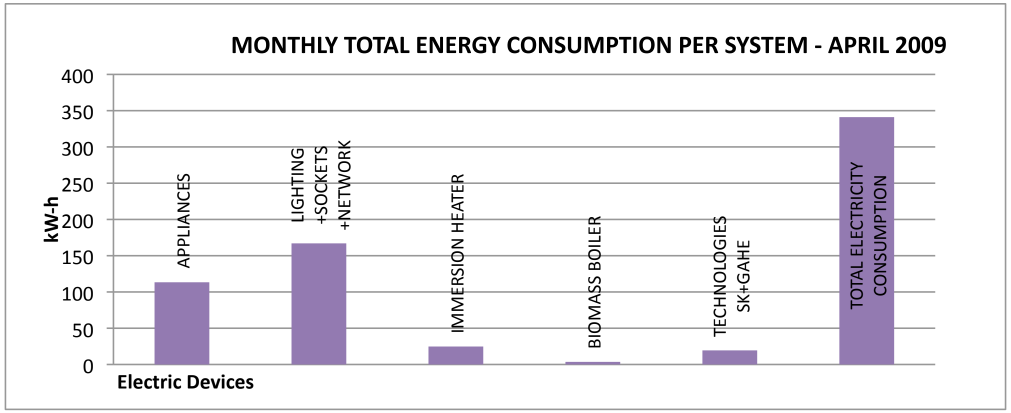
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
FEBRUARY			**kW-h**			
01/02/09	7,6	8,6	0,0	4,1	0,6	21,5
02/02/09	5,8	6,9	0,0	4,1	0,4	17,7
03/02/09	3,8	7,7	0,0	4,0	0,3	16,1
04/02/09	4,6	8,2	0,0	3,9	0,6	17,6
05/02/09	2,4	6,8	0,0	3,6	0,6	13,6
06/02/09	4,4	9,1	0,0	3,7	0,3	18,0
07/02/09	1,9	13,9	0,0	3,7	0,5	20,4
08/02/09	5,2	15,4	0,0	3,4	0,6	25,1
09/02/09	1,4	24,3	4,1	1,9	0,5	32,6
10/02/09	2,7	20,6	2,6	1,9	0,4	28,5
11/02/09	5,0	15,7	8,1	1,9	0,6	31,9
12/02/09	6,9	21,1	5,4	2,7	0,5	37,1
13/02/09	6,9	10,5	0,0	3,8	0,5	22,1
14/02/09	3,6	6,7	0,0	3,6	0,7	15,1
15/02/09	3,4	6,9	5,5	3,7	0,6	20,4
16/02/09	1,8	9,7	5,3	3,7	0,4	21,4
17/02/09	2,6	11,4	2,7	3,7	0,6	21,2
18/02/09	5,7	7,7	0,0	3,7	0,5	18,1
19/02/09	3,6	8,2	0,0	3,7	0,4	16,3
20/02/09	**3,9**	**8,3**	**2,6**	**4,1**	**0,6**	**20,0**
21/02/09	3,1	7,2	0,0	3,9	0,6	15,4
22/02/09	7,2	9,4	0,0	3,9	0,7	21,9
23/02/09	4,8	9,8	2,8	2,9	0,5	21,3
24/02/09	5,2	8,8	0,0	2,9	0,7	18,1
25/02/09	2,2	7,2	0,0	2,8	0,4	13,1
26/02/09	4,7	7,5	2,7	2,2	0,5	18,0
27/02/09	3,0	7,5	0,0	3,4	0,4	14,6
28/02/09	3,1	10,5	0,0	0,0	0,5	14,5
TOTAL	**116,6**	**295,7**	**41,7**	**90,8**	**14,7**	**571,6**



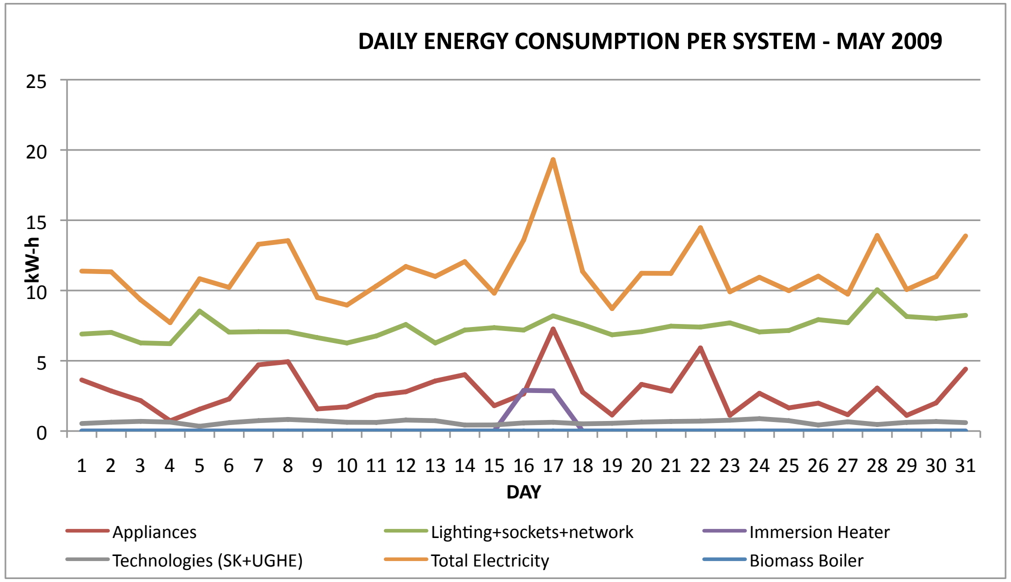


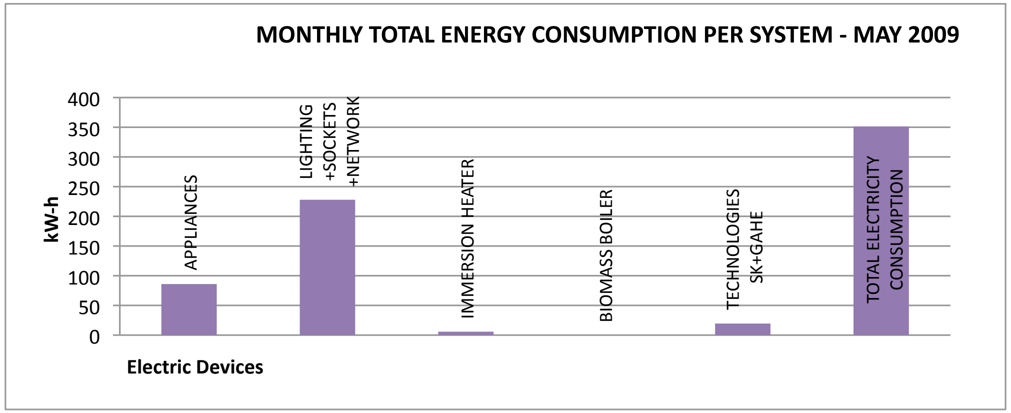
APRIL	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/04/09	2.8	4.6	0.0	1.5	0.7	10.0
02/04/09	2.1	4.0	0.0	0.0	0.8	7.4
03/04/09	**5.4**	**5.1**	**0.0**	**0.0**	**0.4**	**11.4**
04/04/09	1.8	4.5	0.0	0.0	0.6	7.2
05/04/09	3.1	4.5	0.0	0.0	0.6	8.6
06/04/09	6.6	5.5	0.0	0.0	0.7	13.5
07/04/09	3.3	4.7	0.0	0.0	0.6	8.9
08/04/09	3.2	5.0	0.0	0.0	0.7	9.4
09/04/09	7.3	4.5	0.0	0.0	0.8	13.0
10/04/09	4.0	5.0	0.0	0.0	0.5	10.1
11/04/09	9.0	7.0	2.9	0.0	0.5	20.0
12/04/09	6.5	5.3	10.4	0.0	0.6	23.8
13/04/09	6.9	6.4	8.6	0.0	0.6	23.1
14/04/09	5.0	4.8	2.9	0.0	0.7	13.8
15/04/09	1.3	4.2	0.0	0.0	0.7	6.5
16/04/09	7.5	4.9	0.0	0.0	0.6	13.3
17/04/09	0.8	4.0	0.0	0.0	0.4	5.4
18/04/09	0.7	4.1	0.0	0.0	0.6	5.5
19/04/09	0.7	4.1	0.0	0.0	0.7	5.5
20/04/09	0.8	4.2	0.0	0.0	0.6	5.8
21/04/09	0.7	4.0	0.0	0.0	0.6	5.4
22/04/09	3.5	5.6	0.0	0.0	0.7	10.5
23/04/09	1.6	6.6	0.0	0.0	0.6	9.2
24/04/09	4.3	7.2	0.0	0.0	0.6	12.4
25/04/09	2.1	7.4	0.0	0.0	0.8	10.6
26/04/09	2.4	7.2	0.0	0.0	0.5	10.4
27/04/09	3.1	6.7	0.0	0.0	0.6	10.9
28/04/09	4.7	7.2	0.0	0.0	0.5	12.8
29/04/09	4.0	6.6	0.0	2.1	0.7	13.6
30/04/09	1.8	6.8	0.0	0.0	0.8	9.7
TOTAL	**113.4**	**167.0**	**24.8**	**3.6**	**19.5**	**341.1**



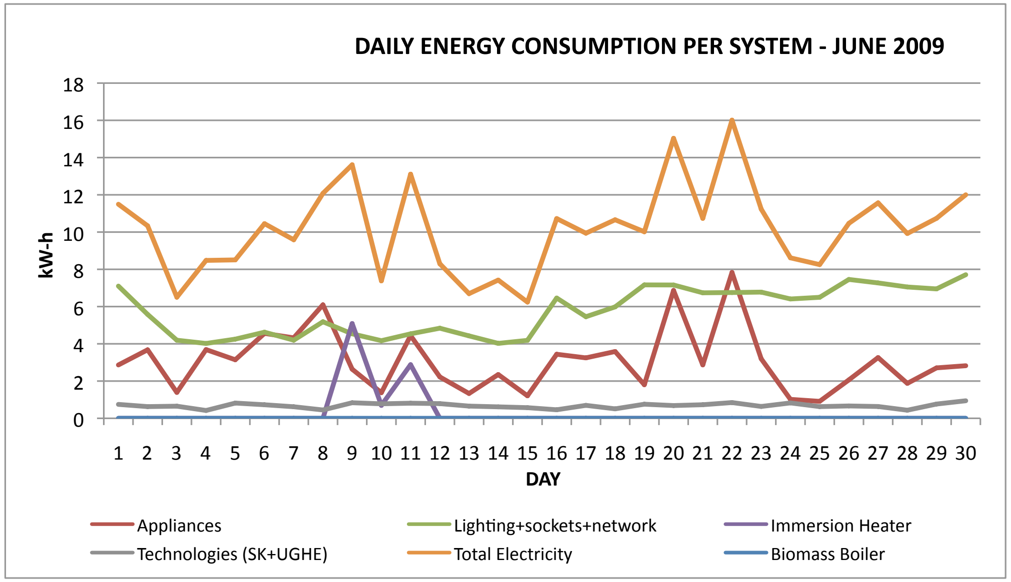


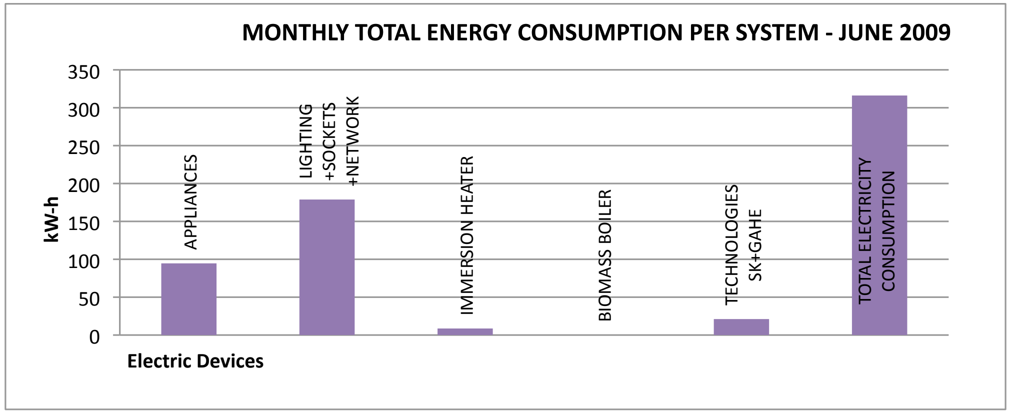
MAY	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/05/09	3.6	6.9	0.0	0.0	0.5	11.4
02/05/09	**2.9**	**7.0**	**0.0**	**0.0**	**0.6**	**11.3**
03/05/09	2.2	6.3	0.0	0.0	0.7	9.3
04/05/09	0.7	6.2	0.0	0.0	0.6	7.7
05/05/09	1.6	8.5	0.0	0.0	0.3	10.8
06/05/09	2.3	7.0	0.0	0.0	0.6	10.2
07/05/09	4.7	7.1	0.0	0.0	0.7	13.3
08/05/09	4.9	7.1	0.0	0.0	0.8	13.5
09/05/09	1.6	6.6	0.0	0.0	0.7	9.5
10/05/09	1.7	6.3	0.0	0.0	0.6	9.0
11/05/09	2.5	6.8	0.0	0.0	0.6	10.3
12/05/09	2.8	7.6	0.0	0.0	0.8	11.7
13/05/09	3.6	6.3	0.0	0.0	0.7	11.0
14/05/09	4.0	7.2	0.0	0.0	0.4	12.1
15/05/09	1.8	7.4	0.0	0.0	0.4	9.8
16/05/09	2.6	7.2	2.9	0.0	0.6	13.6
17/05/09	7.3	8.2	2.9	0.0	0.6	19.3
18/05/09	2.8	7.6	0.0	0.0	0.5	11.4
19/05/09	1.1	6.8	0.0	0.0	0.6	8.7
20/05/09	3.3	7.1	0.0	0.0	0.6	11.2
21/05/09	2.8	7.5	0.0	0.0	0.7	11.2
22/05/09	5.9	7.4	0.0	0.0	0.7	14.5
23/05/09	1.1	7.7	0.0	0.0	0.8	9.9
24/05/09	2.7	7.1	0.0	0.0	0.9	10.9
25/05/09	1.6	7.2	0.0	0.0	0.7	10.0
26/05/09	2.0	7.9	0.0	0.0	0.4	11.0
27/05/09	1.2	7.7	0.0	0.0	0.7	9.7
28/05/09	3.1	10.1	0.0	0.0	0.5	13.9
29/05/09	1.1	8.1	0.0	0.0	0.6	10.1
30/05/09	2.0	8.0	0.0	0.0	0.7	11.0
31/05/09	4.4	8.2	0.0	0.0	0.6	13.9
TOTAL	**86.0**	**227.9**	**5.8**	**0.0**	**19.5**	**351.3**



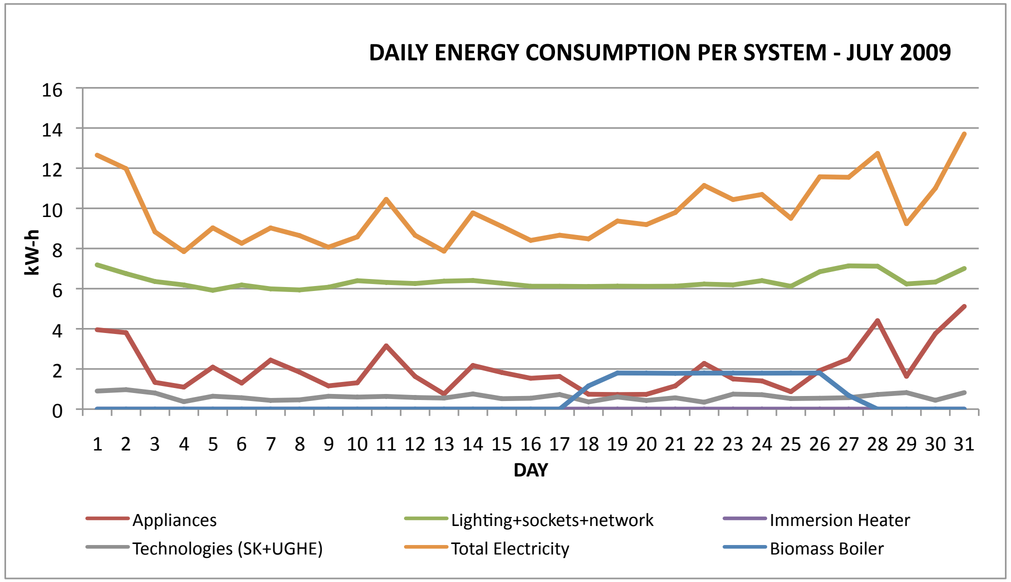


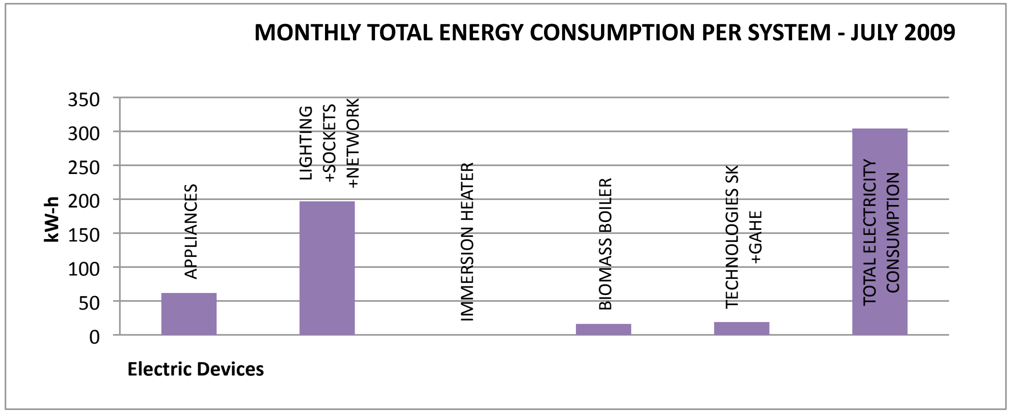
JUNE	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/06/09	2.9	7.1	0.0	0.0	0.7	11.5
02/06/09	3.7	5.6	0.0	0.0	0.6	10.3
03/06/09	1.4	4.2	0.0	0.0	0.7	6.5
04/06/09	3.7	4.0	0.0	0.0	0.4	8.5
05/06/09	3.1	4.3	0.0	0.0	0.8	8.5
06/06/09	4.6	4.6	0.0	0.0	0.7	10.5
07/06/09	4.3	4.2	0.0	0.0	0.6	9.6
08/06/09	6.1	5.2	0.0	0.0	0.4	12.1
09/06/09	2.6	4.5	5.1	0.0	0.8	13.6
10/06/09	1.4	4.2	0.7	0.0	0.8	7.4
11/06/09	4.4	4.5	2.9	0.0	0.8	13.1
12/06/09	2.2	4.8	0.0	0.0	0.8	8.3
13/06/09	1.3	4.4	0.0	0.0	0.7	6.7
14/06/09	2.4	4.0	0.0	0.0	0.6	7.4
15/06/09	1.2	4.2	0.0	0.0	0.6	6.2
16/06/09	3.4	6.5	0.0	0.0	0.5	10.7
17/06/09	3.2	5.5	0.0	0.0	0.7	9.9
18/06/09	3.6	6.0	0.0	0.0	0.5	10.7
19/06/09	1.8	7.2	0.0	0.0	0.8	10.0
20/06/09	6.9	7.2	0.0	0.0	0.7	15.0
21/06/09	2.9	6.7	0.0	0.0	0.7	10.7
22/06/09	7.8	6.8	0.0	0.0	0.8	16.0
23/06/09	3.2	6.8	0.0	0.0	0.6	11.2
24/06/09	1.0	6.4	0.0	0.0	0.8	8.6
25/06/09	0.9	6.5	0.0	0.0	0.6	8.3
26/06/09	**2.1**	**7.5**	**0.0**	**0.0**	**0.7**	**10.5**
27/06/09	3.3	7.3	0.0	0.0	0.6	11.6
28/06/09	1.9	7.1	0.0	0.0	0.4	9.9
29/06/09	2.7	6.9	0.0	0.0	0.8	10.7
30/06/09	2.8	7.7	0.0	0.0	0.9	12.0
TOTAL	**94.6**	**178.9**	**8.7**	**0.0**	**21.1**	**316.1**



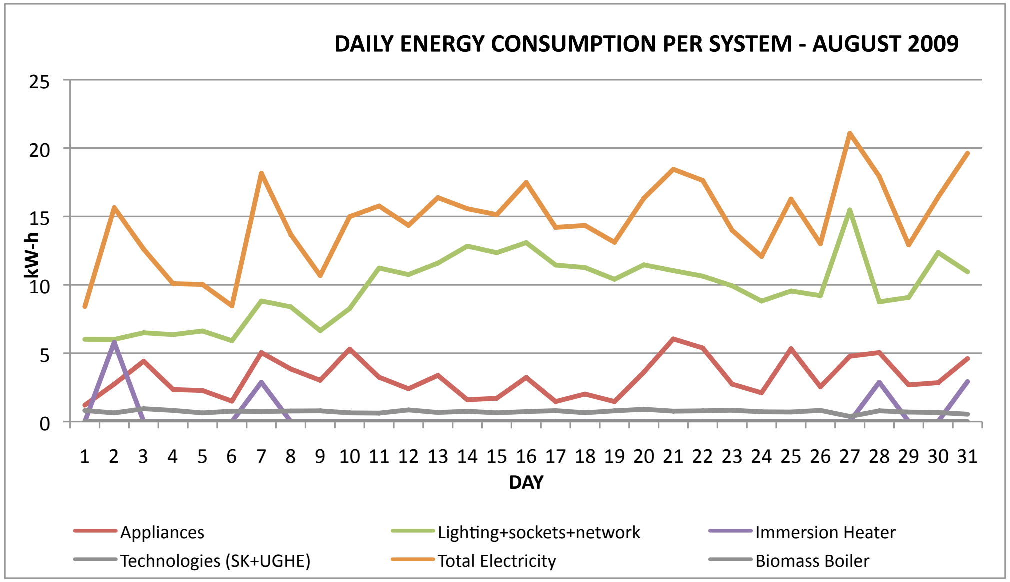


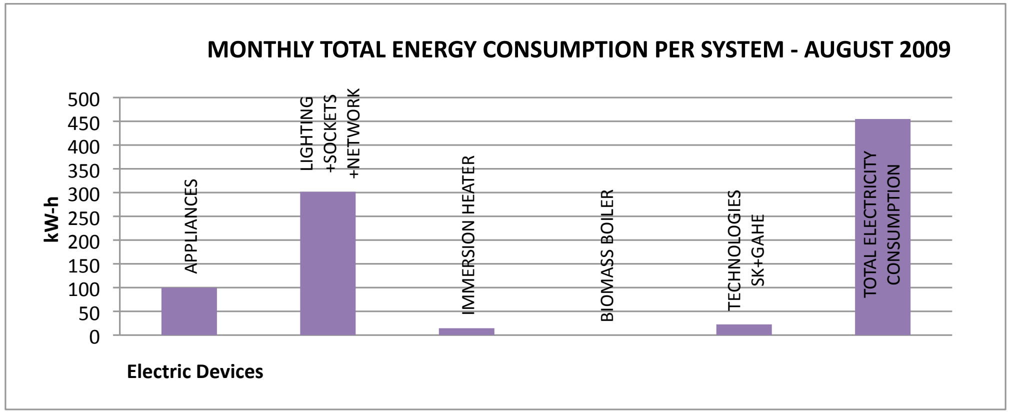
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
JULY			**kW-h**			
01/07/09	4.0	7.2	0.0	0.0	0.9	12.6
02/07/09	3.8	6.7	0.0	0.0	1.0	12.0
03/07/09	1.3	6.4	0.0	0.0	0.8	8.8
04/07/09	1.1	6.2	0.0	0.0	0.4	7.8
05/07/09	2.1	5.9	0.0	0.0	0.6	9.0
06/07/09	1.3	6.2	0.0	0.0	0.6	8.3
07/07/09	2.4	6.0	0.0	0.0	0.4	9.0
08/07/09	1.8	5.9	0.0	0.0	0.5	8.6
09/07/09	1.2	6.1	0.0	0.0	0.6	8.1
10/07/09	1.3	6.4	0.0	0.0	0.6	8.6
11/07/09	3.2	6.3	0.0	0.0	0.6	10.4
12/07/09	1.6	6.3	0.0	0.0	0.6	8.7
13/07/09	0.8	6.4	0.0	0.0	0.6	7.9
14/07/09	2.2	6.4	0.0	0.0	0.8	9.8
15/07/09	1.8	6.3	0.0	0.0	0.5	9.1
16/07/09	1.5	6.1	0.0	0.0	0.5	8.4
17/07/09	1.6	6.1	0.0	0.0	0.7	8.7
18/07/09	0.7	6.1	0.0	1.2	0.4	8.5
19/07/09	0.7	6.1	0.0	1.8	0.6	9.4
20/07/09	0.7	6.1	0.0	1.8	0.4	9.2
21/07/09	**1.2**	**6.1**	**0.0**	**1.8**	**0.6**	**9.8**
22/07/09	2.3	6.2	0.0	1.8	0.3	11.1
23/07/09	1.5	6.2	0.0	1.8	0.7	10.4
24/07/09	1.4	6.4	0.0	1.8	0.7	10.7
25/07/09	0.9	6.1	0.0	1.8	0.5	9.5
26/07/09	1.9	6.8	0.0	1.8	0.5	11.6
27/07/09	2.5	7.1	0.0	0.7	0.6	11.5
28/07/09	4.4	7.1	0.0	0.0	0.7	12.7
29/07/09	1.6	6.2	0.0	0.0	0.8	9.2
30/07/09	3.8	6.3	0.0	0.0	0.4	11.0
31/07/09	5.1	7.0	0.0	0.0	0.8	13.7
TOTAL	**61.8**	**196.9**	**0.0**	**16.2**	**18.9**	**304.2**



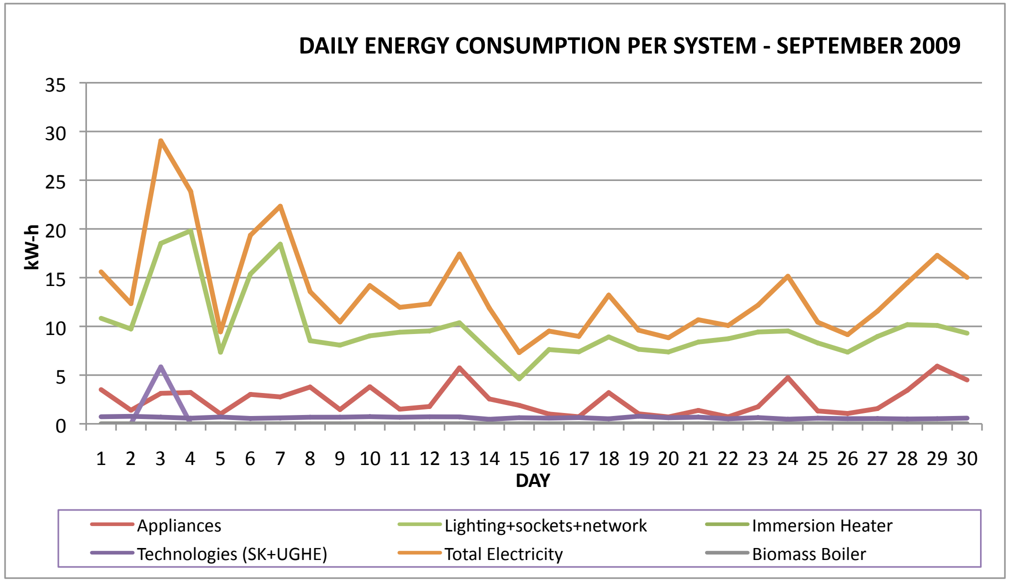


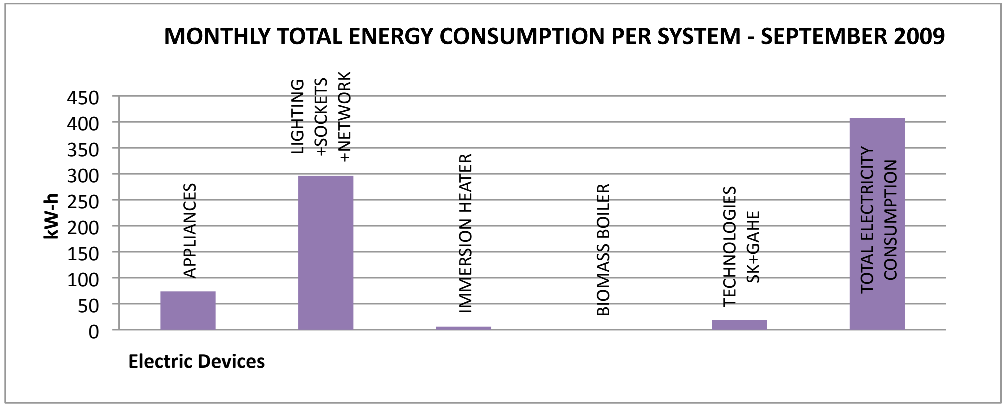
AUGUST	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/08/09	1.2	6.0	0.0	0.0	0.8	8.4
02/08/09	2.7	6.0	5.8	0.0	0.6	15.6
03/08/09	4.4	6.5	0.0	0.0	0.9	12.6
04/08/09	2.3	6.4	0.0	0.0	0.8	10.1
05/08/09	2.3	6.6	0.0	0.0	0.6	10.0
06/08/09	1.5	5.9	0.0	0.0	0.8	8.5
07/08/09	5.0	8.8	2.9	0.0	0.7	18.2
08/08/09	3.8	8.4	0.0	0.0	0.8	13.7
09/08/09	3.0	6.6	0.0	0.0	0.8	10.7
10/08/09	**5.3**	**8.3**	**0.0**	**0.0**	**0.6**	**15.0**
11/08/09	3.2	11.2	0.0	0.0	0.6	15.8
12/08/09	2.4	10.8	0.0	0.0	0.9	14.4
13/08/09	3.4	11.6	0.0	0.0	0.7	16.4
14/08/09	1.6	12.8	0.0	0.0	0.8	15.6
15/08/09	1.7	12.4	0.0	0.0	0.6	15.1
16/08/09	3.2	13.1	0.0	0.0	0.7	17.5
17/08/09	1.5	11.4	0.0	0.0	0.8	14.2
18/08/09	2.0	11.3	0.0	0.0	0.6	14.3
19/08/09	1.5	10.4	0.0	0.0	0.8	13.1
20/08/09	3.6	11.5	0.0	0.0	0.9	16.3
21/08/09	6.0	11.0	0.0	0.0	0.8	18.5
22/08/09	5.4	10.6	0.0	0.0	0.8	17.6
23/08/09	2.7	9.9	0.0	0.0	0.8	14.0
24/08/09	2.1	8.8	0.0	0.0	0.7	12.1
25/08/09	5.3	9.5	0.0	0.0	0.7	16.3
26/08/09	2.5	9.2	0.0	0.0	0.8	13.0
27/08/09	4.8	15.5	0.0	0.0	0.4	21.1
28/08/09	5.0	8.8	2.9	0.0	0.8	17.9
29/08/09	2.7	9.1	0.0	0.0	0.7	12.9
30/08/09	2.8	12.4	0.0	0.0	0.7	16.4
31/08/09	4.6	11.0	2.9	0.0	0.5	19.6
TOTAL	**99.9**	**301.7**	**14.5**	**0.0**	**22.6**	**454.8**



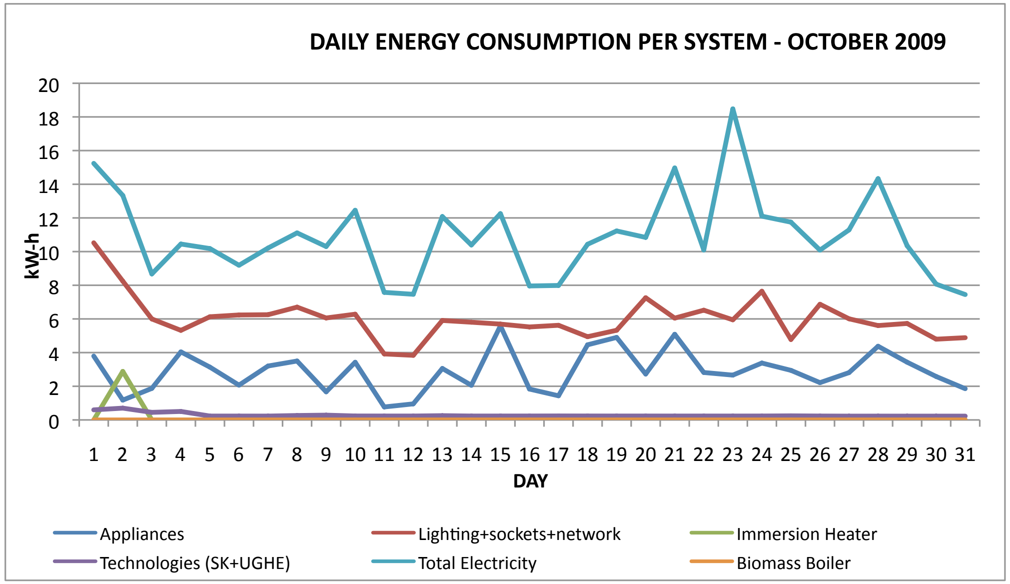


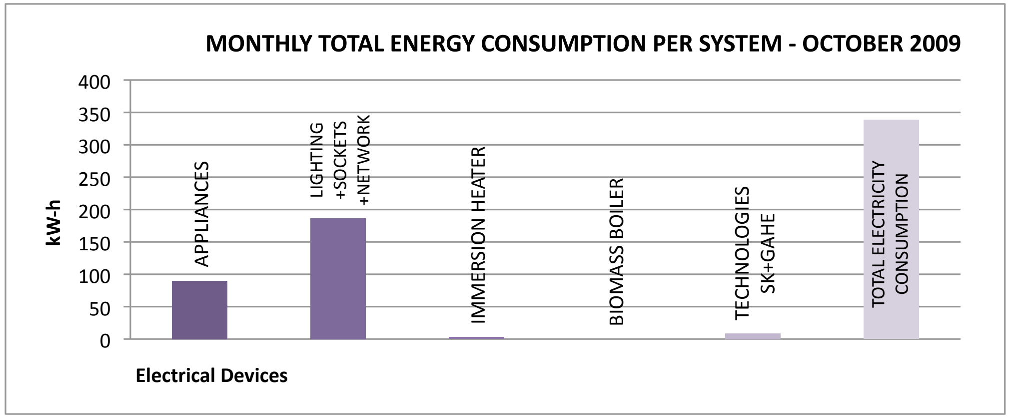
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
SEPTEMBER			**kW-h**			
01/09/09	3.5	10.8	0.0	0.0	0.7	15.6
02/09/09	1.4	9.7	0.0	0.0	0.8	12.3
03/09/09	3.1	18.5	5.8	0.0	0.7	29.0
04/09/09	3.2	19.8	0.0	0.0	0.6	23.9
05/09/09	1.0	7.3	0.0	0.0	0.7	9.4
06/09/09	3.0	15.4	0.0	0.0	0.6	19.3
07/09/09	2.8	18.4	0.0	0.0	0.6	22.3
08/09/09	3.8	8.5	0.0	0.0	0.7	13.6
09/09/09	1.5	8.1	0.0	0.0	0.7	10.4
10/09/09	3.8	9.0	0.0	0.0	0.7	14.2
11/09/09	1.5	9.4	0.0	0.0	0.7	12.0
12/09/09	1.8	9.5	0.0	0.0	0.7	12.3
13/09/09	5.7	10.4	0.0	0.0	0.7	17.4
14/09/09	2.6	7.5	0.0	0.0	0.5	11.9
15/09/09	1.9	4.6	0.0	0.0	0.6	7.3
16/09/09	1.0	7.6	0.0	0.0	0.6	9.5
17/09/09	0.7	7.4	0.0	0.0	0.6	9.0
18/09/09	3.2	8.9	0.0	0.0	0.5	13.2
19/09/09	1.0	7.6	0.0	0.0	0.8	9.6
20/09/09	0.7	7.4	0.0	0.0	0.6	8.8
21/09/09	1.4	8.4	0.0	0.0	0.7	10.7
22/09/09	0.7	8.7	0.0	0.0	0.5	10.1
23/09/09	1.8	9.4	0.0	0.0	0.6	12.2
24/09/09	4.7	9.5	0.0	0.0	0.5	15.1
25/09/09	1.3	8.3	0.0	0.0	0.6	10.4
26/09/09	1.1	7.4	0.0	0.0	0.5	9.1
27/09/09	1.6	9.0	0.0	0.0	0.5	11.6
28/09/09	3.4	10.2	0.0	0.0	0.5	14.5
29/09/09	5.9	10.1	0.0	0.0	0.5	17.3
30/09/09	4.5	9.3	0.0	0.0	0.6	15.0
TOTAL	**73.6**	**296.3**	**5.8**	**0.0**	**18.6**	**407.2**



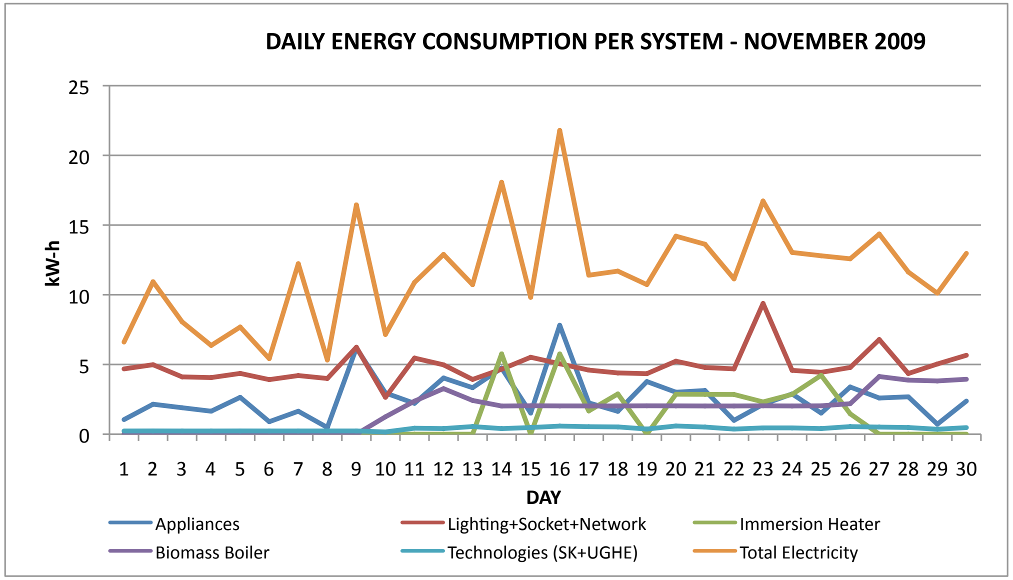


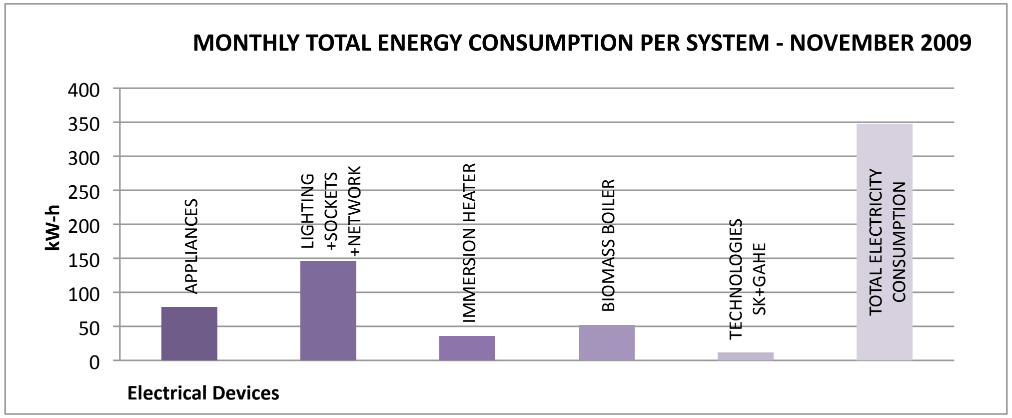
OCTOBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/10/09	3.8	10.5	0.0	0.0	0.6	15.2
02/10/09	1.2	8.2	2.9	0.0	0.7	13.3
03/10/09	1.9	6.0	0.0	0.0	0.5	8.7
04/10/09	4.0	5.3	0.0	0.0	0.5	10.4
05/10/09	3.1	6.1	0.0	0.0	0.2	10.2
06/10/09	2.1	6.2	0.0	0.0	0.2	9.2
07/10/09	3.2	6.3	0.0	0.0	0.2	10.2
08/10/09	3.5	6.7	0.0	0.0	0.3	11.1
09/10/09	1.7	6.1	0.0	0.0	0.3	10.3
10/10/09	3.4	6.3	0.0	0.0	0.2	12.5
11/10/09	0.8	3.9	0.0	0.0	0.2	7.6
12/10/09	1.0	3.8	0.0	0.0	0.2	7.5
13/10/09	3.1	5.9	0.0	0.0	0.3	12.1
14/10/09	2.1	5.8	0.0	0.0	0.2	10.4
15/10/09	5.6	5.7	0.0	0.0	0.2	12.3
16/10/09	1.8	5.5	0.0	0.0	0.2	8.0
17/10/09	1.4	5.6	0.0	0.0	0.2	8.0
18/10/09	4.5	4.9	0.0	0.0	0.2	10.4
19/10/09	4.9	5.3	0.0	0.0	0.2	11.2
20/10/09	**2.7**	**7.3**	**0.0**	**0.0**	**0.2**	**10.8**
21/10/09	5.1	6.0	0.0	0.0	0.2	15.0
22/10/09	2.8	6.5	0.0	0.0	0.2	10.1
23/10/09	2.7	5.9	0.0	0.0	0.2	18.5
24/10/09	3.4	7.6	0.0	0.0	0.2	12.1
25/10/09	2.9	4.8	0.0	0.0	0.2	11.7
26/10/09	2.2	6.9	0.0	0.0	0.2	10.1
27/10/09	2.8	6.0	0.0	0.0	0.2	11.3
28/10/09	4.4	5.6	0.0	0.0	0.2	14.3
29/10/09	3.4	5.7	0.0	0.0	0.2	10.4
30/10/09	2.6	4.8	0.0	0.0	0.2	8.1
31/10/09	1.9	4.9	0.0	0.0	0.2	7.4
TOTAL	**89.8**	**186.4**	**2.9**	**0.0**	**8.6**	**338.3**



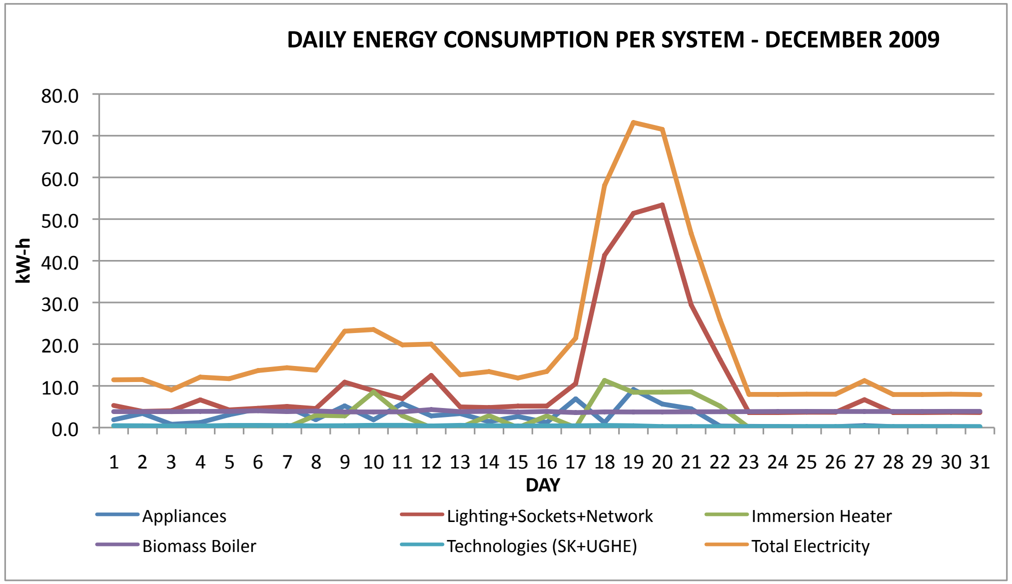


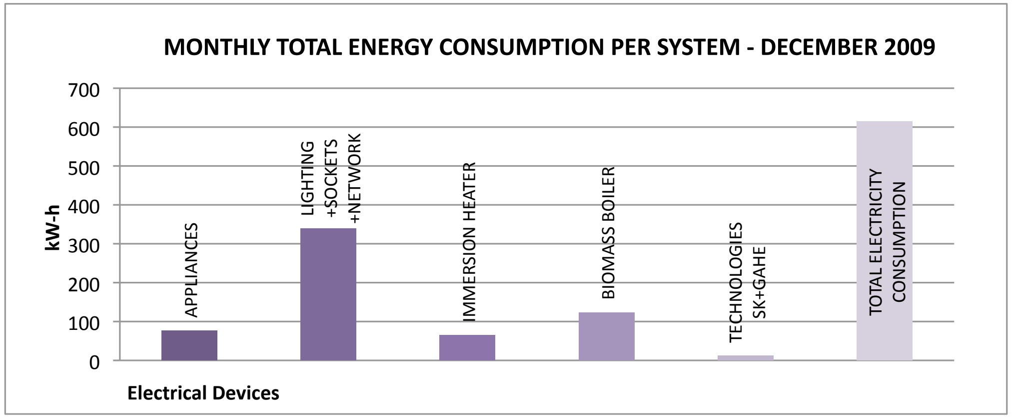
NOVEMBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/11/09	1.0	4.7	0.0	0.0	0.2	6.6
02/11/09	2.1	5.0	0.0	0.0	0.2	10.9
03/11/09	1.9	4.1	0.0	0.0	0.2	8.1
04/11/09	1.6	4.1	0.0	0.0	0.2	6.4
05/11/09	2.6	4.4	0.0	0.0	0.2	7.7
06/11/09	0.9	3.9	0.0	0.0	0.2	5.4
07/11/09	1.6	4.2	0.0	0.0	0.2	12.2
08/11/09	0.5	4.0	0.0	0.0	0.2	5.3
09/11/09	6.2	6.2	0.0	0.0	0.2	16.4
10/11/09	3.0	2.6	0.0	1.2	0.2	7.2
11/11/09	2.2	5.5	0.0	2.4	0.4	10.9
12/11/09	4.0	5.0	0.0	3.3	0.4	12.9
13/11/09	3.3	3.9	0.0	2.4	0.5	10.7
14/11/09	4.7	4.7	5.8	2.0	0.4	18.1
15/11/09	1.5	5.5	0.0	2.0	0.5	9.8
16/11/09	7.8	5.1	5.8	2.0	0.6	21.8
17/11/09	2.2	4.6	1.7	2.0	0.5	11.4
18/11/09	1.6	4.4	2.9	2.0	0.5	11.7
19/11/09	3.8	4.3	0.0	2.0	0.4	10.7
20/11/09	3.0	5.2	2.9	2.0	0.6	14.2
21/11/09	3.1	4.8	2.9	2.0	0.5	13.6
22/11/09	1.0	4.7	2.8	2.0	0.4	11.1
23/11/09	2.1	9.4	2.3	2.0	0.5	16.7
24/11/09	2.9	4.6	2.9	2.0	0.5	13.0
25/11/09	1.5	4.4	4.2	2.0	0.4	12.8
26/11/09	3.4	4.8	1.5	2.2	0.5	12.6
27/11/09	2.6	6.8	0.0	4.1	0.5	14.4
28/11/09	**2.7**	**4.4**	**0.0**	**3.9**	**0.5**	**11.6**
29/11/09	0.7	5.0	0.0	3.8	0.4	10.1
30/11/09	2.4	5.7	0.0	3.9	0.5	13.0
TOTAL	**78.2**	**145.8**	**35.5**	**51.6**	**11.6**	**347.4**





DECEMBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
01/12/09	1.9	5.3	0.0	3.8	0.5	11.5
02/12/09	3.4	3.9	0.0	3.8	0.4	11.5
03/12/09	0.8	4.0	0.0	3.8	0.4	9.0
04/12/09	1.2	6.6	0.0	3.9	0.4	12.1
05/12/09	3.1	4.2	0.0	3.9	0.5	11.7
06/12/09	4.5	4.6	0.0	4.0	0.5	13.7
07/12/09	5.0	5.1	0.0	3.8	0.5	14.4
08/12/09	1.9	4.6	2.9	4.0	0.4	13.8
09/12/09	5.2	10.9	2.8	3.8	0.5	23.1
10/12/09	1.9	8.8	8.5	3.8	0.5	23.5
11/12/09	5.8	6.9	2.8	3.8	0.5	19.8
12/12/09	2.8	12.5	0.0	4.3	0.4	20.0
13/12/09	3.3	5.0	0.0	3.8	0.5	12.7
14/12/09	1.4	4.8	2.9	3.9	0.4	13.4
15/12/09	2.7	5.1	0.0	3.7	0.4	11.9
16/12/09	1.2	5.2	2.8	3.9	0.4	13.5
17/12/09	6.9	10.5	0.0	3.6	0.4	21.5
18/12/09	1.2	41.3	11.3	3.8	0.5	58.1
19/12/09	9.1	51.4	8.5	3.7	0.4	73.2
20/12/09	5.6	53.4	8.5	3.8	0.2	71.5
21/12/09	4.5	29.4	8.6	3.8	0.2	46.5
22/12/09	0.4	16.3	5.1	3.8	0.2	25.9
23/12/09	0.3	3.6	0.0	3.8	0.2	8.0
24/12/09	0.3	3.6	0.0	3.9	0.2	7.9
25/12/09	0.2	3.7	0.0	3.9	0.2	8.0
26/12/09	0.2	3.7	0.0	3.9	0.2	8.0
27/12/09	0.5	6.7	0.0	3.9	0.2	11.3
28/12/09	0.2	3.6	0.0	3.9	0.2	7.9
29/12/09	0.2	3.6	0.0	3.9	0.2	7.9
30/12/09	0.2	3.7	0.0	3.9	0.2	8.0
31/12/09	0.2	3.6	0.0	3.9	0.2	7.9
TOTAL	**76.2**	**339.3**	**64.7**	**123.1**	**11.7**	**615.0**





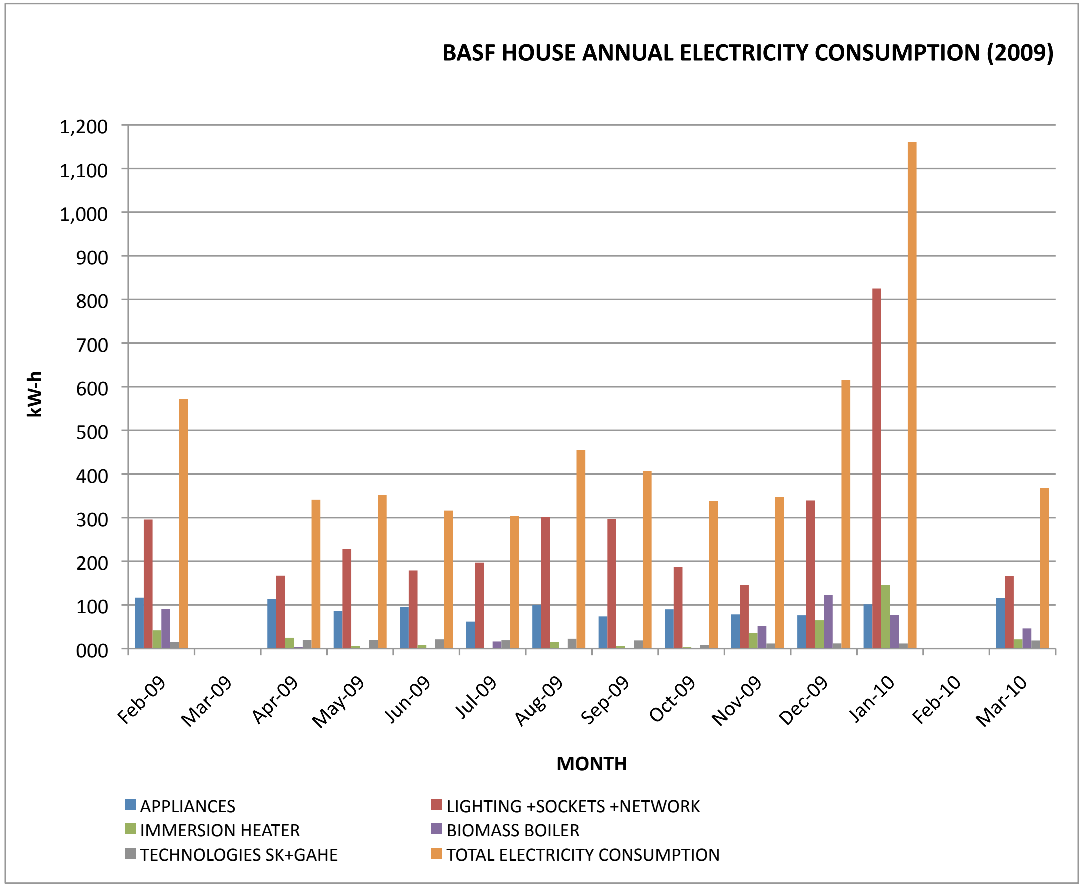
SAMPLE OF BASF HOUSE ANNUAL PERIOD OF ELECTRICITY CONSUMPTION

	APPLIANCES	LIGHTING +SOCKETS +NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
2009-10			**kW-h**			
Jan-10	101.2	825.0	145.3	77.0	11.6	1160.2
Feb-09	116.6	295.7	41.7	90.8	14.7	571.6
Mar-10	115.6	166.7	21.1	46.1	18.5	368.0
Apr-09	113.4	167.0	24.8	3.6	19.5	341.1
May-09	86.0	227.9	5.8	0.0	19.5	351.3
Jun-09	94.6	178.9	8.7	0.0	21.1	316.1
Jul-09	61.8	196.9	0.0	16.2	18.9	304.2
Aug-09	99.9	301.7	14.5	0.0	22.6	454.8
Sep-09	73.6	296.3	5.8	0.0	18.6	407.2
Oct-09	89.8	186.4	2.9	0.0	8.6	338.3
Nov-09	78.2	145.8	35.5	51.6	11.6	347.4
Dec-09	76.2	339.3	64.7	123.1	11.7	615.0
TOTALS	**1106.9**	**3327.6**	**370.8**	**408.4**	**196.8**	**5575.2**

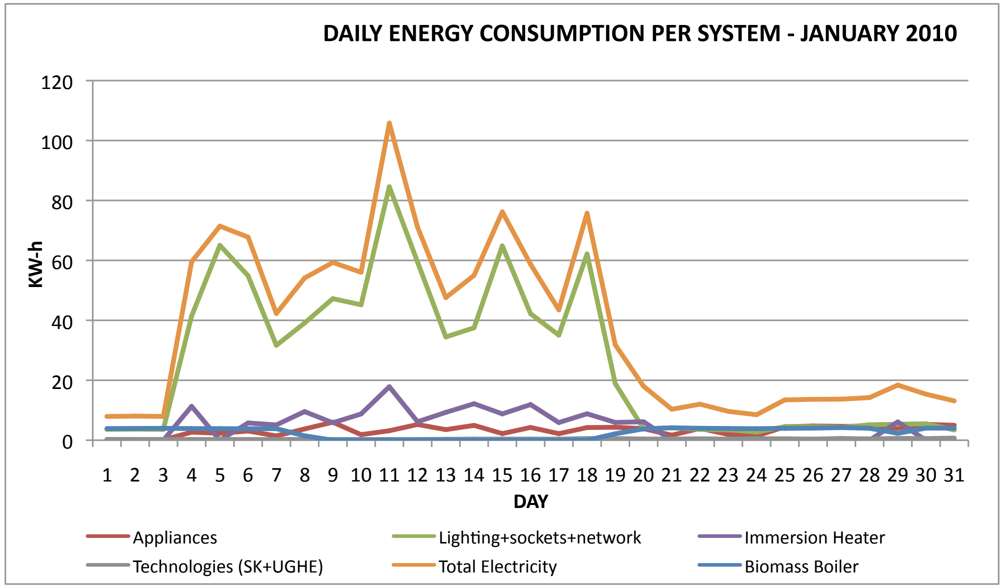
12-MONTHS PERIOD TOTAL ELECTRICITY CONSUMPTION

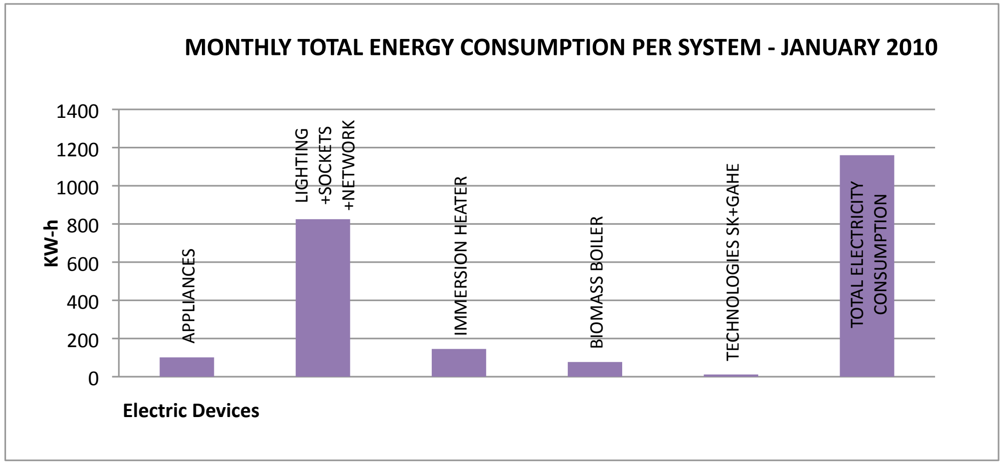
5,575.3 kW-hr/year

The data from January and March 2009 was missing, therefore to calculate the annual electricity consumption for year 2009, for those two months the data from 2010 was used in place of the missing data.

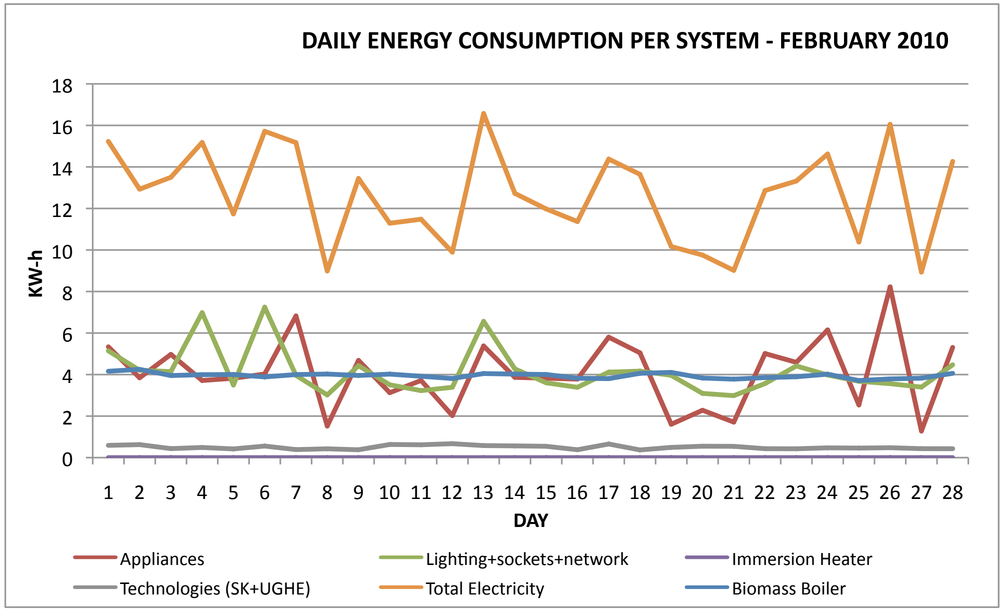


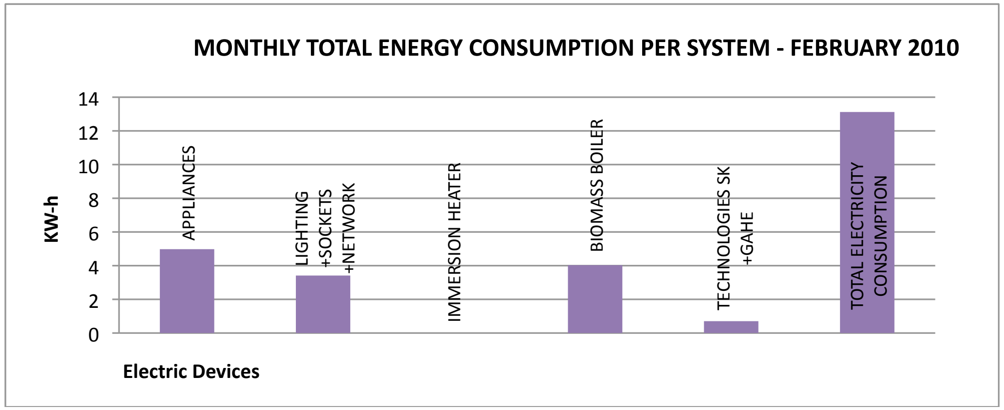
JANUARY	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/1/10	0.19	3.60	0.00	3.89	0.24	7.93
2/1/10	0.19	3.69	0.00	3.92	0.24	8.04
3/1/10	0.12	3.61	0.00	3.96	0.24	7.94
4/1/10	2.68	41.42	11.31	3.88	0.24	59.53
5/1/10	2.30	65.03	0.00	3.86	0.24	71.43
6/1/10	3.06	54.87	5.76	3.83	0.24	67.76
7/1/10	1.43	31.67	5.10	3.85	0.24	42.29
8/1/10	3.76	39.11	9.55	1.47	0.24	54.13
9/1/10	6.01	47.24	5.81	0.00	0.24	59.30
10/1/10	1.85	45.18	8.76	0.00	0.25	56.04
11/1/10	3.17	84.57	17.84	0.00	0.24	105.81
12/1/10	5.24	59.43	6.16	0.00	0.24	71.06
13/1/10	3.53	34.45	9.29	0.00	0.31	47.58
14/1/10	4.95	37.52	12.18	0.00	0.36	55.02
15/1/10	2.20	64.85	8.78	0.00	0.37	76.20
16/1/10	4.25	42.20	11.89	0.00	0.37	58.71
17/1/10	2.19	35.07	5.89	0.00	0.36	43.51
18/1/10	4.21	62.14	8.83	0.00	0.56	75.75
19/1/10	**4.33**	**18.88**	**5.93**	**2.14**	**0.53**	**31.82**
20/1/10	3.85	3.79	6.16	3.79	0.40	17.99
21/1/10	1.68	4.14	0.00	4.15	0.37	10.34
22/1/10	3.94	3.62	0.00	3.98	0.49	12.02
23/1/10	1.91	3.45	0.00	3.90	0.36	9.62
24/1/10	1.42	2.73	0.00	3.85	0.51	8.50
25/1/10	4.47	4.53	0.00	3.96	0.48	13.44
26/1/10	4.75	4.52	0.00	4.02	0.36	13.65
27/1/10	4.62	4.28	0.00	4.20	0.59	13.70
28/1/10	4.65	5.15	0.00	3.98	0.43	14.22
29/1/10	4.03	5.34	6.11	2.30	0.61	18.39
30/1/10	5.30	5.49	0.00	4.04	0.54	15.36
31/1/10	4.98	3.41	0.00	4.03	0.70	13.12
TOTAL	**101.25**	**825.00**	**145.34**	**76.99**	**11.61**	**1160.19**



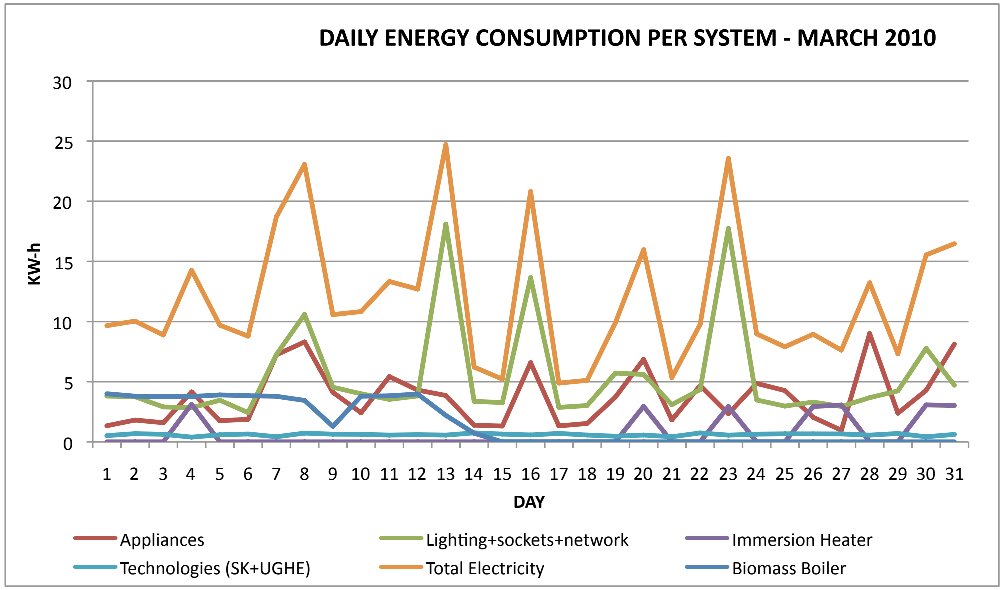


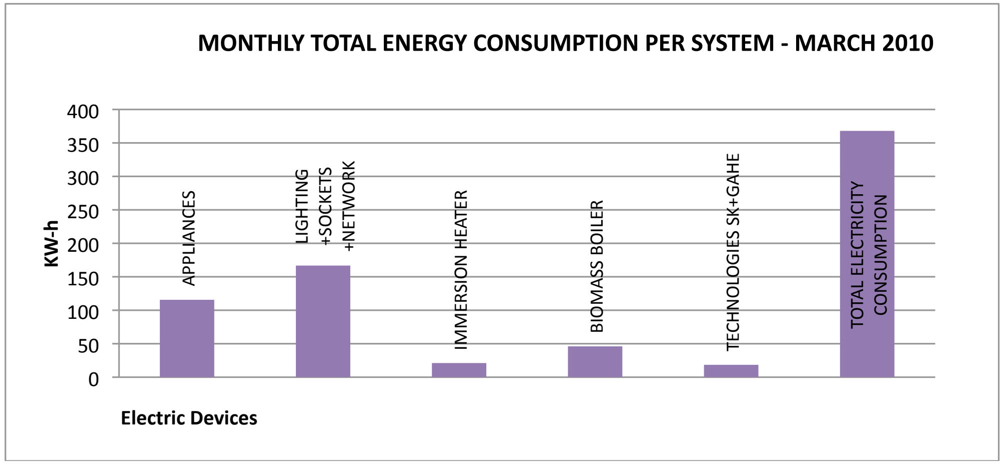
FEBRUARY	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/2/10	5.34	5.14	0.00	4.16	0.59	15.23
2/2/10	3.84	4.21	0.00	4.25	0.63	12.93
3/2/10	4.97	4.14	0.00	3.95	0.43	13.50
4/2/10	3.71	6.98	0.00	3.99	0.49	15.18
5/2/10	3.82	3.50	0.00	4.00	0.42	11.74
6/2/10	4.03	7.25	0.00	3.89	0.56	15.72
7/2/10	6.82	3.96	0.00	4.00	0.39	15.17
8/2/10	1.52	3.02	0.00	4.03	0.43	8.99
9/2/10	4.68	4.43	0.00	3.96	0.38	13.44
10/2/10	3.13	3.51	0.00	4.02	0.63	11.29
11/2/10	3.72	3.23	0.00	3.92	0.62	11.48
12/2/10	2.03	3.39	0.00	3.81	0.67	9.89
13/2/10	5.38	6.57	0.00	4.05	0.58	16.57
14/2/10	**3.86**	**4.27**	**0.00**	**4.02**	**0.57**	**12.73**
15/2/10	3.82	3.60	0.00	4.00	0.55	11.98
16/2/10	3.78	3.39	0.00	3.83	0.38	11.37
17/2/10	5.80	4.12	0.00	3.80	0.66	14.38
18/2/10	5.05	4.17	0.00	4.06	0.37	13.64
19/2/10	1.61	3.96	0.00	4.11	0.49	10.17
20/2/10	2.28	3.09	0.00	3.83	0.55	9.76
21/2/10	1.71	2.98	0.00	3.78	0.54	9.02
22/2/10	5.01	3.57	0.00	3.85	0.43	12.86
23/2/10	4.59	4.41	0.00	3.89	0.43	13.32
24/2/10	6.15	3.98	0.00	4.02	0.47	14.62
25/2/10	2.54	3.68	0.00	3.71	0.46	10.39
26/2/10	8.22	3.56	0.00	3.79	0.48	16.05
27/2/10	1.28	3.40	0.00	3.83	0.43	8.94
28/2/10	5.31	4.47	0.00	4.06	0.43	14.27
TOTAL	**114.01**	**115.96**	**0.00**	**110.62**	**14.03**	**354.61**



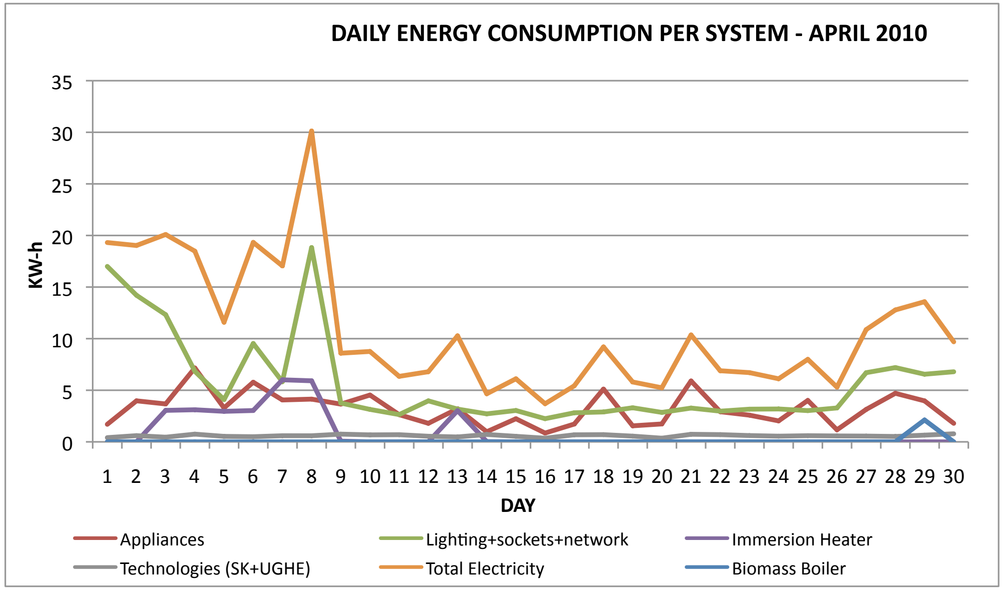


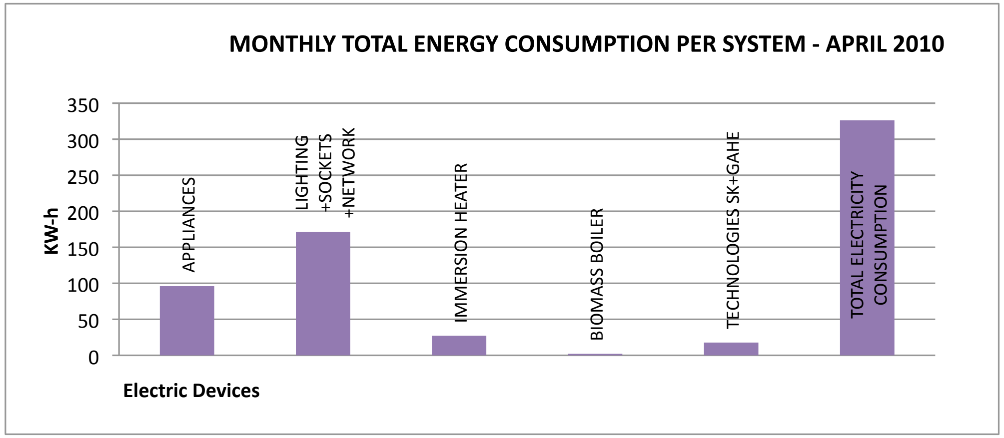
MARCH	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/3/10	1.34	3.81	0.00	4.00	0.52	9.66
2/3/10	1.81	3.75	0.00	3.79	0.68	10.04
3/3/10	1.59	2.90	0.00	3.76	0.63	8.88
4/3/10	4.15	2.84	3.13	3.77	0.39	14.27
5/3/10	1.76	3.46	0.00	3.90	0.58	9.70
6/3/10	1.87	2.43	0.00	3.84	0.65	8.79
7/3/10	7.23	7.25	0.00	3.79	0.42	18.69
8/3/10	8.31	10.59	0.00	3.44	0.73	23.06
9/3/10	4.11	4.54	0.00	1.29	0.64	10.58
10/3/10	2.42	3.99	0.00	3.79	0.63	10.83
11/3/10	5.42	3.53	0.00	3.82	0.56	13.33
12/3/10	**4.30**	**3.81**	**0.00**	**3.98**	**0.60**	**12.70**
13/3/10	3.85	18.11	0.00	2.20	0.56	24.72
14/3/10	1.38	3.37	0.00	0.72	0.74	6.21
15/3/10	1.31	3.26	0.00	0.00	0.64	5.22
16/3/10	6.58	13.65	0.00	0.00	0.57	20.80
17/3/10	1.32	2.86	0.00	0.00	0.70	4.88
18/3/10	1.53	3.02	0.00	0.00	0.57	5.11
19/3/10	3.72	5.71	0.00	0.00	0.47	9.90
20/3/10	6.86	5.60	2.95	0.00	0.57	15.97
21/3/10	1.82	3.09	0.00	0.00	0.42	5.34
22/3/10	4.68	4.34	0.00	0.00	0.74	9.76
23/3/10	2.33	17.75	2.92	0.00	0.56	23.56
24/3/10	4.86	3.48	0.00	0.00	0.64	8.98
25/3/10	4.26	2.97	0.00	0.00	0.67	7.90
26/3/10	2.04	3.31	2.93	0.00	0.66	8.94
27/3/10	0.96	2.94	3.06	0.00	0.66	7.62
28/3/10	9.00	3.67	0.00	0.00	0.56	13.23
29/3/10	2.38	4.23	0.00	0.00	0.69	7.31
30/3/10	4.28	7.77	3.07	0.00	0.42	15.54
31/3/10	8.13	4.70	3.02	0.00	0.62	16.47
TOTAL	**115.60**	**166.75**	**21.09**	**46.08**	**18.46**	**367.98**



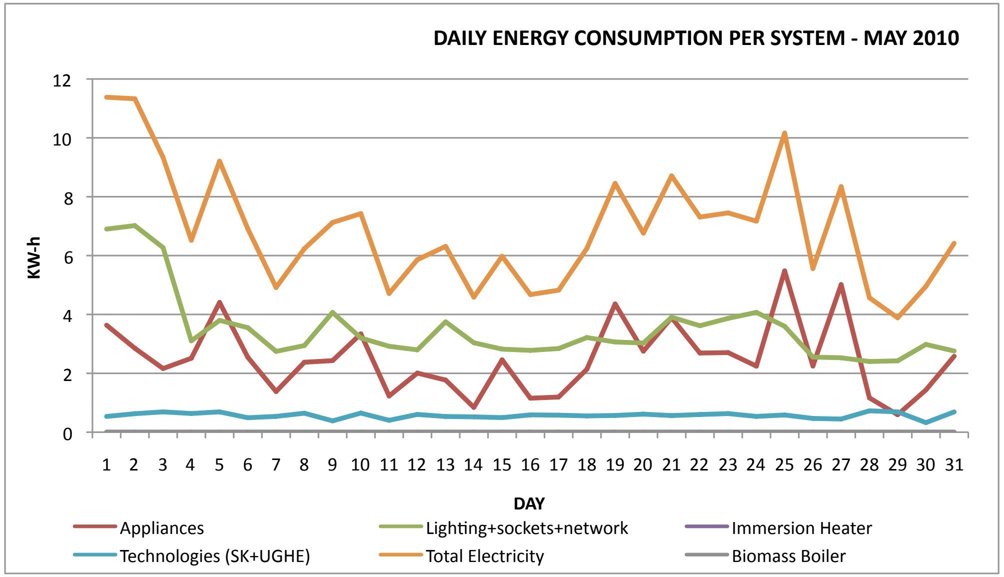


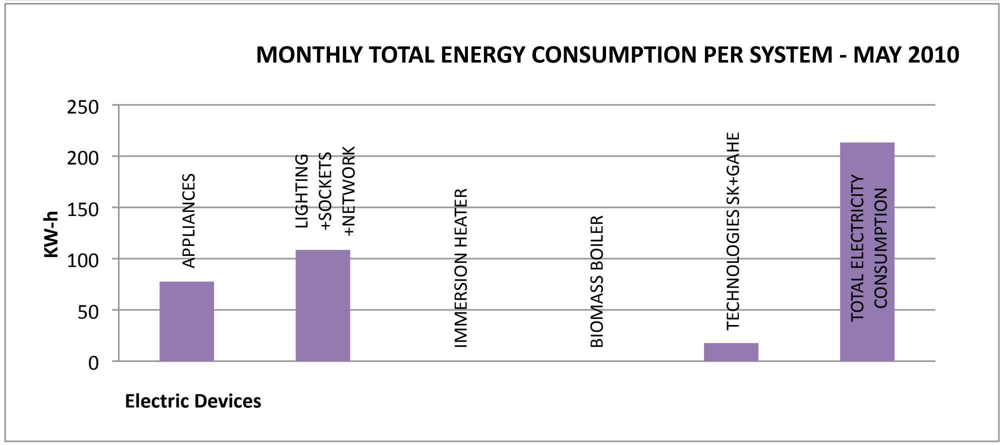
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
APRIL			**kW-h**			
1/4/10	1.70	17.00	0.00	0.00	0.41	19.31
2/4/10	3.98	14.21	0.00	0.00	0.60	19.03
3/4/10	3.67	12.32	3.05	0.00	0.45	20.10
4/4/10	7.16	6.84	3.11	0.00	0.75	18.48
5/4/10	3.29	4.09	2.96	0.00	0.53	11.59
6/4/10	5.78	9.53	3.04	0.00	0.50	19.33
7/4/10	4.06	5.83	6.01	0.00	0.59	17.05
8/4/10	4.14	18.83	5.92	0.00	0.59	30.12
9/4/10	3.66	3.76	0.07	0.00	0.75	8.59
10/4/10	4.54	3.14	0.00	0.00	0.68	8.76
11/4/10	2.63	2.64	0.00	0.00	0.69	6.35
12/4/10	1.80	3.97	0.00	0.00	0.54	6.80
13/4/10	3.21	3.18	3.03	0.00	0.48	10.27
14/4/10	0.98	2.71	0.02	0.00	0.72	4.66
15/4/10	2.24	3.04	0.00	0.00	0.54	6.11
16/4/10	0.85	2.25	0.00	0.00	0.35	3.69
17/4/10	1.73	2.82	0.00	0.00	0.68	5.43
18/4/10	5.11	2.90	0.00	0.00	0.70	9.20
19/4/10	1.55	3.30	0.00	0.00	0.55	5.80
20/4/10	1.73	2.85	0.00	0.00	0.36	5.24
21/4/10	5.90	3.27	0.00	0.00	0.73	10.36
22/4/10	2.92	2.97	0.00	0.00	0.70	6.89
23/4/10	2.59	3.17	0.00	0.00	0.61	6.71
24/4/10	2.03	3.19	0.00	0.00	0.55	6.11
25/4/10	4.01	3.03	0.00	0.00	0.60	7.99
26/4/10	1.16	3.28	0.00	0.00	0.57	5.30
27/4/10	**3.14**	**6.70**	**0.00**	**0.00**	**0.56**	**10.88**
28/4/10	4.70	7.20	0.00	0.00	0.52	12.78
29/4/10	3.97	6.55	0.00	2.12	0.65	13.58
30/4/10	1.79	6.79	0.00	0.00	0.78	9.69
TOTAL	**96.03**	**171.38**	**27.20**	**2.12**	**17.75**	**326.22**



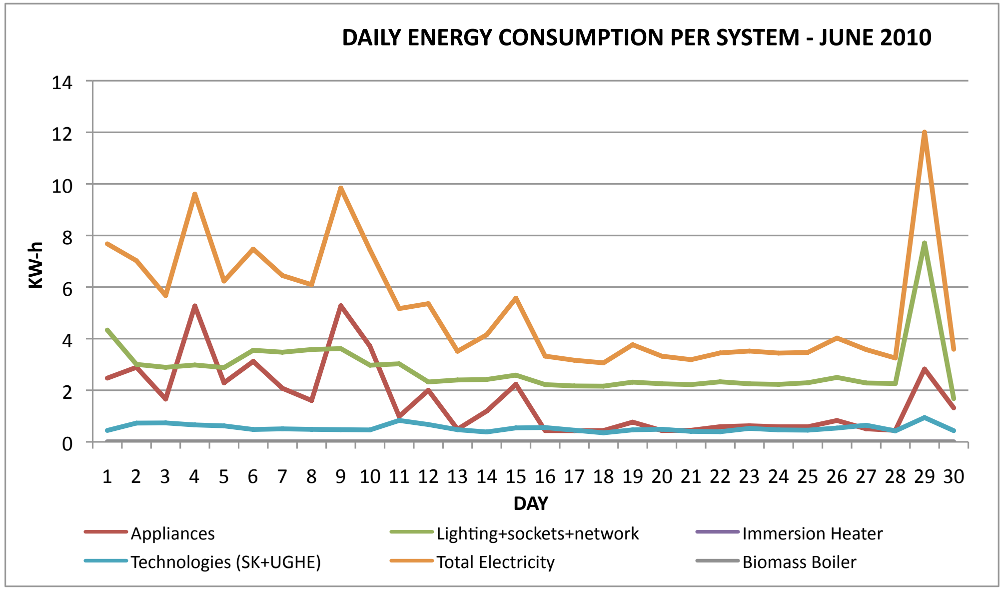


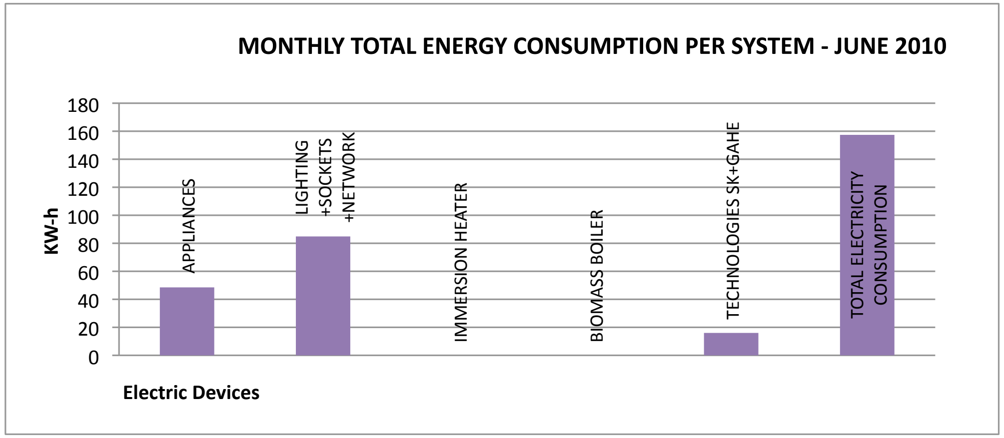
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
MAY	**kW-h**					
1/5/10	3.64	6.90	0.00	0.00	0.54	11.38
2/5/10	2.85	7.02	0.00	0.00	0.63	11.33
3/5/10	2.16	6.27	0.00	0.00	0.69	9.33
4/5/10	2.51	3.10	0.00	0.00	0.63	6.52
5/5/10	4.41	3.80	0.00	0.00	0.69	9.21
6/5/10	2.54	3.55	0.00	0.00	0.49	6.91
7/5/10	1.38	2.75	0.00	0.00	0.54	4.92
8/5/10	2.38	2.94	0.00	0.00	0.64	6.23
9/5/10	2.43	4.07	0.00	0.00	0.38	7.12
10/5/10	3.34	3.20	0.00	0.00	0.65	7.43
11/5/10	1.23	2.92	0.00	0.00	0.40	4.71
12/5/10	2.01	2.80	0.00	0.00	0.60	5.86
13/5/10	1.77	3.75	0.00	0.00	0.53	6.31
14/5/10	0.84	3.04	0.00	0.00	0.52	4.59
15/5/10	2.46	2.82	0.00	0.00	0.49	5.98
16/5/10	1.15	2.78	0.00	0.00	0.59	4.68
17/5/10	1.19	2.84	0.00	0.00	0.58	4.82
18/5/10	2.14	3.21	0.00	0.00	0.55	6.24
19/5/10	4.36	3.06	0.00	0.00	0.57	8.45
20/5/10	**2.75**	**3.03**	**0.00**	**0.00**	**0.61**	**6.76**
21/5/10	3.89	3.91	0.00	0.00	0.56	8.71
22/5/10	2.69	3.62	0.00	0.00	0.60	7.31
23/5/10	2.70	3.87	0.00	0.00	0.63	7.45
24/5/10	2.25	4.07	0.00	0.00	0.54	7.17
25/5/10	5.48	3.60	0.00	0.00	0.58	10.16
26/5/10	2.25	2.55	0.00	0.00	0.47	5.56
27/5/10	5.01	2.53	0.00	0.00	0.45	8.34
28/5/10	1.17	2.40	0.00	0.00	0.73	4.57
29/5/10	0.59	2.42	0.00	0.00	0.69	3.89
30/5/10	1.44	2.98	0.00	0.00	0.32	4.95
31/5/10	2.58	2.76	0.00	0.00	0.69	6.42
TOTAL	**77.59**	**108.56**	**0.00**	**0.00**	**17.59**	**213.32**



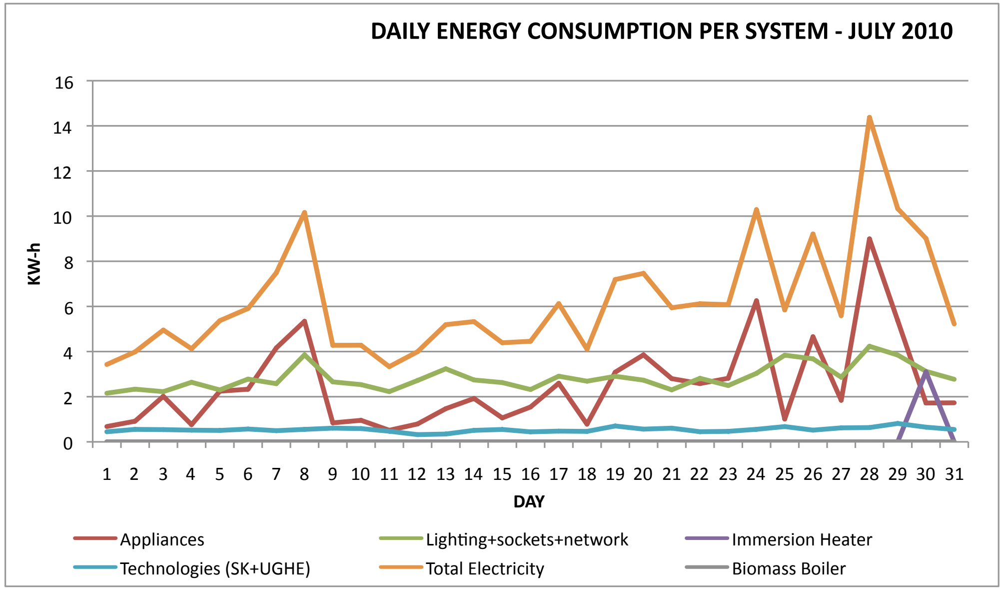


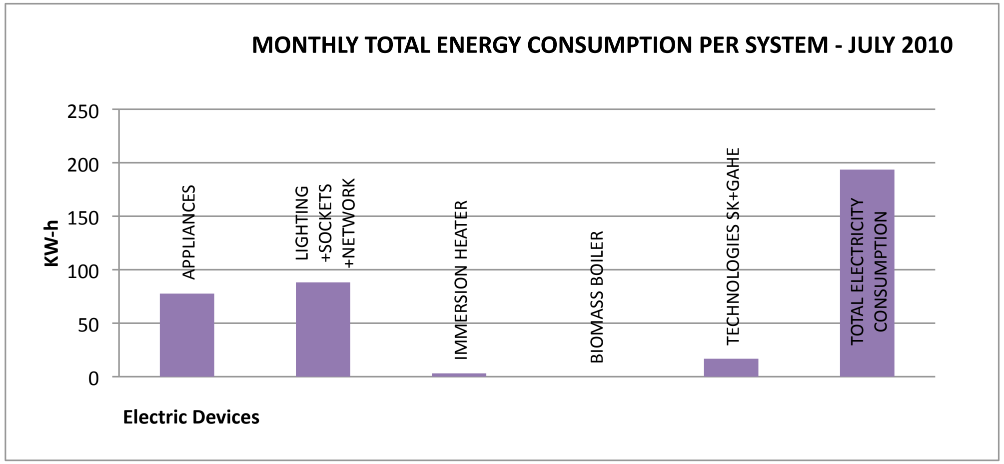
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
JUNE			**kW-h**			
1/6/10	2.47	4.33	0.00	0.00	0.44	7.68
2/6/10	2.89	3.00	0.00	0.00	0.73	7.02
3/6/10	1.66	2.89	0.00	0.00	0.73	5.67
4/6/10	5.27	2.98	0.00	0.00	0.66	9.61
5/6/10	2.29	2.88	0.00	0.00	0.62	6.23
6/6/10	3.12	3.55	0.00	0.00	0.48	7.47
7/6/10	2.08	3.47	0.00	0.00	0.50	6.45
8/6/10	1.60	3.58	0.00	0.00	0.49	6.09
9/6/10	5.28	3.62	0.00	0.00	0.47	9.84
10/6/10	3.71	2.97	0.00	0.00	0.46	7.44
11/6/10	0.98	3.03	0.00	0.00	0.83	5.17
12/6/10	**2.00**	**2.32**	**0.00**	**0.00**	**0.67**	**5.36**
13/6/10	0.49	2.40	0.00	0.00	0.47	3.51
14/6/10	1.19	2.42	0.00	0.00	0.38	4.15
15/6/10	2.23	2.59	0.00	0.00	0.54	5.57
16/6/10	0.44	2.22	0.00	0.00	0.55	3.32
17/6/10	0.43	2.17	0.00	0.00	0.45	3.16
18/6/10	0.44	2.16	0.00	0.00	0.35	3.06
19/6/10	0.77	2.31	0.00	0.00	0.47	3.77
20/6/10	0.44	2.25	0.00	0.00	0.49	3.32
21/6/10	0.45	2.22	0.00	0.00	0.41	3.19
22/6/10	0.59	2.33	0.00	0.00	0.39	3.45
23/6/10	0.62	2.25	0.00	0.00	0.52	3.52
24/6/10	0.59	2.23	0.00	0.00	0.46	3.44
25/6/10	0.58	2.29	0.00	0.00	0.45	3.47
26/6/10	0.83	2.50	0.00	0.00	0.54	4.02
27/6/10	0.51	2.28	0.00	0.00	0.65	3.58
28/6/10	0.45	2.26	0.00	0.00	0.43	3.25
29/6/10	2.82	7.71	0.00	0.00	0.94	12.00
30/6/10	1.32	1.68	0.00	0.00	0.43	3.59
TOTAL	**48.52**	**84.88**	**0.00**	**0.00**	**16.01**	**157.40**



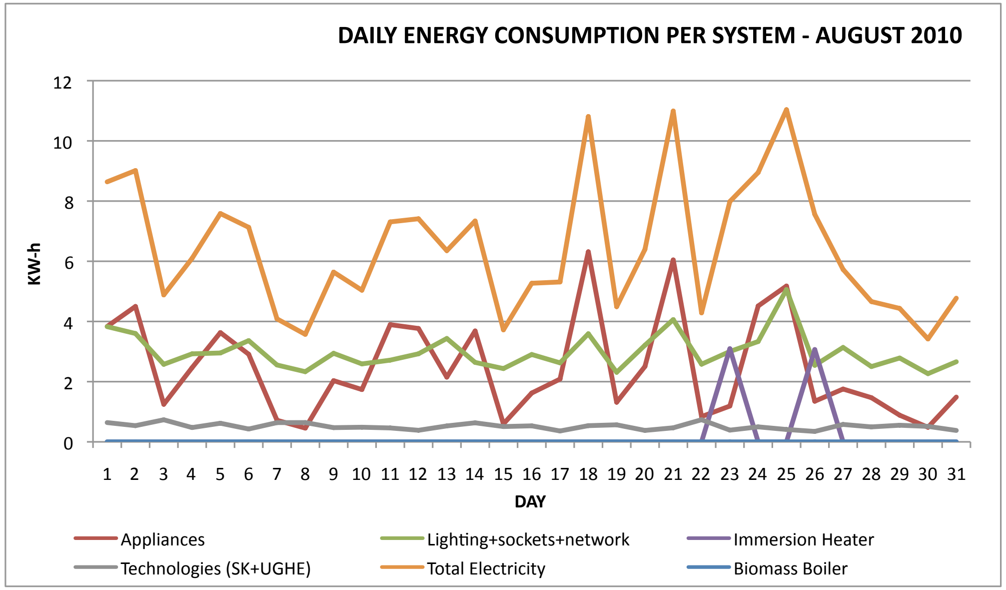


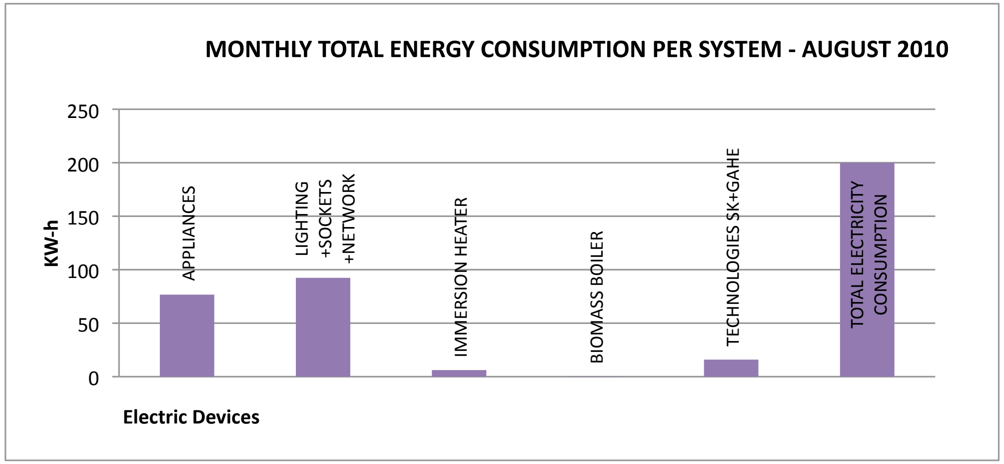
JULY	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/7/10	0.68	2.15	0.00	0.00	0.45	3.43
2/7/10	0.92	2.33	0.00	0.00	0.55	3.99
3/7/10	2.02	2.22	0.00	0.00	0.54	4.95
4/7/10	0.76	2.64	0.00	0.00	0.52	4.12
5/7/10	2.24	2.30	0.00	0.00	0.51	5.37
6/7/10	2.33	2.78	0.00	0.00	0.57	5.91
7/7/10	4.16	2.58	0.00	0.00	0.50	7.49
8/7/10	5.34	3.86	0.00	0.00	0.55	10.16
9/7/10	0.84	2.66	0.00	0.00	0.61	4.28
10/7/10	0.95	2.54	0.00	0.00	0.59	4.28
11/7/10	0.51	2.23	0.00	0.00	0.47	3.33
12/7/10	0.79	2.72	0.00	0.00	0.32	3.99
13/7/10	1.47	3.24	0.00	0.00	0.35	5.19
14/7/10	1.92	2.74	0.00	0.00	0.51	5.33
15/7/10	1.06	2.63	0.00	0.00	0.55	4.39
16/7/10	1.54	2.32	0.00	0.00	0.44	4.46
17/7/10	**2.60**	**2.91**	**0.00**	**0.00**	**0.48**	**6.12**
18/7/10	0.78	2.69	0.00	0.00	0.46	4.10
19/7/10	3.09	2.90	0.00	0.00	0.70	7.19
20/7/10	3.85	2.73	0.00	0.00	0.56	7.47
21/7/10	2.80	2.30	0.00	0.00	0.61	5.94
22/7/10	2.58	2.82	0.00	0.00	0.45	6.12
23/7/10	2.82	2.49	0.00	0.00	0.47	6.08
24/7/10	6.25	3.03	0.00	0.00	0.56	10.29
25/7/10	1.01	3.84	0.00	0.00	0.68	5.84
26/7/10	4.66	3.68	0.00	0.00	0.52	9.21
27/7/10	1.84	2.86	0.00	0.00	0.62	5.59
28/7/10	8.99	4.23	0.00	0.00	0.63	14.38
29/7/10	5.37	3.85	0.00	0.00	0.81	10.33
30/7/10	1.72	3.12	3.10	0.00	0.65	9.01
31/7/10	1.73	2.77	0.00	0.00	0.55	5.22
TOTAL	**77.65**	**88.17**	**3.10**	**0.00**	**16.76**	**193.56**



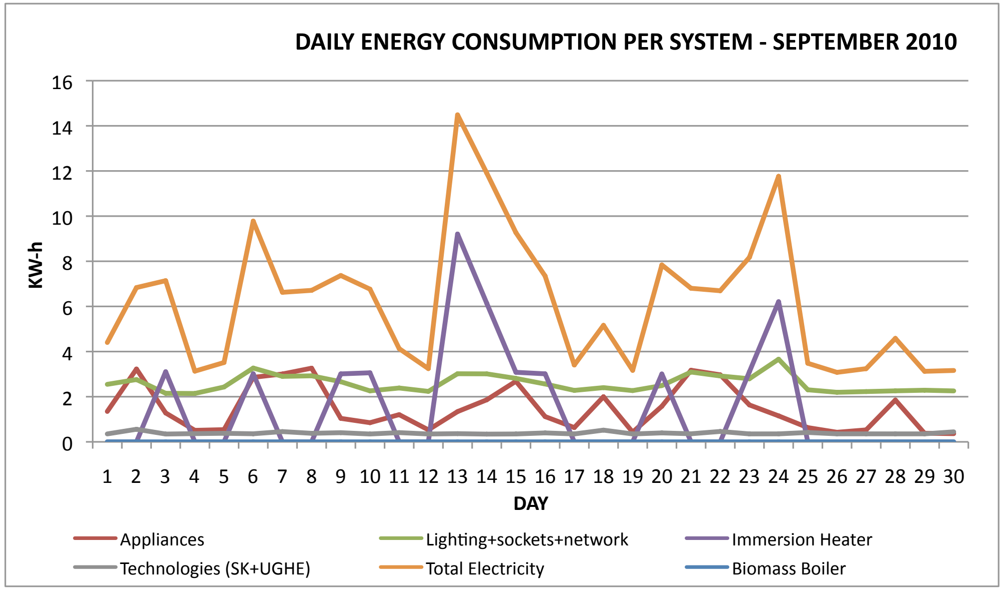


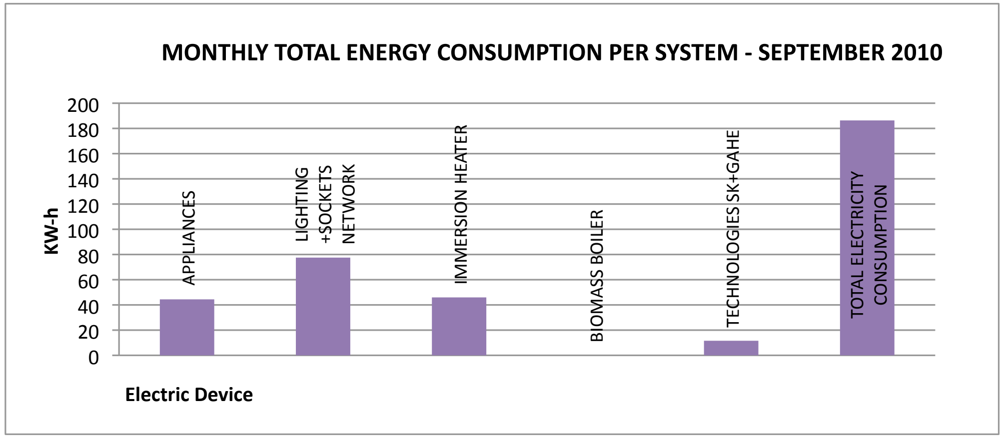
	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
AUGUST	**kW-h**					
1/8/10	3.83	3.83	0.00	0.00	0.64	8.64
2/8/10	4.50	3.60	0.00	0.00	0.54	9.01
3/8/10	1.25	2.58	0.00	0.00	0.73	4.88
4/8/10	2.46	2.92	0.00	0.00	0.48	6.10
5/8/10	3.63	2.95	0.00	0.00	0.62	7.59
6/8/10	2.91	3.36	0.00	0.00	0.43	7.13
7/8/10	0.72	2.55	0.00	0.00	0.64	4.09
8/8/10	0.46	2.33	0.00	0.00	0.64	3.57
9/8/10	2.03	2.94	0.00	0.00	0.47	5.64
10/8/10	1.74	2.59	0.00	0.00	0.49	5.04
11/8/10	3.89	2.71	0.00	0.00	0.46	7.31
12/8/10	3.77	2.93	0.00	0.00	0.38	7.41
13/8/10	**2.15**	**3.44**	**0.00**	**0.00**	**0.53**	**6.35**
14/8/10	3.69	2.64	0.00	0.00	0.63	7.34
15/8/10	0.60	2.43	0.00	0.00	0.51	3.72
16/8/10	1.62	2.90	0.00	0.00	0.53	5.27
17/8/10	2.09	2.62	0.00	0.00	0.36	5.31
18/8/10	6.32	3.59	0.00	0.00	0.54	10.81
19/8/10	1.32	2.31	0.00	0.00	0.57	4.49
20/8/10	2.50	3.21	0.00	0.00	0.38	6.39
21/8/10	6.05	4.06	0.00	0.00	0.47	10.99
22/8/10	0.84	2.58	0.00	0.00	0.74	4.29
23/8/10	1.19	3.00	3.10	0.00	0.39	7.99
24/8/10	4.51	3.33	0.00	0.00	0.50	8.95
25/8/10	5.18	5.06	0.00	0.00	0.41	11.04
26/8/10	1.35	2.54	3.07	0.00	0.35	7.56
27/8/10	1.76	3.14	0.00	0.00	0.58	5.73
28/8/10	1.47	2.50	0.00	0.00	0.50	4.66
29/8/10	0.89	2.79	0.00	0.00	0.55	4.43
30/8/10	0.48	2.27	0.00	0.00	0.51	3.42
31/8/10	1.49	2.66	0.00	0.00	0.38	4.77
TOTAL	**76.66**	**92.39**	**6.16**	**0.00**	**15.93**	**199.92**



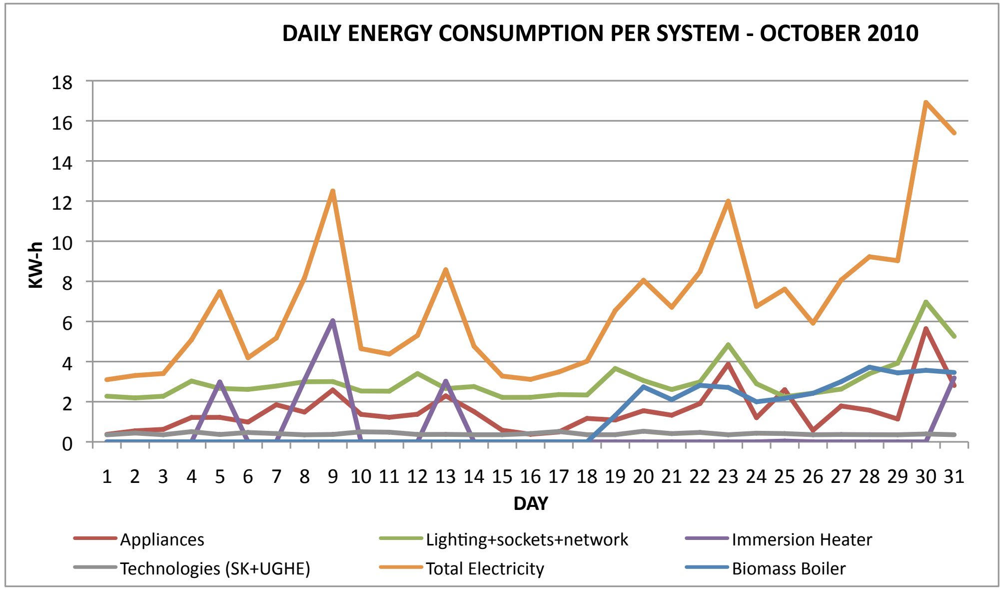


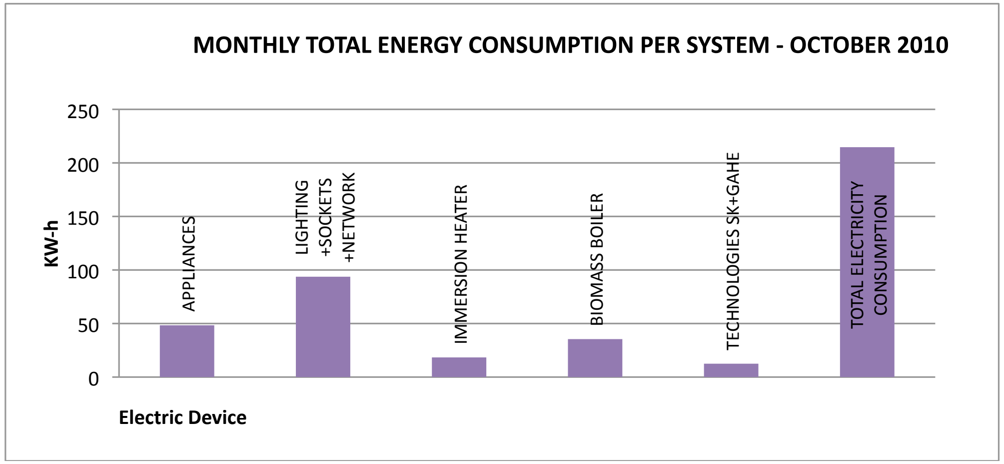
SEPTEMBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/9/10	1.35	2.55	0.00	0.00	0.35	4.40
2/9/10	3.23	2.76	0.00	0.00	0.56	6.84
3/9/10	1.28	2.15	3.11	0.00	0.35	7.14
4/9/10	0.51	2.14	0.00	0.00	0.36	3.13
5/9/10	0.54	2.43	0.00	0.00	0.38	3.51
6/9/10	2.86	3.27	3.02	0.00	0.36	9.78
7/9/10	**3.01**	**2.90**	**0.00**	**0.00**	**0.45**	**6.62**
8/9/10	3.26	2.93	0.00	0.00	0.38	6.71
9/9/10	1.04	2.67	3.01	0.00	0.41	7.37
10/9/10	0.85	2.26	3.06	0.00	0.35	6.77
11/9/10	1.21	2.39	0.00	0.00	0.41	4.13
12/9/10	0.53	2.24	0.00	0.00	0.35	3.24
13/9/10	1.34	3.02	9.21	0.00	0.36	14.49
14/9/10	1.86	3.01	6.14	0.00	0.34	11.91
15/9/10	2.68	2.81	3.08	0.00	0.35	9.27
16/9/10	1.12	2.56	3.01	0.00	0.40	7.35
17/9/10	0.63	2.28	0.00	0.00	0.35	3.40
18/9/10	2.00	2.40	0.00	0.00	0.52	5.16
19/9/10	0.43	2.27	0.00	0.00	0.35	3.17
20/9/10	1.58	2.49	3.01	0.00	0.40	7.84
21/9/10	3.17	3.09	0.00	0.00	0.36	6.80
22/9/10	2.97	2.92	0.00	0.00	0.46	6.69
23/9/10	1.64	2.80	3.11	0.00	0.35	8.17
24/9/10	1.15	3.66	6.21	0.00	0.35	11.76
25/9/10	0.63	2.31	0.00	0.00	0.42	3.48
26/9/10	0.42	2.19	0.00	0.00	0.35	3.08
27/9/10	0.53	2.23	0.00	0.00	0.36	3.24
28/9/10	1.85	2.26	0.00	0.00	0.35	4.58
29/9/10	0.38	2.29	0.00	0.00	0.35	3.13
30/9/10	0.36	2.26	0.00	0.00	0.44	3.16
TOTAL	**44.41**	**77.52**	**45.96**	**0.00**	**11.57**	**186.34**



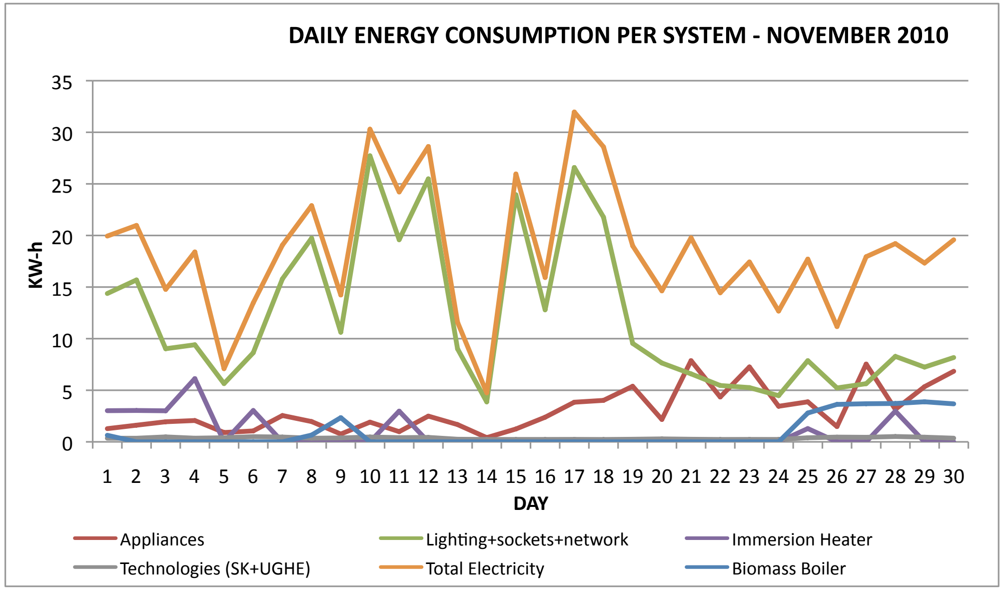


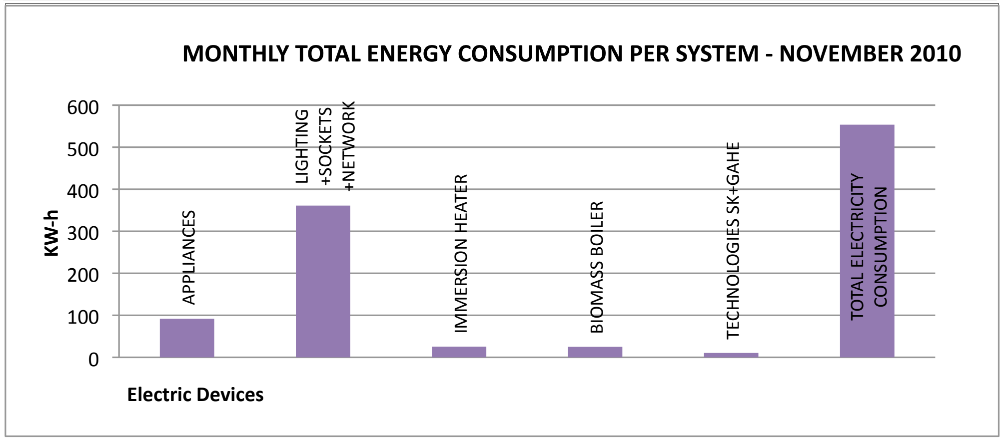
OCTOBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/10/10	0.37	2.27	0.00	0.00	0.35	3.10
2/10/10	0.55	2.19	0.00	0.00	0.44	3.31
3/10/10	0.62	2.27	0.00	0.00	0.36	3.40
4/10/10	1.22	3.03	0.00	0.00	0.51	5.09
5/10/10	1.22	2.66	2.98	0.00	0.37	7.49
6/10/10	0.99	2.61	0.00	0.00	0.47	4.19
7/10/10	1.85	2.78	0.00	0.00	0.41	5.17
8/10/10	1.48	2.99	3.08	0.00	0.35	8.18
9/10/10	2.59	3.00	6.04	0.00	0.37	12.50
10/10/10	1.37	2.53	0.00	0.00	0.50	4.65
11/10/10	1.22	2.53	0.00	0.00	0.48	4.37
12/10/10	1.38	3.40	0.00	0.00	0.37	5.30
13/10/10	2.29	2.66	3.02	0.00	0.37	8.58
14/10/10	1.51	2.76	0.00	0.00	0.36	4.77
15/10/10	0.58	2.21	0.00	0.00	0.36	3.28
16/10/10	0.38	2.22	0.00	0.00	0.41	3.11
17/10/10	0.49	2.36	0.00	0.00	0.52	3.48
18/10/10	1.17	2.34	0.00	0.00	0.36	4.02
19/10/10	1.09	3.66	0.00	1.31	0.36	6.55
20/10/10	1.55	3.05	0.00	2.74	0.53	8.05
21/10/10	**1.33**	**2.61**	**0.00**	**2.11**	**0.41**	**6.71**
22/10/10	1.91	2.99	0.00	2.82	0.47	8.47
23/10/10	3.87	4.83	0.00	2.71	0.35	11.99
24/10/10	1.20	2.90	0.00	2.00	0.43	6.75
25/10/10	2.60	2.25	0.04	2.17	0.41	7.61
26/10/10	0.58	2.43	0.00	2.42	0.36	5.92
27/10/10	1.79	2.63	0.00	3.00	0.37	8.07
28/10/10	1.58	3.40	0.00	3.72	0.36	9.22
29/10/10	1.14	3.92	0.00	3.44	0.35	9.03
30/10/10	5.64	6.97	0.00	3.57	0.39	16.92
31/10/10	2.81	5.26	3.19	3.46	0.36	15.40
TOTAL	**48.35**	**93.71**	**18.35**	**35.45**	**12.49**	**214.67**



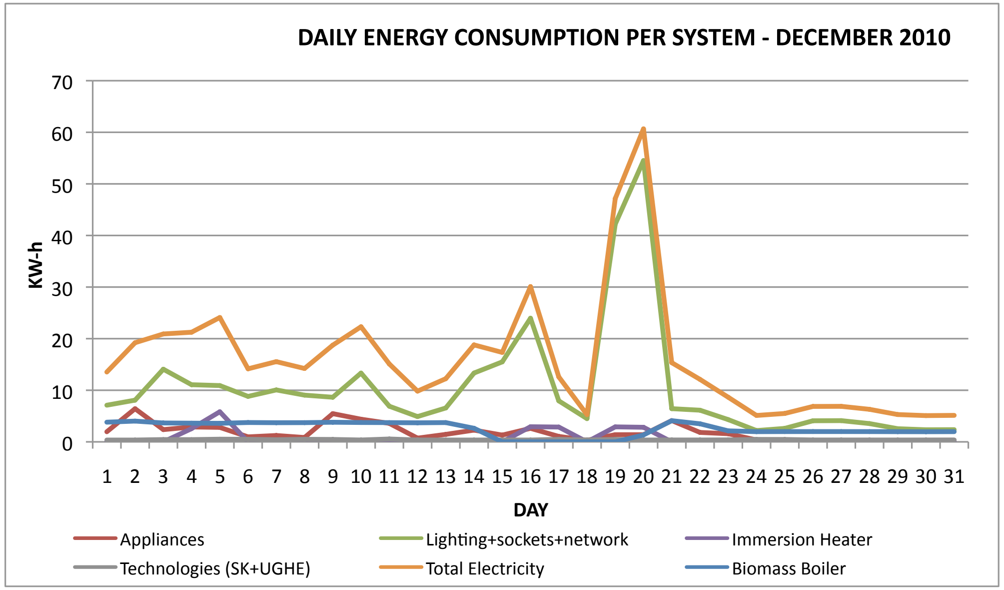


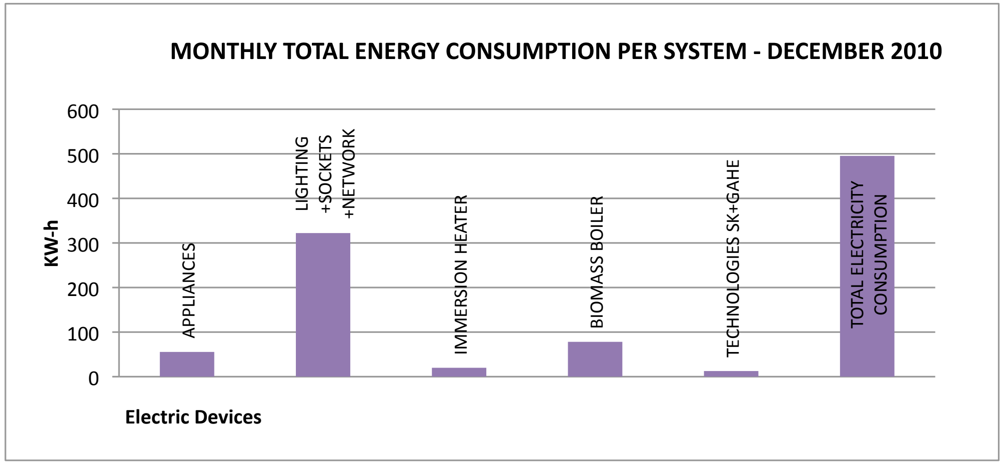
NOVEMBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/11/10	1.28	14.37	3.02	0.64	0.35	19.94
2/11/10	1.61	15.69	3.04	0.00	0.35	20.97
3/11/10	1.95	9.02	3.01	0.00	0.48	14.77
4/11/10	**2.07**	**9.41**	**6.13**	**0.00**	**0.36**	**18.41**
5/11/10	0.91	5.64	0.00	0.00	0.40	7.09
6/11/10	1.06	8.63	3.04	0.00	0.50	13.46
7/11/10	2.55	15.79	0.00	0.00	0.47	19.07
8/11/10	1.97	19.74	0.00	0.66	0.35	22.89
9/11/10	0.76	10.62	0.00	2.35	0.38	14.23
10/11/10	1.91	27.72	0.00	0.00	0.47	30.30
11/11/10	0.99	19.59	2.98	0.00	0.41	24.22
12/11/10	2.49	25.49	0.00	0.00	0.43	28.62
13/11/10	1.67	9.01	0.00	0.00	0.25	11.59
14/11/10	0.41	3.87	0.00	0.00	0.23	4.76
15/11/10	1.25	23.94	0.00	0.00	0.23	25.96
16/11/10	2.39	12.80	0.00	0.00	0.23	15.92
17/11/10	3.84	26.59	0.00	0.00	0.24	31.97
18/11/10	4.02	21.78	0.00	0.00	0.23	28.59
19/11/10	5.38	9.54	0.00	0.00	0.25	19.00
20/11/10	2.17	7.64	0.00	0.00	0.29	14.63
21/11/10	7.87	6.59	0.00	0.00	0.25	19.77
22/11/10	4.35	5.46	0.00	0.00	0.23	14.45
23/11/10	7.26	5.26	0.00	0.00	0.24	17.43
24/11/10	3.45	4.48	0.00	0.00	0.23	12.67
25/11/10	3.88	7.87	1.29	2.79	0.40	17.71
26/11/10	1.48	5.23	0.00	3.63	0.46	11.17
27/11/10	7.54	5.64	0.00	3.70	0.44	17.94
28/11/10	3.15	8.28	2.98	3.72	0.52	19.21
29/11/10	5.35	7.24	0.00	3.88	0.45	17.32
30/11/10	6.84	8.17	0.00	3.68	0.36	19.58
TOTAL	**91.82**	**361.12**	**25.48**	**25.04**	**10.49**	**553.67**





DECEMBER	APPLIANCES	LIGHTING+SOCKETS+ NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
	kW-h					
1/12/10	1.95	7.10	0.00	3.81	0.36	13.53
2/12/10	6.42	8.08	0.00	4.02	0.35	19.21
3/12/10	2.37	14.08	0.00	3.66	0.45	20.91
4/12/10	2.89	11.07	2.56	3.62	0.44	21.25
5/12/10	2.80	10.91	5.83	3.59	0.52	24.10
6/12/10	0.97	8.81	0.00	3.75	0.49	14.15
7/12/10	**1.23**	**10.06**	**0.00**	**3.71**	**0.42**	**15.55**
8/12/10	0.84	9.06	0.00	3.72	0.49	14.22
9/12/10	5.47	8.64	0.00	3.80	0.47	18.74
10/12/10	4.39	13.33	0.00	3.75	0.36	22.31
11/12/10	3.59	6.91	0.00	3.73	0.55	15.10
12/12/10	0.72	4.90	0.00	3.69	0.36	9.83
13/12/10	1.45	6.56	0.00	3.73	0.36	12.24
14/12/10	2.28	13.34	0.00	2.63	0.36	18.79
15/12/10	1.31	15.50	0.00	0.00	0.37	17.33
16/12/10	2.62	23.96	2.93	0.00	0.36	30.10
17/12/10	1.06	7.95	2.87	0.00	0.49	12.60
18/12/10	0.31	4.50	0.00	0.00	0.36	5.28
19/12/10	1.39	42.20	2.90	0.00	0.48	47.15
20/12/10	1.39	54.51	2.82	1.34	0.36	60.67
21/12/10	4.12	6.43	0.00	4.10	0.37	15.35
22/12/10	1.83	6.14	0.00	3.50	0.36	12.11
23/12/10	1.58	4.31	0.00	2.13	0.38	8.64
24/12/10	0.37	2.19	0.00	1.97	0.48	5.12
25/12/10	0.33	2.61	0.00	1.99	0.46	5.50
26/12/10	0.31	4.09	0.00	1.99	0.36	6.87
27/12/10	0.30	4.11	0.00	1.99	0.37	6.88
28/12/10	0.30	3.54	0.00	1.99	0.36	6.31
29/12/10	0.30	2.55	0.00	1.97	0.36	5.29
30/12/10	0.31	2.34	0.00	1.96	0.36	5.09
31/12/10	0.32	2.36	0.00	1.98	0.36	5.13
TOTAL	**55.50**	**322.16**	**19.92**	**78.14**	**12.62**	**495.35**





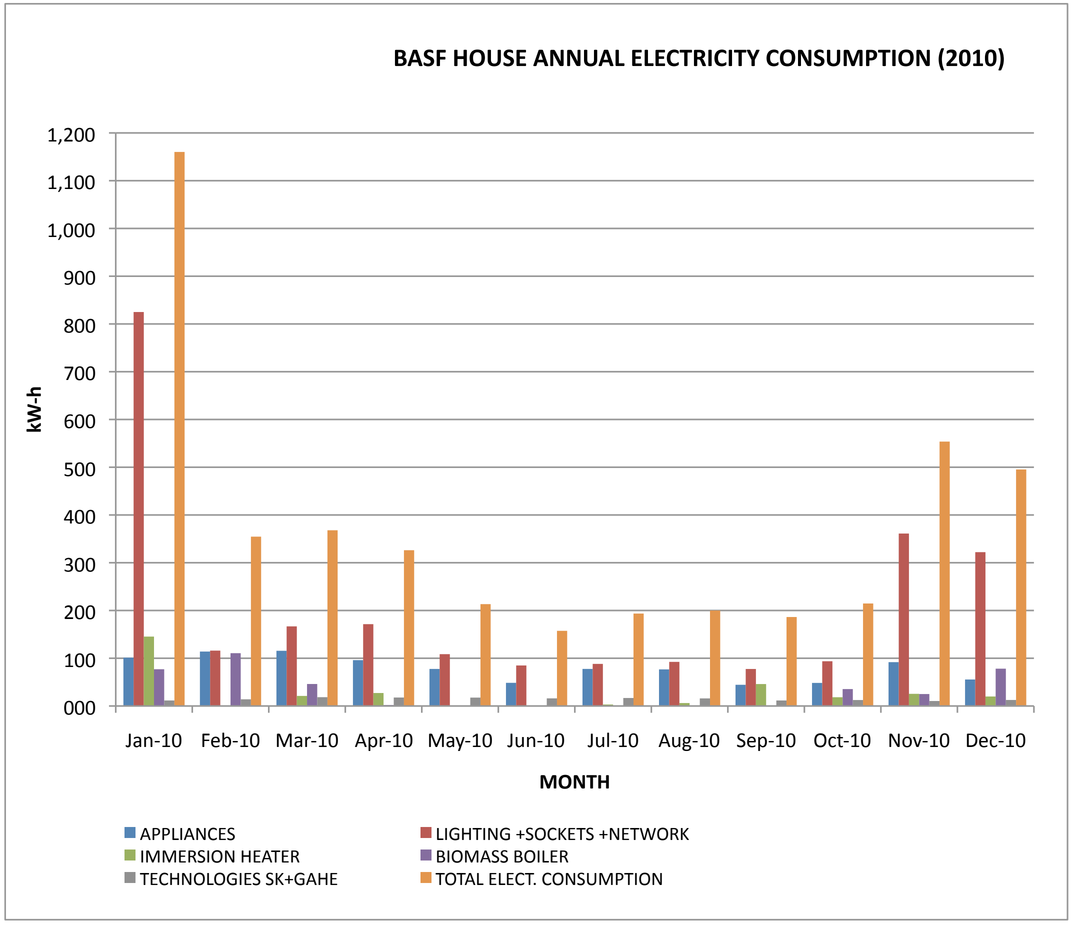
SAMPLE OF BASF HOUSE ANNUAL PERIOD OF ELECTRICITY CONSUMPTION

	APPLIANCES	LIGHTING +SOCKETS +NETWORK	IMMERSION HEATER	BIOMASS BOILER	TECHNOLOGIES SK+GAHE	TOTAL ELECT. CONSUMPTION
2010	**kW-h**					
Jan-10	101.2	825.0	145.3	77.0	11.6	1160.2
Feb-10	114.0	116.0	0.0	110.6	14.0	354.6
Mar-10	115.6	166.7	21.1	46.1	18.5	368.0
Apr-10	96.0	171.4	27.2	2.1	17.8	326.2
May-10	77.6	108.6	0.0	0.0	17.6	213.3
Jun-10	48.5	84.9	0.0	0.0	16.0	157.4
Jul-10	77.6	88.2	3.1	0.0	16.8	193.6
Aug-10	76.7	92.4	6.2	0.0	15.9	199.9
Sep-10	44.4	77.5	46.0	0.0	11.6	186.3
Oct-10	48.3	93.7	18.4	35.4	12.5	214.7
Nov-10	91.8	361.1	25.5	25.0	10.5	553.7
Dec-10	55.5	322.2	19.9	78.1	12.6	495.3
TOTALS	**947.4**	**2507.6**	**312.6**	**374.5**	**175.3**	**4423.2**

12-MONTHS PERIOD TOTAL ELECTRICITY CONSUMPTION

5,575.3 kW-hr/year

The data from January and March 2009 was missing, therefore to



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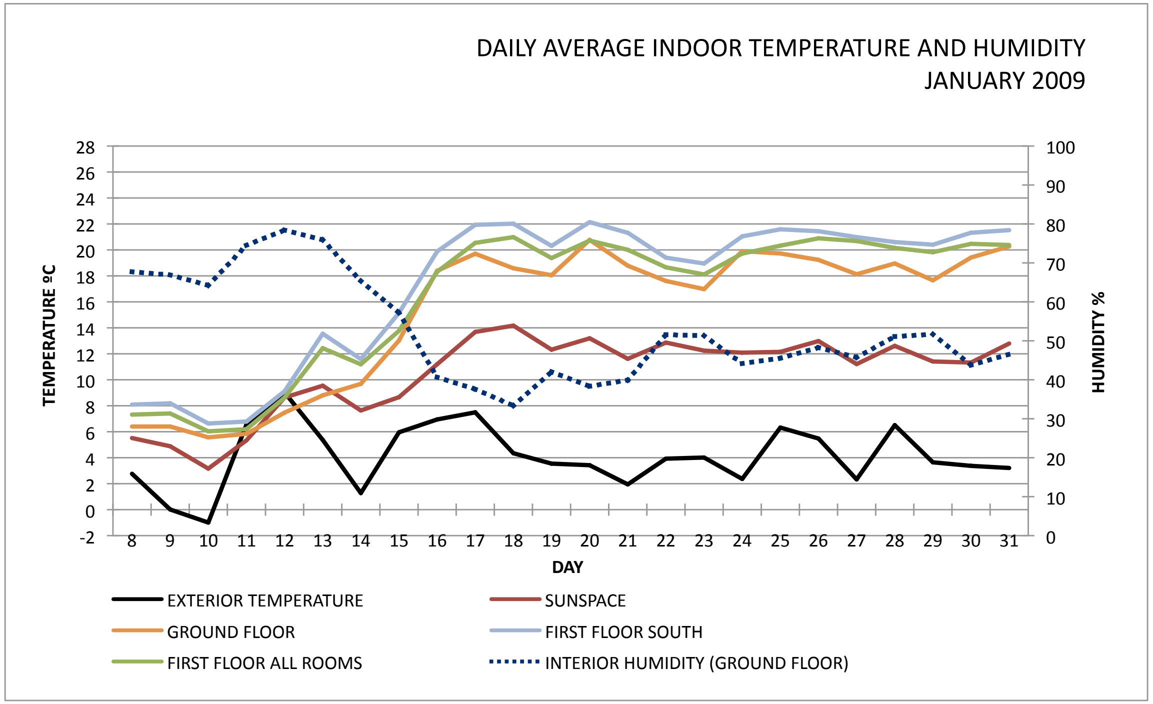
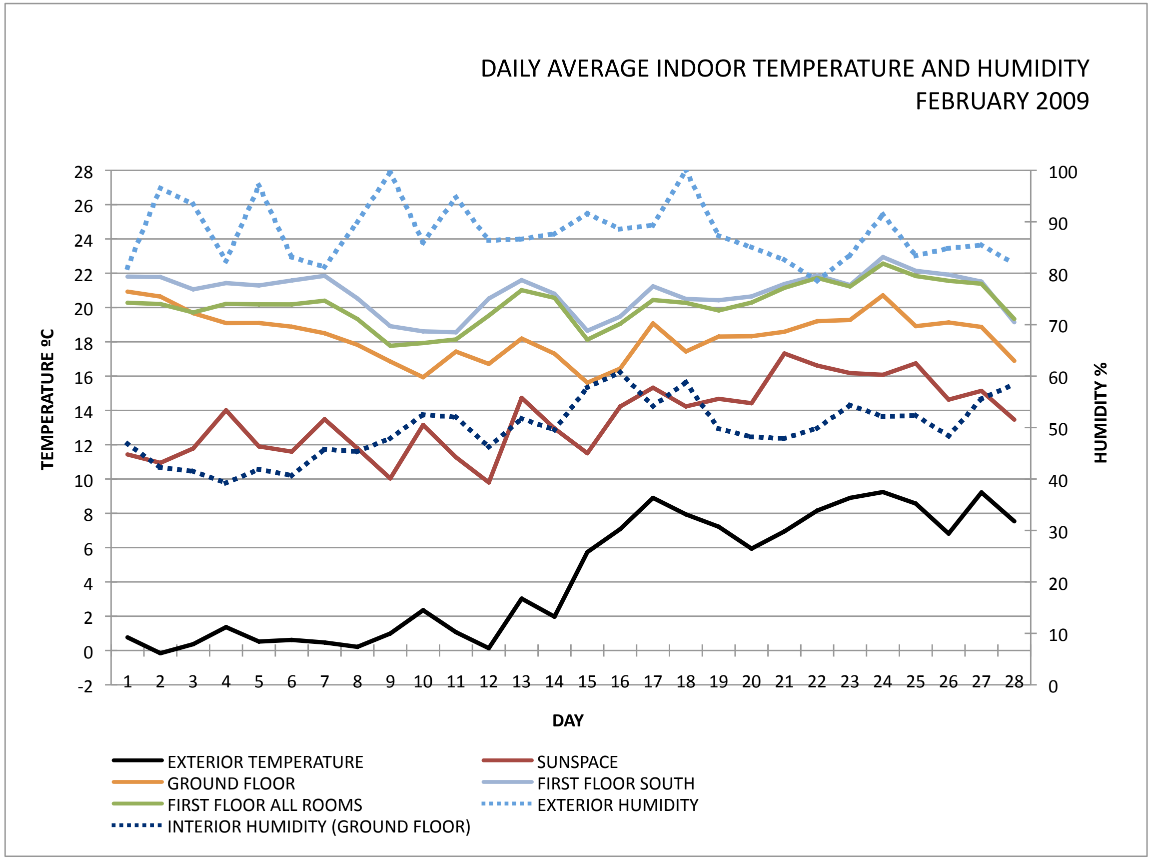
EXTERIOR AND INTERIOR AVERAGE TEMPERATURES AND HUMIDITY OF THE BASF HOUSE -YEAR 2009

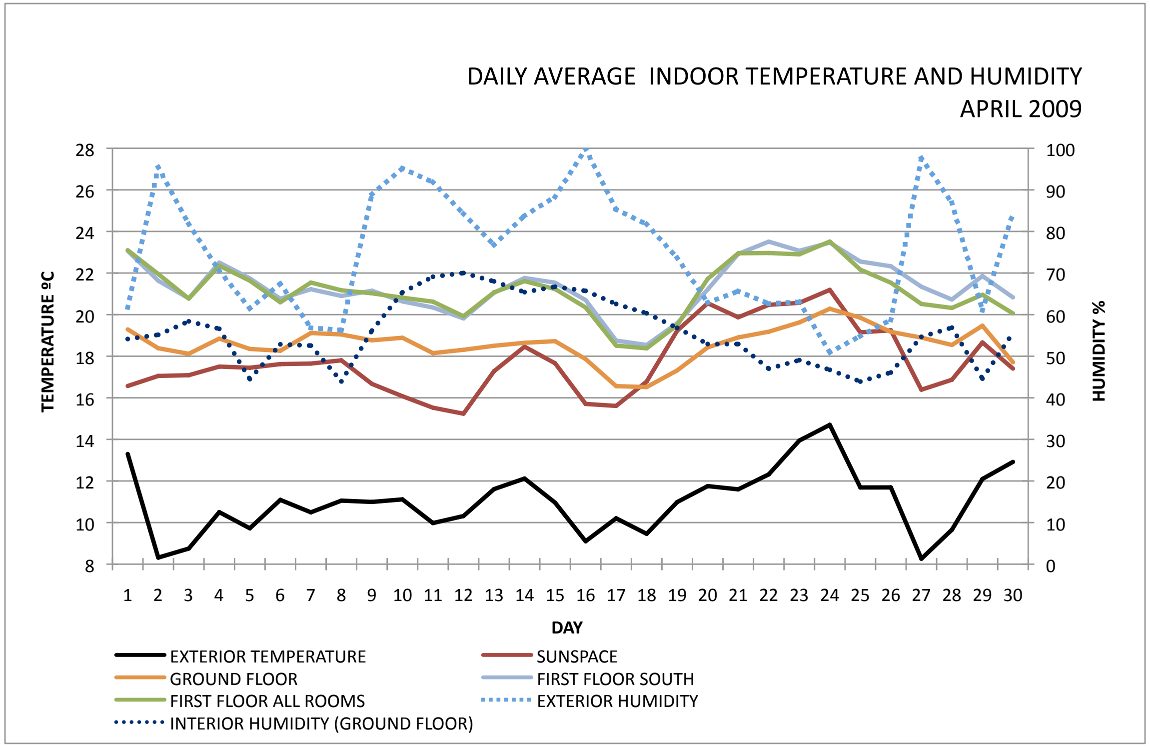
DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
8/1/09	2.76	5.51	6.40	8.09	7.32		67.7
9/1/09	0.01	4.88	6.40	8.19	7.41		66.9
10/1/09	-0.99	3.16	5.57	6.63	6.03		64.2
11/1/09	6.54	5.34	5.83	6.78	6.20		74.5
12/1/09	9.02	8.63	7.47	9.12	8.63		78.4
13/1/09	5.37	9.54	8.80	13.55	12.43		75.9
14/1/09	1.28	7.64	9.69	11.59	11.19		65.4
15/1/09	5.96	8.66	13.02	15.15	13.77		57.2
16/1/09	6.94	11.19	18.39	19.88	18.32		40.7
17/1/09	7.49	13.68	19.71	21.93	20.54		37.6
18/1/09	4.34	14.17	18.59	22.02	20.99		33.4
19/1/09	3.54	12.32	18.05	20.31	19.37	DATA MISSING	42.0
20/1/09	3.42	13.19	20.77	22.14	20.72		38.3
21/1/09	1.95	11.61	18.78	21.32	20.01		39.9
22/1/09	3.93	12.87	17.61	19.40	18.66		51.6
23/1/09	4.01	12.25	16.98	18.95	18.11		51.3
24/1/09	2.37	12.09	19.91	21.04	19.72		44.2
25/1/09	6.32	12.15	19.73	21.59	20.33		45.6
26/1/09	5.48	12.98	19.23	21.44	20.89		48.3
27/1/09	2.33	11.21	18.13	20.99	20.69		45.7
28/1/09	6.50	12.61	18.96	20.60	20.16		51.1
29/1/09	3.65	11.41	17.66	20.40	19.82		51.7
30/1/09	3.37	11.33	19.42	21.32	20.47		43.8
31/1/09	3.21	12.79	20.27	21.52	20.38		46.5
Monthly Max	**9.02**	**14.17**	**20.77**	**22.14**	**20.99**		**78.41**
Monthly Average	**4.12**	**10.47**	**15.22**	**17.25**	**16.34**		**52.58**
Monthly Min	**-0.99**	**3.16**	**5.57**	**6.63**	**6.03**		**33.35**



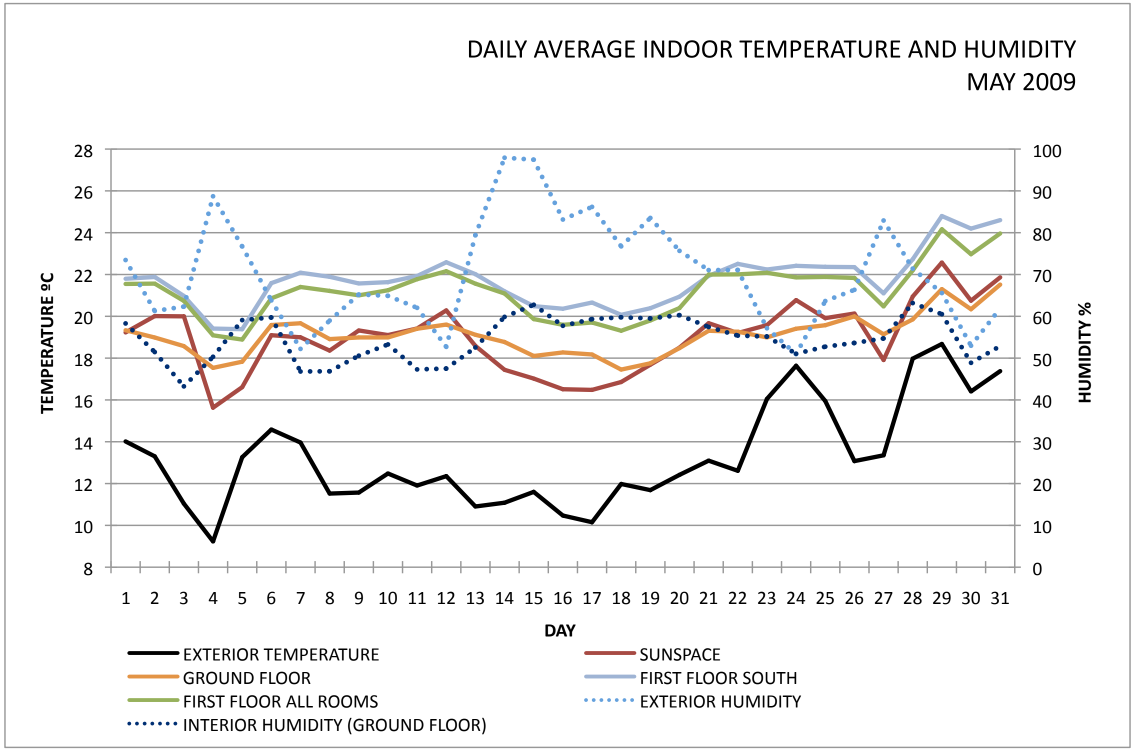
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/2/09	0.77	11.43	20.93	21.80	20.28	81.12	46.84
2/2/09	-0.16	10.94	20.64	21.78	20.20	96.52	42.23
3/2/09	0.37	11.78	19.67	21.06	19.71	93.42	41.49
4/2/09	1.36	14.01	19.09	21.43	20.21	82.38	39.26
5/2/09	0.52	11.90	19.10	21.29	20.19	97.06	41.87
6/2/09	0.62	11.60	18.88	21.58	20.18	83.11	40.70
7/2/09	0.47	13.49	18.50	21.85	20.40	81.24	45.77
8/2/09	0.21	11.79	17.82	20.53	19.33	89.96	45.35
9/2/09	0.99	10.04	16.85	18.91	17.77	99.66	47.91
10/2/09	2.35	13.15	15.93	18.61	17.93	85.96	52.50
11/2/09	1.07	11.27	17.43	18.56	18.14	94.75	52.03
12/2/09	0.13	9.80	16.71	20.52	19.53	86.39	46.25
13/2/09	3.03	14.73	18.19	21.60	21.01	86.64	51.74
14/2/09	1.97	12.95	17.31	20.80	20.57	87.67	49.56
15/2/09	5.74	11.50	15.62	18.64	18.13	91.56	57.81
16/2/09	7.08	14.23	16.44	19.47	19.05	88.60	60.74
17/2/09	8.90	15.33	19.08	21.24	20.44	89.33	54.16
18/2/09	7.94	14.23	17.43	20.50	20.27	99.99	58.79
19/2/09	7.22	14.68	18.31	20.43	19.83	87.27	49.78
20/2/09	5.94	14.42	18.33	20.65	20.29	85.04	48.18
21/2/09	6.95	17.32	18.59	21.37	21.15	82.60	47.90
22/2/09	8.16	16.61	19.20	21.87	21.73	78.55	49.90
23/2/09	8.90	16.18	19.28	21.31	21.23	83.52	54.34
24/2/09	9.24	16.08	20.71	22.94	22.56	91.40	52.15
25/2/09	8.57	16.75	18.91	22.14	21.84	83.41	52.33
26/2/09	6.82	14.63	19.13	21.92	21.56	84.84	48.39
27/2/09	9.22	15.14	18.87	21.51	21.39	85.46	55.60
28/2/09	7.53	13.46	16.89	19.14	19.33	81.87	58.43
Monthly Max	**-0.16**	**9.80**	**15.62**	**18.56**	**17.77**	**99.99**	**60.74**
Monthly Average	**4.35**	**13.55**	**18.35**	**20.84**	**20.15**	**87.83**	**49.72**
Monthly Min	**9.24**	**17.32**	**20.93**	**22.94**	**22.56**	**78.55**	**39.26**



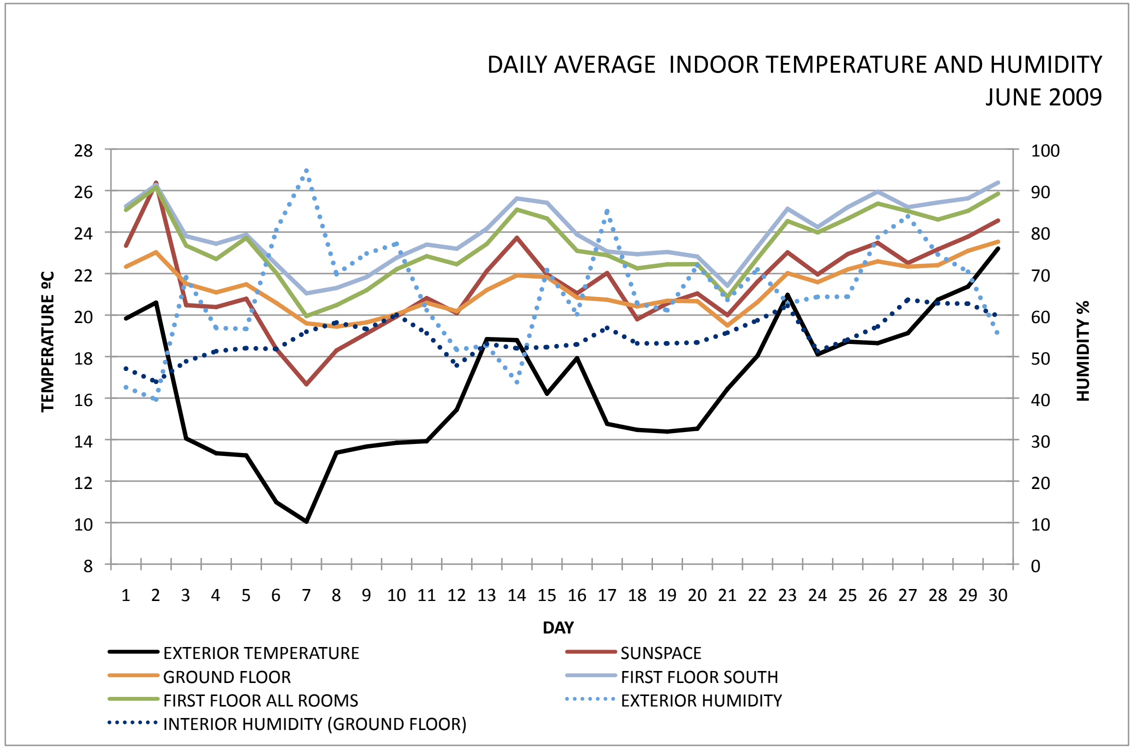
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/4/09	13.30	16.57	19.29	23.07	23.10	61.76	54.14
2/4/09	8.32	17.05	18.38	21.63	21.95	95.43	55.15
3/4/09	8.75	17.09	18.12	20.78	20.77	81.75	58.38
4/4/09	10.50	17.50	18.85	22.50	22.35	70.54	56.59
5/4/09	9.72	17.45	18.35	21.74	21.63	61.50	44.50
6/4/09	11.09	17.62	18.26	20.76	20.59	67.41	52.85
7/4/09	10.49	17.65	19.11	21.22	21.54	56.82	52.55
8/4/09	11.06	17.80	19.05	20.90	21.17	56.28	43.95
9/4/09	10.99	16.67	18.76	21.15	21.02	88.96	56.16
10/4/09	11.12	16.08	18.89	20.63	20.81	95.16	65.36
11/4/09	9.98	15.52	18.15	20.34	20.62	91.82	69.11
12/4/09	10.31	15.24	18.31	19.82	19.92	84.23	70.01
13/4/09	11.61	17.28	18.50	21.05	21.07	76.77	67.99
14/4/09	12.12	18.46	18.65	21.76	21.61	83.79	65.41
15/4/09	10.96	17.66	18.72	21.54	21.23	88.33	66.70
16/4/09	9.10	15.71	17.86	20.70	20.35	99.84	65.71
17/4/09	10.20	15.61	16.56	18.75	18.51	85.28	62.56
18/4/09	9.46	16.78	16.52	18.54	18.38	81.73	60.32
19/4/09	10.99	19.23	17.32	19.59	19.49	73.63	56.81
20/4/09	11.75	20.55	18.42	21.21	21.72	62.89	52.93
21/4/09	11.60	19.87	18.90	22.92	22.95	65.62	52.92
22/4/09	12.32	20.47	19.18	23.51	22.96	62.64	47.00
23/4/09	13.94	20.57	19.62	23.07	22.90	63.03	49.05
24/4/09	14.70	21.19	20.28	23.46	23.52	50.94	46.72
25/4/09	11.69	19.15	19.85	22.55	22.16	54.85	43.91
26/4/09	11.69	19.25	19.17	22.32	21.53	58.75	46.08
27/4/09	8.26	16.39	18.90	21.34	20.51	97.60	54.66
28/4/09	9.66	16.87	18.54	20.73	20.32	86.85	56.86
29/4/09	12.10	18.66	19.47	21.86	20.96	61.06	44.61
30/4/09	12.92	17.40	17.71	20.83	20.06	84.38	55.63
Monthly Max	**8.26**	**15.24**	**16.52**	**18.54**	**18.38**	**99.84**	**70.01**
Monthly Average	**11.02**	**17.78**	**18.59**	**21.34**	**21.19**	**74.99**	**55.82**
Monthly Min	**14.70**	**21.19**	**20.28**	**23.51**	**23.52**	**50.94**	**43.91**



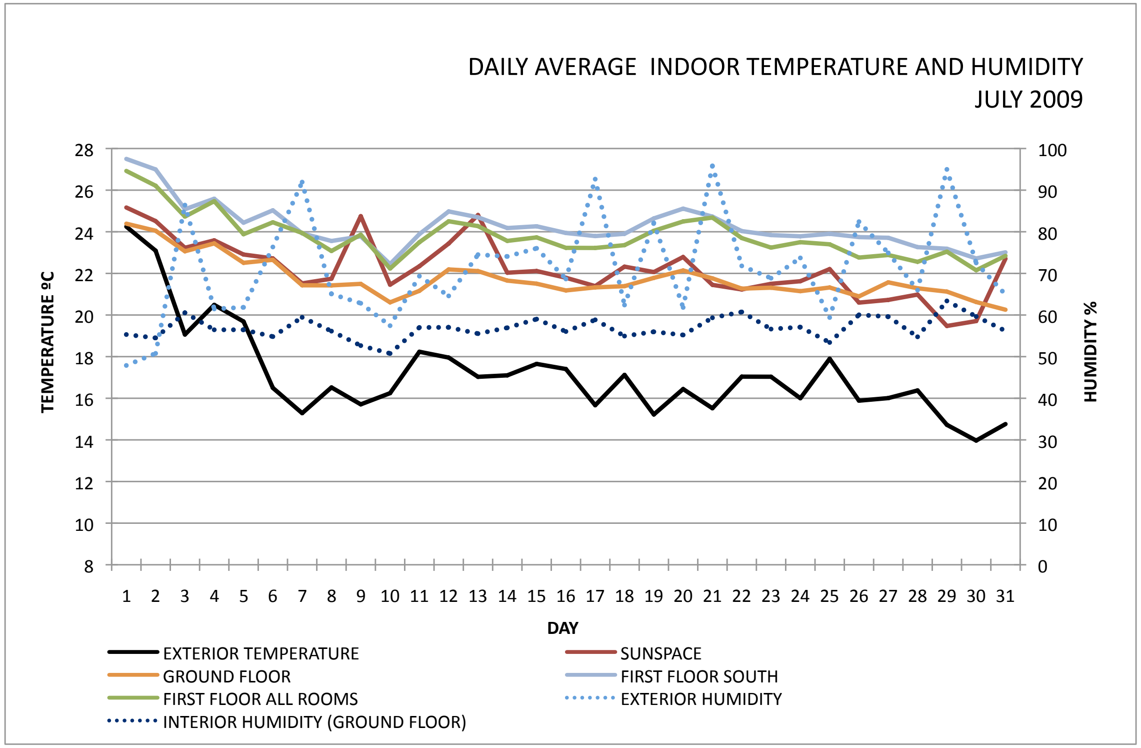
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/5/09	14.0	19.2	19.3	21.8	21.5	73.46	58.3
2/5/09	13.3	20.0	19.0	21.9	21.6	61.28	51.5
3/5/09	11.0	20.0	18.6	21.0	20.7	62.32	43.2
4/5/09	9.2	15.6	17.5	19.4	19.1	88.71	50.3
5/5/09	13.3	16.6	17.8	19.4	18.9	76.70	59.1
6/5/09	14.6	19.1	19.6	21.6	20.9	63.81	59.7
7/5/09	14.0	19.0	19.7	22.1	21.4	52.21	46.8
8/5/09	11.5	18.4	18.9	21.9	21.2	58.98	46.9
9/5/09	11.6	19.3	19.0	21.6	21.0	65.23	50.6
10/5/09	12.5	19.1	19.0	21.6	21.2	64.90	53.3
11/5/09	11.9	19.4	19.4	21.9	21.8	62.03	47.3
12/5/09	12.4	20.3	19.6	22.6	22.2	52.70	47.5
13/5/09	10.9	18.6	19.1	22.0	21.6	79.43	52.5
14/5/09	11.1	17.4	18.8	21.2	21.1	97.93	59.9
15/5/09	11.6	17.0	18.1	20.5	19.9	97.46	62.8
16/5/09	10.5	16.5	18.3	20.4	19.6	83.15	57.7
17/5/09	10.2	16.5	18.2	20.7	19.7	86.18	59.3
18/5/09	12.0	16.9	17.5	20.1	19.3	76.73	59.8
19/5/09	11.7	17.7	17.8	20.4	19.8	83.52	59.5
20/5/09	12.4	18.5	18.5	20.9	20.4	75.65	60.3
21/5/09	13.1	19.7	19.3	21.9	22.0	71.05	57.4
22/5/09	12.6	19.2	19.3	22.5	22.0	71.08	55.4
23/5/09	16.0	19.6	19.0	22.2	22.1	57.15	55.2
24/5/09	17.6	20.8	19.4	22.4	21.9	50.96	51.1
25/5/09	16.0	19.9	19.6	22.4	21.9	63.65	52.7
26/5/09	13.1	20.1	20.0	22.4	21.8	66.33	53.6
27/5/09	13.4	17.9	19.1	21.1	20.5	82.91	54.7
28/5/09	18.0	20.9	19.9	22.7	22.2	71.41	63.2
29/5/09	18.7	22.6	21.3	24.8	24.2	65.56	60.5
30/5/09	16.4	20.7	20.3	24.2	23.0	52.97	48.9
31/5/09	17.4	21.9	21.5	24.6	24.0	61.91	52.9
Monthly Max	**9.23**	**15.63**	**17.45**	**19.38**	**18.89**	**97.93**	**63.17**
Monthly Average	**13.28**	**18.98**	**19.10**	**21.74**	**21.23**	**70.24**	**54.57**
Monthly Min	**18.68**	**22.57**	**21.52**	**24.80**	**24.16**	**50.96**	**43.25**



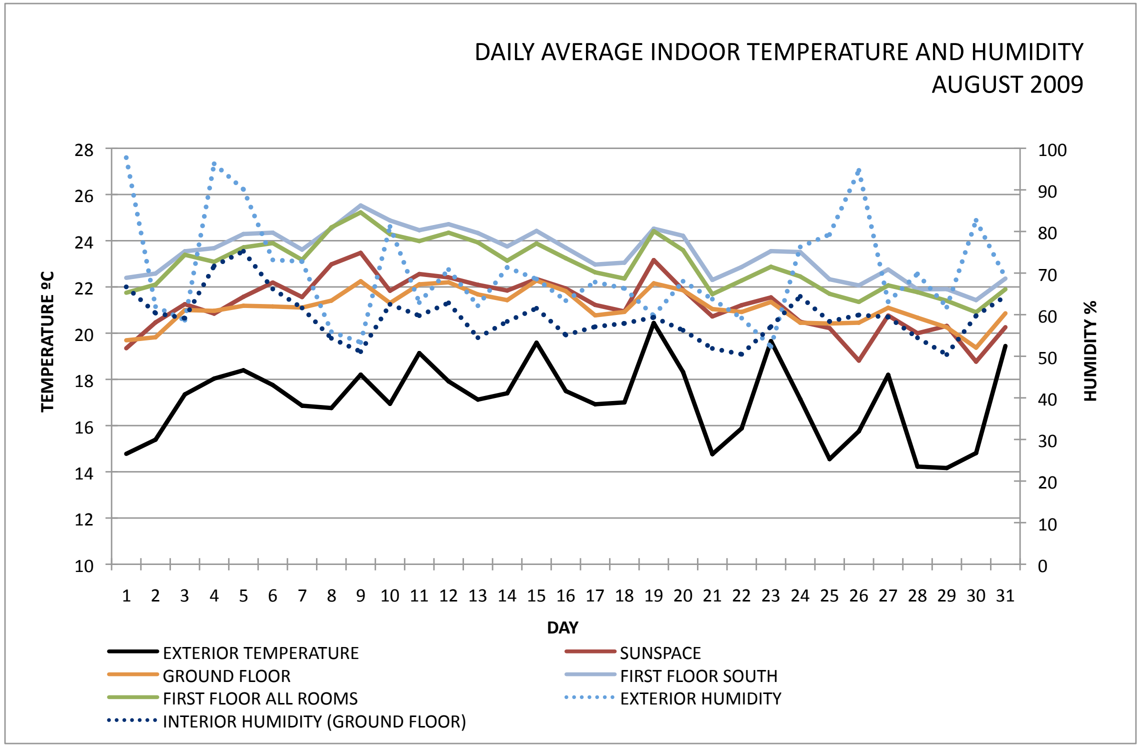
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/6/09	19.8	23.3	22.3	25.2	25.1	42.60	47.1
2/6/09	20.6	26.4	23.0	26.3	26.2	39.67	43.9
3/6/09	14.1	20.5	21.5	23.8	23.3	69.10	48.9
4/6/09	13.3	20.4	21.1	23.4	22.7	56.88	51.3
5/6/09	13.2	20.8	21.5	23.9	23.7	56.68	52.0
6/6/09	11.0	18.4	20.6	22.4	22.0	80.49	51.8
7/6/09	10.0	16.7	19.6	21.0	20.0	94.78	56.0
8/6/09	13.4	18.3	19.4	21.3	20.5	69.85	58.2
9/6/09	13.7	19.1	19.6	21.8	21.2	74.83	56.6
10/6/09	13.8	19.9	20.0	22.8	22.2	77.16	60.0
11/6/09	13.9	20.8	20.6	23.4	22.8	61.18	55.6
12/6/09	15.4	20.1	20.2	23.2	22.4	51.63	47.9
13/6/09	18.8	22.1	21.2	24.2	23.4	52.68	53.1
14/6/09	18.8	23.7	21.9	25.6	25.1	43.85	52.0
15/6/09	16.2	22.0	21.8	25.4	24.7	70.83	52.3
16/6/09	17.9	21.0	20.8	23.9	23.1	60.22	52.9
17/6/09	14.8	22.0	20.7	23.1	22.9	85.03	56.9
18/6/09	14.5	19.8	20.4	22.9	22.3	62.82	53.2
19/6/09	14.4	20.6	20.7	23.0	22.4	61.17	53.2
20/6/09	14.5	21.0	20.7	22.8	22.5	71.97	53.4
21/6/09	16.4	20.0	19.5	21.4	20.9	63.67	55.7
22/6/09	18.0	21.6	20.6	23.3	22.7	70.99	58.7
23/6/09	21.0	23.0	22.0	25.1	24.5	62.86	62.2
24/6/09	18.1	22.0	21.6	24.2	24.0	64.39	51.3
25/6/09	18.7	22.9	22.2	25.2	24.6	64.43	54.1
26/6/09	18.6	23.5	22.6	25.9	25.4	78.72	57.3
27/6/09	19.1	22.5	22.3	25.2	25.0	83.76	63.7
28/6/09	20.7	23.2	22.4	25.4	24.6	74.59	62.8
29/6/09	21.4	23.8	23.1	25.6	25.0	70.44	62.7
30/6/09	23.2	24.6	23.5	26.4	25.8	55.27	59.8
Monthly Max	**10.05**	**16.67**	**19.44**	**21.05**	**19.95**	**94.78**	**63.70**
Monthly Average	**16.59**	**21.47**	**21.26**	**23.91**	**23.37**	**65.75**	**54.83**
Monthly Min	**23.21**	**26.37**	**23.53**	**26.39**	**26.15**	**39.67**	**43.94**



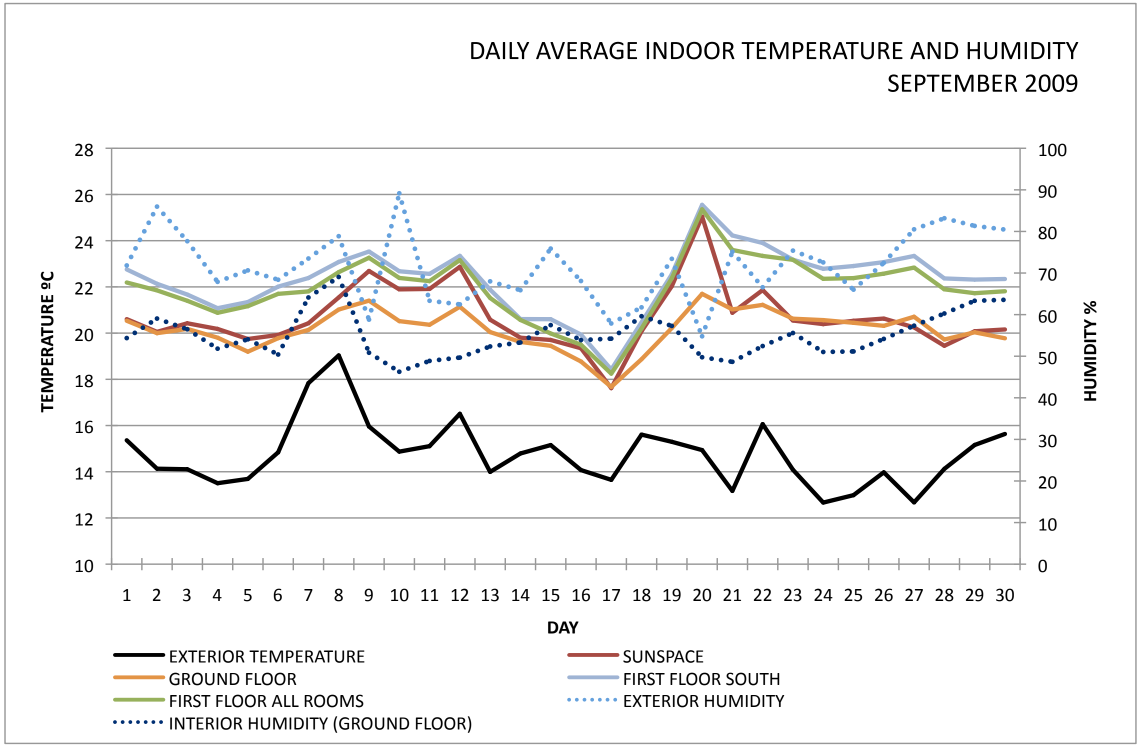
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/7/09	24.2	25.2	24.4	27.5	26.9	47.88	55.3
2/7/09	23.1	24.5	24.0	27.0	26.2	50.78	54.5
3/7/09	19.1	23.2	23.1	25.1	24.7	86.40	60.5
4/7/09	20.5	23.6	23.4	25.6	25.5	61.47	56.5
5/7/09	19.7	22.9	22.5	24.4	23.9	61.84	56.5
6/7/09	16.5	22.7	22.7	25.0	24.5	76.34	54.8
7/7/09	15.3	21.5	21.4	23.9	23.9	91.93	59.4
8/7/09	16.5	21.7	21.4	23.6	23.1	65.06	56.1
9/7/09	15.7	24.8	21.5	23.8	23.9	62.82	52.6
10/7/09	16.2	21.5	20.6	22.4	22.2	57.44	50.8
11/7/09	18.2	22.3	21.2	23.9	23.5	69.34	57.0
12/7/09	18.0	23.4	22.2	25.0	24.5	64.59	57.0
13/7/09	17.0	24.8	22.1	24.7	24.3	74.50	55.5
14/7/09	17.1	22.0	21.7	24.2	23.6	74.07	56.9
15/7/09	17.7	22.1	21.5	24.3	23.7	76.02	59.0
16/7/09	17.4	21.8	21.2	23.9	23.2	68.66	56.0
17/7/09	15.7	21.4	21.3	23.8	23.2	92.64	58.8
18/7/09	17.1	22.3	21.4	23.9	23.4	62.41	54.9
19/7/09	15.2	22.1	21.8	24.6	24.0	82.12	56.0
20/7/09	16.4	22.8	22.1	25.1	24.5	61.82	55.2
21/7/09	15.5	21.4	21.8	24.7	24.7	95.84	59.3
22/7/09	17.0	21.2	21.3	24.0	23.7	71.80	60.7
23/7/09	17.0	21.5	21.3	23.8	23.2	68.85	56.6
24/7/09	16.0	21.6	21.1	23.8	23.5	73.71	57.1
25/7/09	17.9	22.2	21.3	23.9	23.4	59.40	53.4
26/7/09	15.9	20.6	20.9	23.7	22.8	82.42	60.0
27/7/09	16.0	20.7	21.6	23.7	22.9	74.92	59.6
28/7/09	16.4	21.0	21.3	23.3	22.6	65.99	54.8
29/7/09	14.7	19.5	21.1	23.2	23.0	94.99	63.4
30/7/09	14.0	19.7	20.6	22.7	22.2	72.51	59.6
31/7/09	14.8	22.7	20.3	23.0	22.8	64.92	56.2
Monthly Max	**13.97**	**19.47**	**20.25**	**22.45**	**22.15**	**95.84**	**63.38**
Monthly Average	**17.16**	**22.22**	**21.74**	**24.25**	**23.79**	**71.40**	**56.92**
Monthly Min	**24.25**	**25.17**	**24.39**	**27.50**	**26.92**	**47.88**	**50.76**



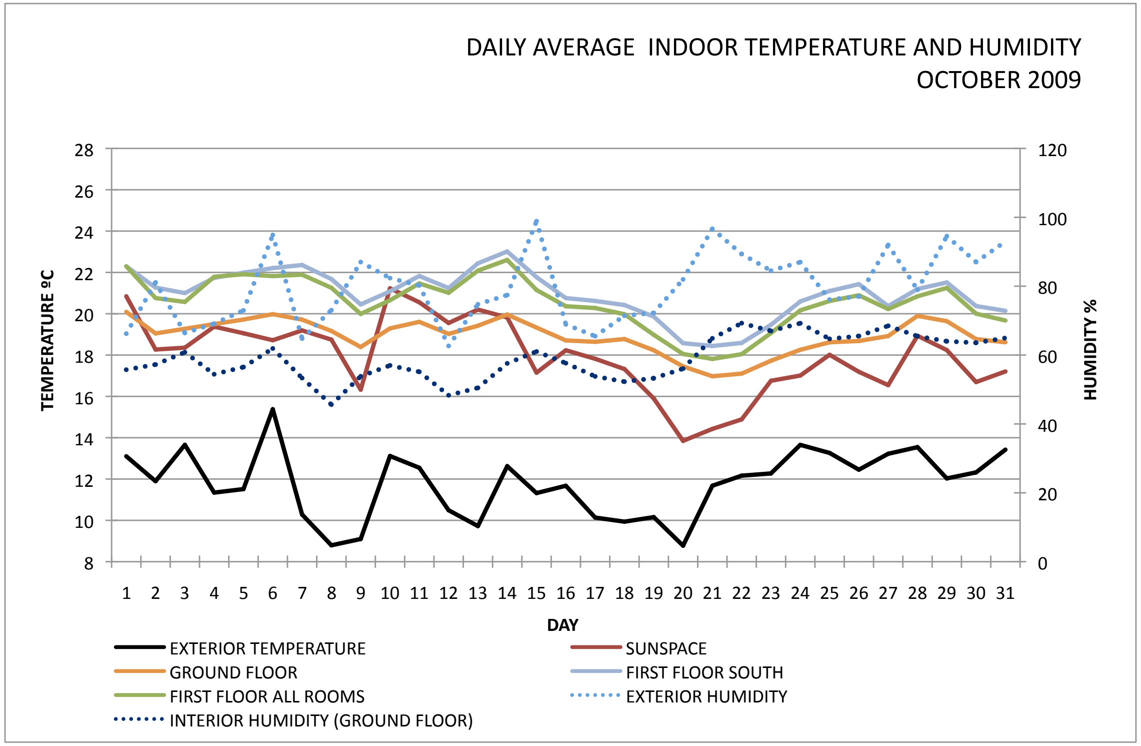
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/8/09	14.8	19.3	19.7	22.4	21.7	97.75	66.7
2/8/09	15.4	20.5	19.8	22.6	22.1	61.94	60.4
3/8/09	17.4	21.3	21.0	23.5	23.4	58.67	59.2
4/8/09	18.0	20.8	21.0	23.7	23.1	96.27	71.7
5/8/09	18.4	21.6	21.2	24.3	23.7	90.12	75.2
6/8/09	17.8	22.2	21.2	24.3	23.9	73.17	66.2
7/8/09	16.9	21.6	21.1	23.6	23.2	72.78	61.6
8/8/09	16.8	23.0	21.4	24.5	24.6	55.89	54.3
9/8/09	18.2	23.5	22.2	25.5	25.2	53.33	51.1
10/8/09	16.9	21.8	21.3	24.9	24.3	81.19	62.5
11/8/09	19.1	22.6	22.1	24.5	24.0	62.92	59.8
12/8/09	17.9	22.4	22.2	24.7	24.3	70.84	62.8
13/8/09	17.1	22.1	21.7	24.3	23.9	62.15	54.5
14/8/09	17.4	21.8	21.4	23.8	23.1	71.35	58.4
15/8/09	19.6	22.3	22.3	24.4	23.9	68.54	61.5
16/8/09	17.5	21.9	21.8	23.7	23.2	63.37	55.1
17/8/09	16.9	21.2	20.8	23.0	22.6	67.83	57.1
18/8/09	17.0	20.9	20.9	23.1	22.4	66.31	57.9
19/8/09	20.4	23.2	22.2	24.5	24.4	59.75	59.4
20/8/09	18.3	21.9	21.9	24.2	23.6	68.03	56.3
21/8/09	14.8	20.7	21.0	22.3	21.7	63.74	51.9
22/8/09	15.9	21.2	20.9	22.9	22.3	59.17	50.5
23/8/09	19.7	21.5	21.4	23.6	22.9	52.34	57.1
24/8/09	17.1	20.5	20.5	23.5	22.5	76.28	64.4
25/8/09	14.6	20.2	20.4	22.3	21.7	79.28	58.4
26/8/09	15.8	18.8	20.5	22.1	21.4	94.69	59.9
27/8/09	18.2	20.8	21.1	22.8	22.1	63.10	59.4
28/8/09	14.2	20.0	20.7	21.9	21.8	69.80	54.4
29/8/09	14.2	20.3	20.3	21.9	21.4	61.82	50.4
30/8/09	14.8	18.8	19.4	21.4	20.9	82.68	59.7
31/8/09	19.4	20.3	20.9	22.4	21.9	68.93	64.4
Monthly Max	**14.16**	**18.77**	**19.37**	**21.43**	**20.90**	**97.75**	**75.24**
Monthly Average	**17.11**	**21.26**	**21.10**	**23.44**	**22.94**	**70.13**	**59.43**
Monthly Min	**20.44**	**23.48**	**22.28**	**25.53**	**25.23**	**52.34**	**50.42**



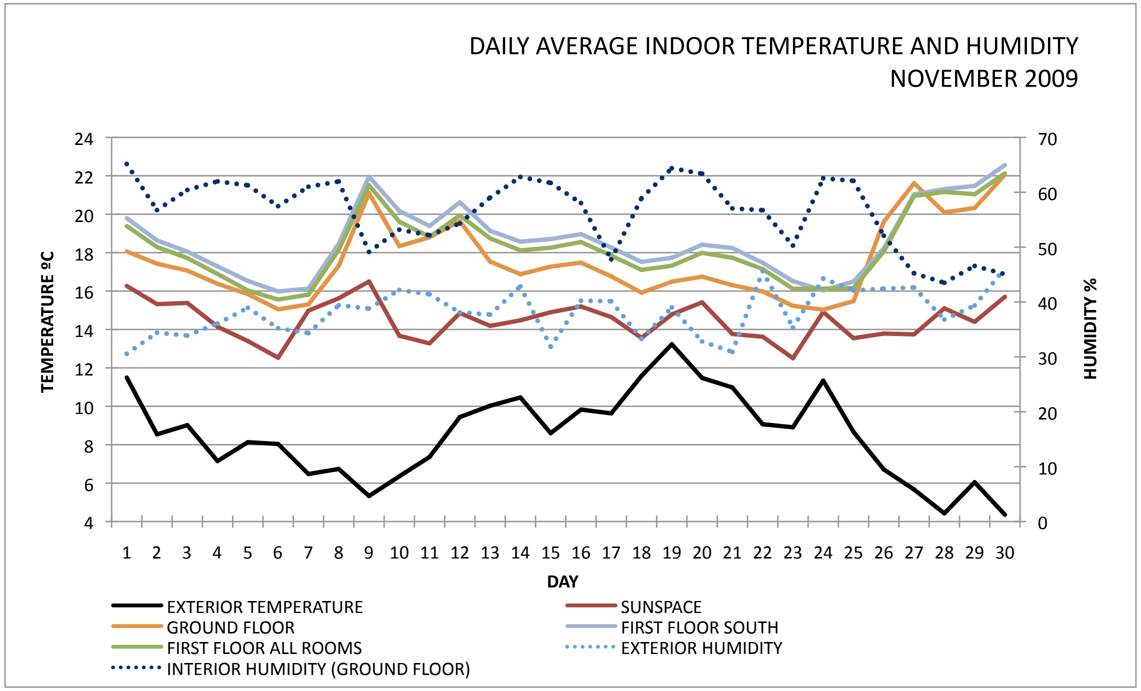
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/9/09	15.4	20.6	20.5	22.8	22.2	71.82	54.4
2/9/09	14.1	20.1	20.0	22.1	21.8	85.97	59.1
3/9/09	14.1	20.4	20.2	21.7	21.4	77.65	56.5
4/9/09	13.5	20.2	19.8	21.1	20.9	67.89	51.8
5/9/09	13.7	19.7	19.2	21.3	21.2	70.64	54.1
6/9/09	14.8	19.9	19.8	22.0	21.7	68.39	50.4
7/9/09	17.8	20.4	20.1	22.4	21.8	73.49	64.1
8/9/09	19.0	21.5	21.0	23.1	22.6	78.86	69.1
9/9/09	16.0	22.7	21.4	23.5	23.3	58.80	50.8
10/9/09	14.9	21.9	20.5	22.7	22.4	89.17	46.3
11/9/09	15.1	21.9	20.4	22.6	22.2	63.33	48.9
12/9/09	16.5	22.9	21.1	23.3	23.2	62.46	49.7
13/9/09	14.0	20.6	20.0	21.9	21.5	68.00	52.3
14/9/09	14.8	19.8	19.6	20.6	20.6	65.88	53.3
15/9/09	15.2	19.7	19.5	20.6	20.0	75.88	57.5
16/9/09	14.1	19.3	18.8	19.9	19.5	68.08	53.9
17/9/09	13.6	17.6	17.7	18.4	18.2	57.88	54.2
18/9/09	15.6	20.1	18.9	20.5	20.2	61.75	59.6
19/9/09	15.3	22.0	20.2	22.5	22.4	73.42	57.3
20/9/09	14.9	25.0	21.7	25.5	25.4	54.79	49.8
21/9/09	13.2	20.9	21.0	24.2	23.6	75.13	48.7
22/9/09	16.1	21.9	21.2	23.9	23.3	66.58	52.4
23/9/09	14.1	20.5	20.6	23.2	23.2	75.39	55.6
24/9/09	12.7	20.4	20.6	22.8	22.4	72.56	51.0
25/9/09	13.0	20.5	20.4	22.9	22.4	66.01	51.1
26/9/09	14.0	20.6	20.3	23.1	22.6	72.44	54.2
27/9/09	12.7	20.2	20.7	23.3	22.8	80.51	57.3
28/9/09	14.1	19.5	19.7	22.4	21.9	83.17	60.3
29/9/09	15.2	20.1	20.0	22.3	21.7	81.33	63.3
30/9/09	15.6	20.2	19.8	22.3	21.8	80.45	63.6
Monthly Max	**12.67**	**17.62**	**17.67**	**18.42**	**18.25**	**89.17**	**69.06**
Monthly Average	**14.77**	**20.71**	**20.16**	**22.30**	**21.94**	**71.59**	**55.01**
Monthly Min	**19.04**	**25.04**	**21.70**	**25.55**	**25.36**	**54.79**	**46.26**



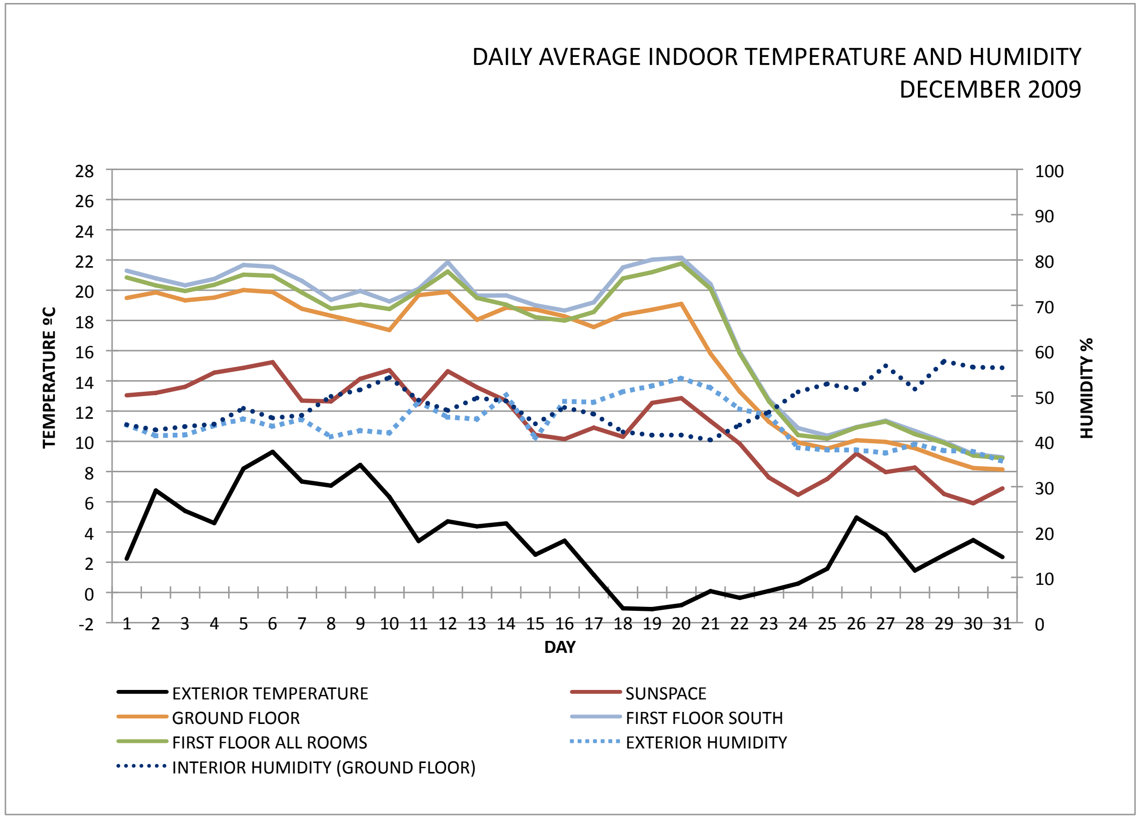
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/10/09	13.1	20.8	20.1	22.3	22.3	66.21	55.7
2/10/09	11.9	18.3	19.0	21.3	20.8	81.10	57.3
3/10/09	13.7	18.4	19.3	21.0	20.6	66.41	60.8
4/10/09	11.3	19.4	19.5	21.7	21.8	69.12	54.4
5/10/09	11.5	19.1	19.7	22.0	21.9	72.98	56.5
6/10/09	15.4	18.7	20.0	22.2	21.8	94.86	61.9
7/10/09	10.3	19.2	19.7	22.4	21.9	64.77	53.3
8/10/09	8.8	18.7	19.2	21.7	21.3	73.03	45.6
9/10/09	9.1	16.3	18.4	20.4	20.0	87.01	53.8
10/10/09	13.1	21.2	19.3	21.1	20.7	82.34	57.0
11/10/09	12.5	20.6	19.6	21.8	21.5	80.23	55.1
12/10/09	10.5	19.6	19.0	21.2	21.0	62.66	48.3
13/10/09	9.7	20.2	19.4	22.4	22.1	74.75	50.5
14/10/09	12.6	19.8	20.0	23.0	22.6	77.43	57.6
15/10/09	11.3	17.1	19.3	21.8	21.2	98.87	61.0
16/10/09	11.7	18.2	18.7	20.8	20.4	68.90	57.7
17/10/09	10.1	17.8	18.6	20.6	20.3	65.48	53.8
18/10/09	9.9	17.3	18.8	20.4	20.0	71.42	52.3
19/10/09	10.2	15.9	18.2	19.9	19.0	72.23	53.3
20/10/09	8.8	13.8	17.5	18.6	18.1	81.98	56.1
21/10/09	11.7	14.4	17.0	18.4	17.8	96.65	64.9
22/10/09	12.2	14.9	17.1	18.6	18.0	89.34	69.3
23/10/09	12.3	16.8	17.7	19.5	19.1	84.51	67.0
24/10/09	13.7	17.0	18.3	20.6	20.2	86.99	69.2
25/10/09	13.3	18.0	18.6	21.1	20.6	76.11	64.7
26/10/09	12.5	17.2	18.7	21.4	20.9	77.03	65.5
27/10/09	13.2	16.5	18.9	20.4	20.2	91.96	68.5
28/10/09	13.5	18.9	19.9	21.2	20.8	78.95	65.5
29/10/09	12.0	18.2	19.6	21.5	21.2	94.52	64.0
30/10/09	12.3	16.7	18.8	20.4	20.0	87.01	63.6
31/10/09	13.4	17.2	18.6	20.1	19.7	92.97	65.0
Monthly Max	**8.78**	**13.85**	**16.97**	**18.44**	**17.81**	**98.87**	**69.26**
Monthly Average	**11.79**	**17.95**	**18.92**	**20.96**	**20.56**	**79.61**	**59.00**
Monthly Min	**15.38**	**21.23**	**20.09**	**23.01**	**22.60**	**62.66**	**45.62**



DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/11/09	11.50	16.27	18.06	19.80	19.38	30.58	65.2
2/11/09	8.54	15.32	17.42	18.64	18.29	34.41	56.8
3/11/09	9.02	15.38	17.07	18.05	17.72	33.88	60.4
4/11/09	7.15	14.14	16.38	17.28	16.89	36.08	62.0
5/11/09	8.13	13.40	15.84	16.53	16.03	38.95	61.3
6/11/09	8.04	12.53	15.05	15.98	15.56	35.22	57.5
7/11/09	6.47	14.98	15.31	16.13	15.81	34.34	61.0
8/11/09	6.74	15.62	17.31	18.46	18.14	39.42	62.0
9/11/09	5.33	16.50	21.10	21.95	21.51	38.82	49.1
10/11/09	6.35	13.67	18.34	20.17	19.61	42.20	53.2
11/11/09	7.36	13.28	18.80	19.39	18.83	41.41	52.2
12/11/09	9.44	14.85	19.64	20.62	19.94	38.10	54.3
13/11/09	10.03	14.19	17.53	19.14	18.74	37.72	59.0
14/11/09	10.46	14.48	16.88	18.57	18.12	42.85	62.8
15/11/09	8.60	14.90	17.27	18.71	18.26	31.86	61.7
16/11/09	9.83	15.20	17.48	18.96	18.55	40.24	58.0
17/11/09	9.63	14.65	16.76	18.27	17.85	40.14	47.8
18/11/09	11.58	13.56	15.91	17.52	17.10	33.30	58.9
19/11/09	13.23	14.78	16.49	17.73	17.32	39.01	64.4
20/11/09	11.48	15.41	16.75	18.41	17.99	32.82	63.4
21/11/09	10.98	13.77	16.31	18.24	17.73	30.91	57.1
22/11/09	9.07	13.62	15.98	17.47	17.15	45.63	56.7
23/11/09	8.91	12.51	15.23	16.52	16.12	35.35	50.3
24/11/09	11.34	14.91	15.03	16.03	16.13	44.28	62.6
25/11/09	8.67	13.55	15.47	16.50	16.15	42.10	62.1
26/11/09	6.71	13.79	19.61	18.22	18.06	42.43	52.1
27/11/09	5.67	13.74	21.61	21.04	20.95	42.65	45.2
28/11/09	4.43	15.10	20.10	21.31	21.16	36.81	43.5
29/11/09	6.04	14.39	20.32	21.47	21.04	39.37	46.6
30/11/09	4.36	15.70	22.06	22.56	22.13	46.15	45.1
Monthly Max	**13.23**	**16.50**	**22.06**	**22.56**	**22.13**	**46.15**	**65.15**
Monthly Average	**8.50**	**14.47**	**17.57**	**18.66**	**18.28**	**38.23**	**56.40**
Monthly Min	**4.36**	**12.51**	**15.03**	**15.98**	**15.56**	**30.58**	**43.51**

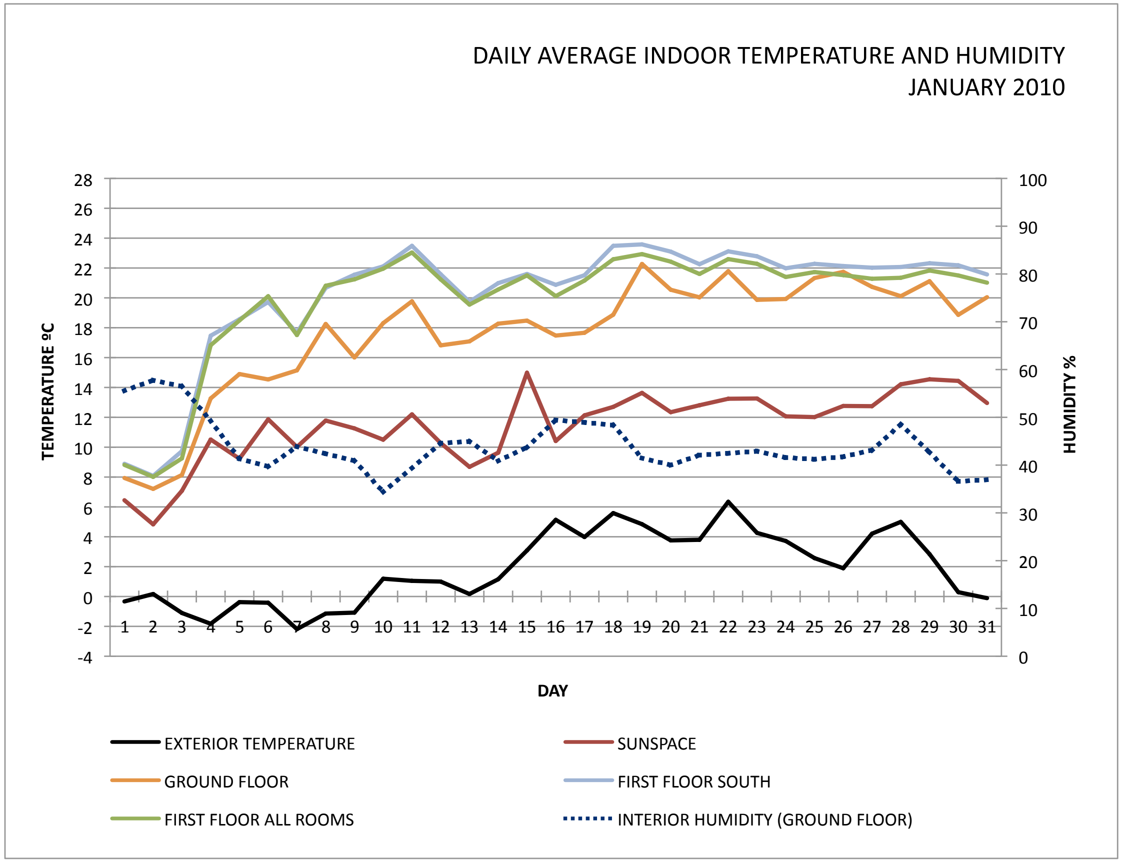


DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	EXTERIOR HUMIDITY	INTERIOR HUMIDITY (GROUND FLOOR)
1/12/09	2.23	13.05	19.49	21.29	20.84	43.61	43.7
2/12/09	6.74	13.20	19.85	20.79	20.32	41.23	42.5
3/12/09	5.40	13.61	19.33	20.32	19.95	41.43	43.3
4/12/09	4.59	14.55	19.51	20.75	20.36	43.47	43.8
5/12/09	8.20	14.86	20.01	21.67	21.03	44.92	47.3
6/12/09	9.31	15.24	19.88	21.55	20.96	43.34	45.2
7/12/09	7.34	12.69	18.77	20.62	19.85	44.82	45.7
8/12/09	7.07	12.64	18.31	19.36	18.78	41.04	49.9
9/12/09	8.44	14.14	17.86	19.95	19.05	42.36	51.4
10/12/09	6.32	14.71	17.36	19.26	18.76	41.88	54.1
11/12/09	3.41	12.45	19.67	20.09	19.95	48.71	49.1
12/12/09	4.71	14.64	19.89	21.86	21.24	45.32	46.8
13/12/09	4.37	13.58	18.04	19.64	19.49	44.93	49.6
14/12/09	4.57	12.68	18.84	19.65	19.04	50.23	48.9
15/12/09	2.50	10.43	18.73	19.00	18.21	40.78	43.9
16/12/09	3.42	10.15	18.27	18.65	17.99	48.82	47.5
17/12/09	1.17	10.91	17.56	19.19	18.56	48.64	46.0
18/12/09	-1.05	10.30	18.37	21.51	20.78	50.95	42.1
19/12/09	-1.10	12.54	18.71	22.02	21.19	52.24	41.4
20/12/09	-0.84	12.86	19.10	22.15	21.77	53.87	41.4
21/12/09	0.09	11.33	15.80	20.41	20.10	51.80	40.3
22/12/09	-0.36	9.85	13.29	15.92	15.82	47.10	43.6
23/12/09	0.10	7.61	11.29	12.76	12.65	45.73	46.5
24/12/09	0.59	6.46	9.92	10.88	10.41	38.57	50.9
25/12/09	1.57	7.51	9.52	10.37	10.18	38.10	52.7
26/12/09	4.95	9.19	10.07	10.94	10.92	38.09	51.4
27/12/09	3.80	7.96	9.96	11.36	11.31	37.44	56.7
28/12/09	1.45	8.26	9.54	10.69	10.48	39.37	51.5
29/12/09	2.48	6.52	8.84	9.97	9.90	37.96	57.7
30/12/09	3.46	5.90	8.23	9.16	9.06	37.72	56.4
31/12/09	2.34	6.89	8.14	8.95	8.89	35.6	56.2
Monthly Max	**9.31**	**15.24**	**20.01**	**22.15**	**21.77**	**53.87**	**57.65**
Monthly Average	**3.46**	**11.18**	**15.88**	**17.44**	**17.03**	**43.87**	**47.97**
Monthly Min	**-1.10**	**5.90**	**8.14**	**8.95**	**8.89**	**35.61**	**40.30**

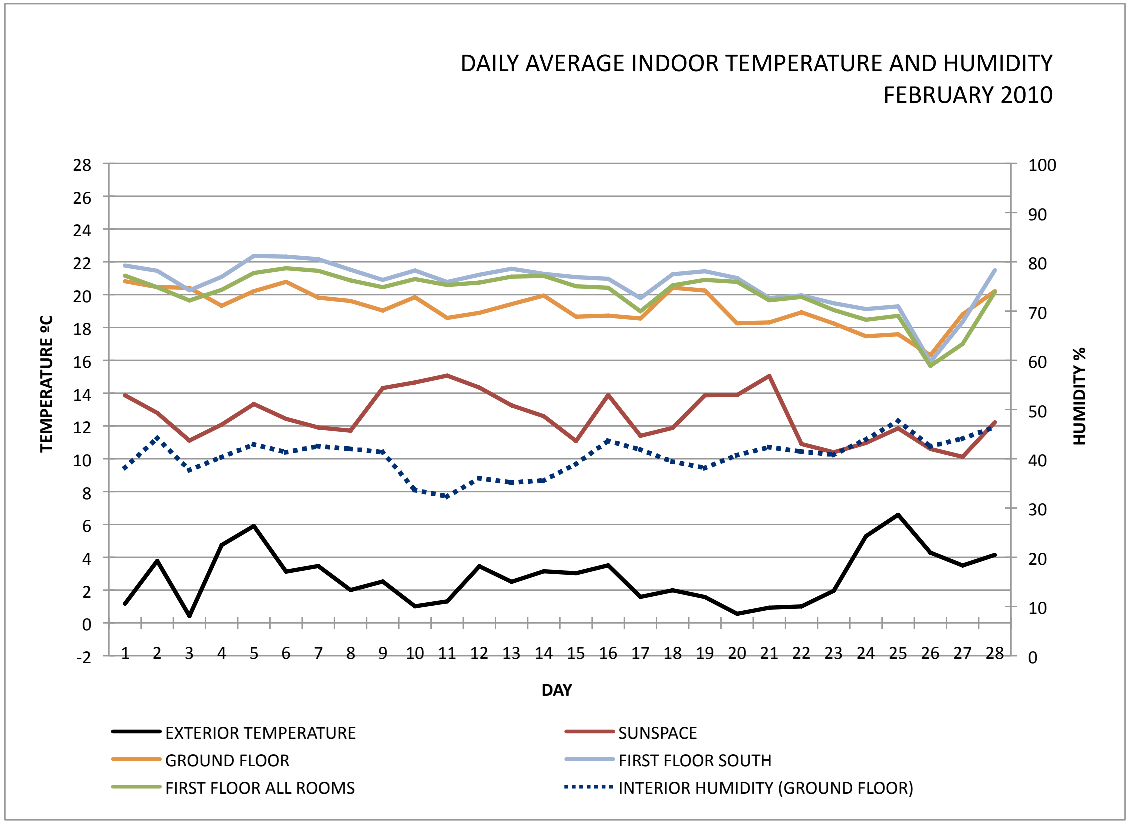


EXTERIOR AND INTERIOR AVERAGE TEMPERATURES AND HUMIDITY OF THE BASF HOUSE - YEAR 2010

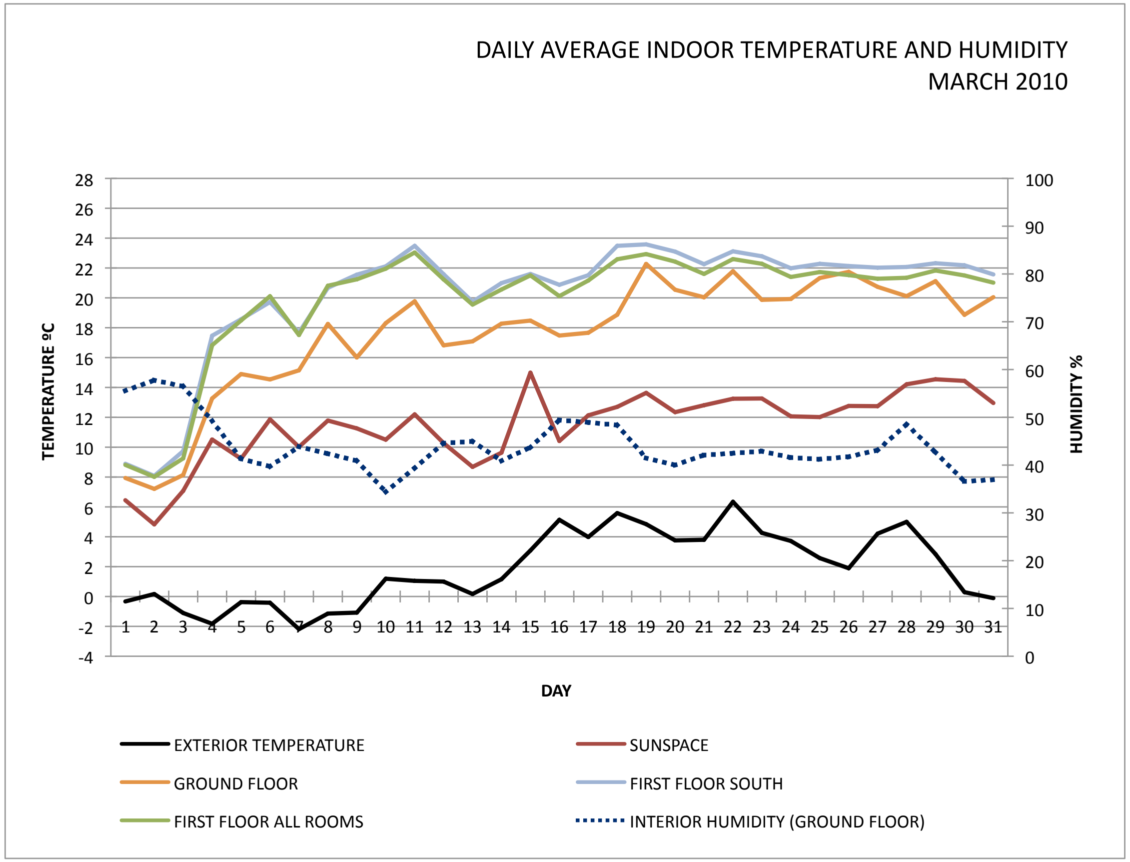
DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/1/10	-0.33	6.45	7.94	8.89	8.81	55.6
2/1/10	0.17	4.83	7.21	8.08	8.01	57.8
3/1/10	-1.10	7.08	8.14	9.74	9.25	56.5
4/1/10	-1.83	10.51	13.26	17.47	16.83	49.2
5/1/10	-0.38	9.23	14.90	18.57	18.49	41.3
6/1/10	-0.42	11.87	14.54	19.72	20.11	39.7
7/1/10	-2.19	10.01	15.15	17.67	17.51	43.9
8/1/10	-1.14	11.78	18.25	20.67	20.81	42.4
9/1/10	-1.08	11.26	16.01	21.55	21.24	40.9
10/1/10	1.19	10.50	18.31	22.11	21.96	34.4
11/1/10	1.05	12.20	19.77	23.49	23.04	39.4
12/1/10	1.00	10.27	16.82	21.58	21.24	44.6
13/1/10	0.17	8.68	17.09	19.74	19.55	44.9
14/1/10	1.16	9.63	18.27	20.99	20.56	40.9
15/1/10	3.08	14.99	18.48	21.60	21.51	43.7
16/1/10	5.14	10.41	17.48	20.87	20.12	49.4
17/1/10	3.98	12.13	17.66	21.52	21.16	48.9
18/1/10	5.59	12.70	18.87	23.48	22.58	48.4
19/1/10	4.84	13.64	22.27	23.58	22.93	41.5
20/1/10	3.76	12.34	20.54	23.10	22.43	40.0
21/1/10	3.80	12.81	20.04	22.26	21.60	42.1
22/1/10	6.34	13.24	21.79	23.12	22.60	42.5
23/1/10	4.26	13.26	19.87	22.78	22.28	42.9
24/1/10	3.72	12.06	19.92	21.98	21.40	41.6
25/1/10	2.57	12.02	21.33	22.28	21.73	41.2
26/1/10	1.89	12.76	21.74	22.13	21.52	41.8
27/1/10	4.21	12.75	20.74	22.02	21.28	43.1
28/1/10	5.00	14.21	20.11	22.07	21.34	48.5
29/1/10	2.84	14.55	21.12	22.32	21.83	42.7
30/1/10	0.29	14.44	18.86	22.18	21.50	36.6
31/1/10	-0.11	12.96	20.05	21.57	21.02	36.9
Monthly Max	**-2.19**	**4.83**	**7.21**	**8.08**	**8.01**	**57.75**
Monthly Average	**1.85**	**11.47**	**17.63**	**20.29**	**19.88**	**43.98**
Monthly Min	**6.34**	**14.99**	**22.27**	**23.58**	**23.04**	**34.41**



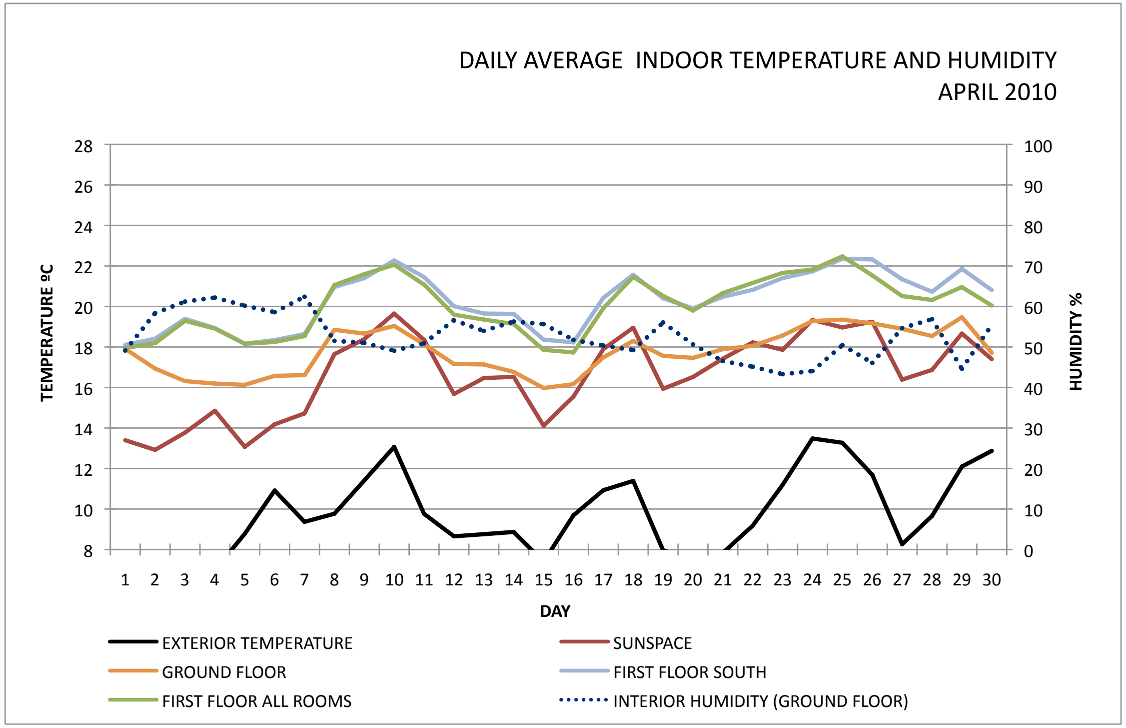
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/2/10	1.17	13.87	20.82	21.77	21.16	38.23
2/2/10	3.78	12.80	20.46	21.45	20.45	44.18
3/2/10	0.42	11.11	20.42	20.27	19.65	37.72
4/2/10	4.74	12.08	19.32	21.09	20.29	40.35
5/2/10	5.91	13.34	20.21	22.36	21.32	42.91
6/2/10	3.12	12.43	20.78	22.32	21.61	41.34
7/2/10	3.47	11.91	19.82	22.16	21.45	42.55
8/2/10	2.00	11.71	19.62	21.52	20.87	42.00
9/2/10	2.52	14.31	19.03	20.90	20.45	41.34
10/2/10	1.01	14.65	19.85	21.47	20.95	33.63
11/2/10	1.31	15.07	18.58	20.77	20.59	32.37
12/2/10	3.45	14.34	18.89	21.21	20.74	36.04
13/2/10	2.50	13.25	19.43	21.58	21.10	35.20
14/2/10	3.15	12.59	19.94	21.27	21.14	35.60
15/2/10	3.03	11.08	18.66	21.07	20.51	38.96
16/2/10	3.51	13.89	18.72	20.97	20.42	43.64
17/2/10	1.59	11.40	18.55	19.79	18.98	41.85
18/2/10	1.99	11.88	20.43	21.24	20.57	39.40
19/2/10	1.58	13.87	20.25	21.43	20.90	38.15
20/2/10	0.56	13.89	18.25	21.01	20.78	40.75
21/2/10	0.93	15.05	18.31	19.79	19.66	42.35
22/2/10	1.01	10.90	18.92	19.95	19.86	41.46
23/2/10	1.96	10.40	18.24	19.48	19.06	40.85
24/2/10	5.29	10.97	17.46	19.12	18.47	43.94
25/2/10	6.59	11.86	17.59	19.29	18.71	47.69
26/2/10	4.28	10.60	16.31	15.91	15.66	42.53
27/2/10	3.50	10.12	18.80	18.34	17.00	44.12
28/2/10	4.15	12.22	20.21	21.49	20.15	46.45
Monthly Max	**0.42**	**10.12**	**16.31**	**15.91**	**15.66**	**47.69**
Monthly Average	**2.80**	**12.56**	**19.21**	**20.68**	**20.09**	**40.56**
Monthly Min	**6.59**	**15.07**	**20.82**	**22.36**	**21.61**	**32.37**



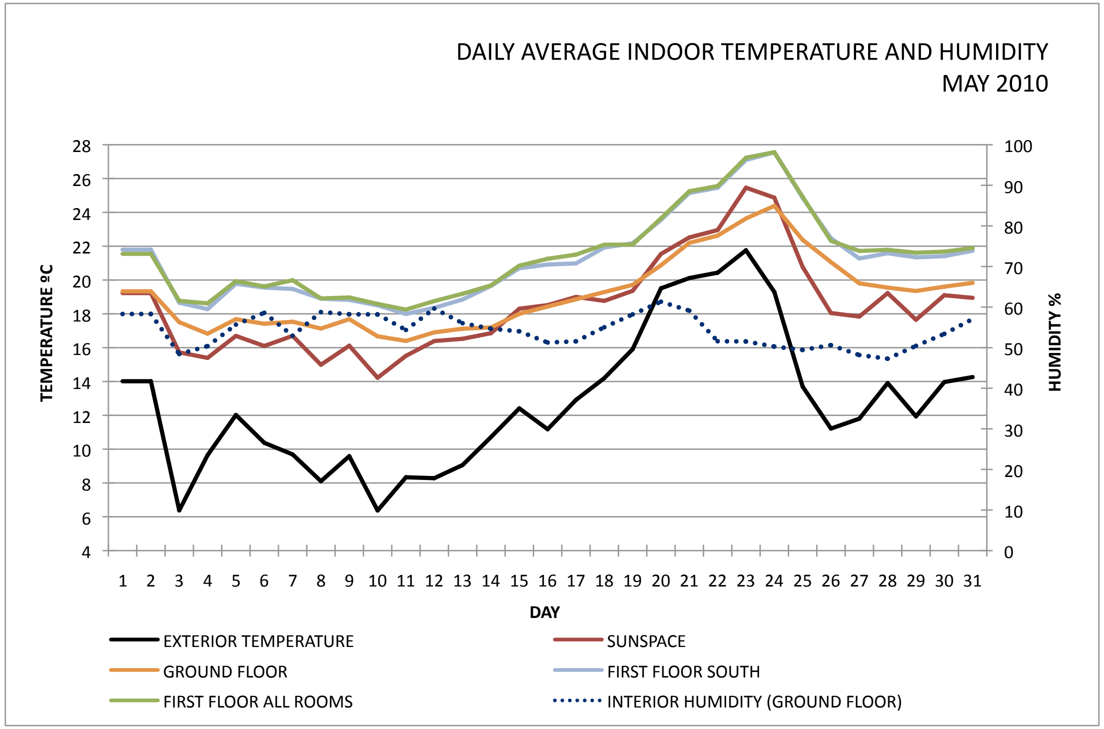
DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/3/10	3.92	17.86	20.47	22.41	21.81	41.4
2/3/10	3.27	19.02	19.19	21.91	21.79	42.8
3/3/10	2.84	14.02	17.21	19.63	19.58	44.5
4/3/10	3.13	14.94	17.02	18.32	18.39	46.2
5/3/10	3.45	16.48	19.36	18.64	19.23	39.1
6/3/10	3.52	13.67	17.21	18.25	18.60	44.3
7/3/10	0.77	16.14	17.84	20.49	20.62	46.4
8/3/10	2.24	15.57	17.24	20.22	20.20	46.0
9/3/10	5.59	16.72	19.95	21.96	21.84	41.5
10/3/10	4.44	14.37	18.42	21.10	20.70	44.4
11/3/10	3.57	14.03	19.34	20.97	20.70	38.6
12/3/10	5.66	14.31	19.33	21.31	21.09	40.0
13/3/10	6.08	17.31	18.52	21.15	21.29	43.8
14/3/10	7.41	17.41	17.61	20.48	20.77	46.6
15/3/10	6.68	18.01	17.45	19.66	20.07	44.8
16/3/10	6.97	15.82	17.28	19.57	19.59	45.5
17/3/10	9.52	15.36	16.18	18.48	18.63	47.5
18/3/10	11.05	14.23	15.76	18.04	17.98	51.2
19/3/10	10.53	16.49	17.12	19.43	19.59	52.3
20/3/10	10.18	14.91	16.84	19.79	19.84	61.6
21/3/10	6.97	14.92	16.76	19.49	19.35	63.7
22/3/10	8.06	15.14	18.06	19.46	19.46	51.9
23/3/10	7.62	14.24	16.91	18.90	18.88	51.9
24/3/10	11.01	15.01	16.39	18.89	18.75	59.1
25/3/10	11.57	16.68	17.21	19.92	19.96	60.2
26/3/10	9.50	17.15	17.30	20.57	20.60	54.7
27/3/10	9.39	17.52	17.66	20.67	20.84	52.9
28/3/10	8.36	18.74	18.86	21.48	21.53	51.7
29/3/10	7.70	15.01	17.91	20.26	20.32	54.5
30/3/10	8.46	14.42	18.04	19.45	19.33	64.0
31/3/10	4.38	12.19	17.15	18.23	17.93	56.3
Monthly Max	**0.77**	**12.19**	**15.76**	**18.04**	**17.93**	**64.02**
Monthly Average	**6.58**	**15.73**	**17.79**	**19.97**	**19.98**	**49.33**
Monthly Min	**11.57**	**19.02**	**20.47**	**22.41**	**21.84**	**38.62**



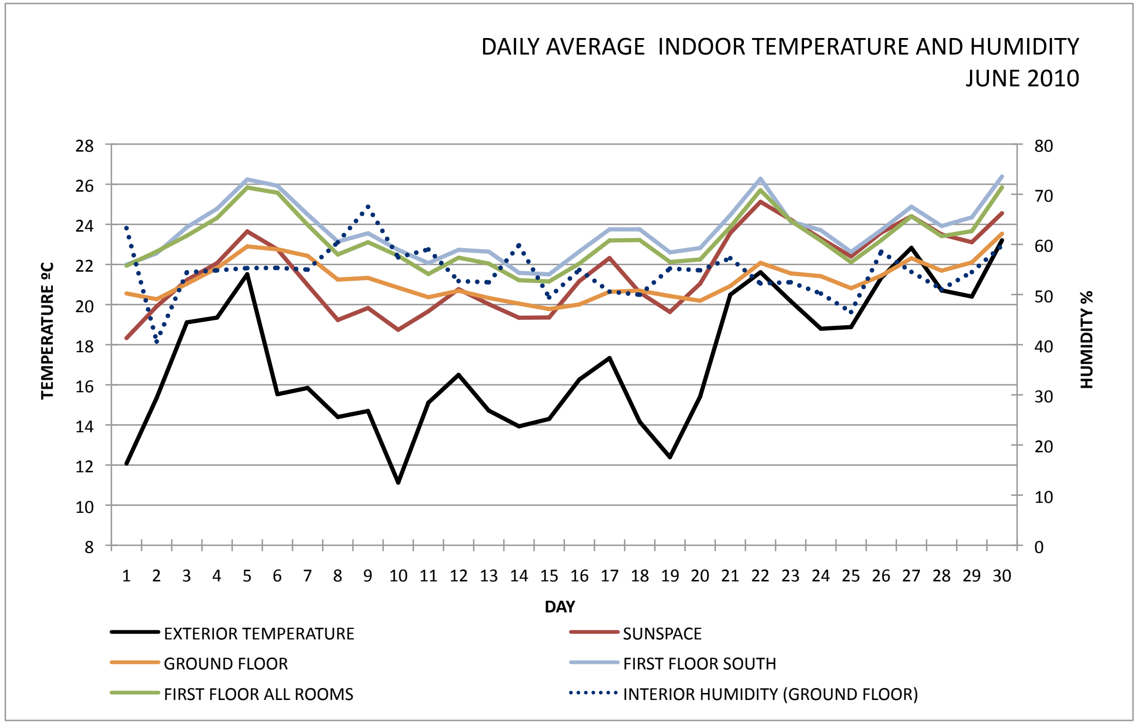
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/4/10	4.78	13.40	17.91	18.11	17.95	49.13
2/4/10	6.46	12.92	16.93	18.41	18.19	58.35
3/4/10	7.29	13.77	16.31	19.39	19.29	61.20
4/4/10	6.98	14.85	16.19	18.93	18.91	62.19
5/4/10	8.78	13.07	16.13	18.16	18.16	60.19
6/4/10	10.91	14.18	16.58	18.34	18.25	58.60
7/4/10	9.37	14.72	16.61	18.64	18.54	62.40
8/4/10	9.77	17.65	18.85	20.96	21.06	51.52
9/4/10	11.41	18.39	18.66	21.40	21.59	51.02
10/4/10	13.07	19.65	19.04	22.27	22.06	49.07
11/4/10	9.76	18.35	18.14	21.45	21.08	50.91
12/4/10	8.65	15.68	17.16	20.02	19.59	56.60
13/4/10	8.76	16.47	17.14	19.65	19.35	53.97
14/4/10	8.87	16.52	16.77	19.63	19.13	56.28
15/4/10	7.40	14.12	15.97	18.37	17.86	55.63
16/4/10	9.69	15.55	16.16	18.23	17.73	51.77
17/4/10	10.93	17.90	17.49	20.43	19.91	50.35
18/4/10	11.39	18.95	18.30	21.57	21.46	49.24
19/4/10	7.96	15.94	17.56	20.40	20.52	56.04
20/4/10	7.47	16.52	17.46	19.91	19.80	50.63
21/4/10	7.84	17.42	17.89	20.48	20.66	46.54
22/4/10	9.18	18.23	18.06	20.82	21.16	45.12
23/4/10	11.19	17.86	18.57	21.40	21.66	43.29
24/4/10	13.48	19.33	19.28	21.73	21.82	44.06
25/4/10	13.27	18.97	19.35	22.36	22.47	50.46
26/4/10	11.69	19.25	19.17	22.32	21.53	46.08
27/4/10	8.26	16.39	18.90	21.34	20.51	54.66
28/4/10	9.66	16.87	18.54	20.73	20.32	56.86
29/4/10	12.10	18.66	19.47	21.86	20.96	44.61
30/4/10	12.87	17.40	17.71	20.81	20.04	55.45
Monthly Max	**13.48**	**19.65**	**19.47**	**22.36**	**22.47**	**62.40**
Monthly Average	**9.64**	**16.63**	**17.74**	**20.27**	**20.05**	**52.74**
Monthly Min	**4.78**	**12.92**	**15.97**	**18.11**	**17.73**	**43.29**



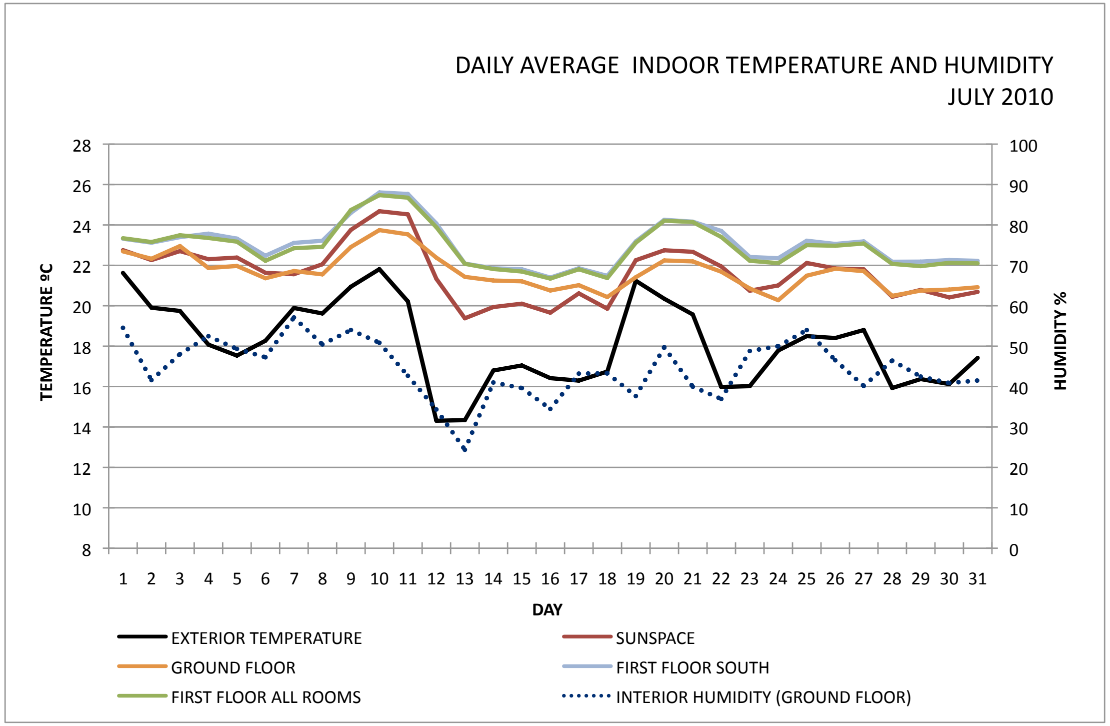
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/5/10	14.0	19.2	19.3	21.8	21.5	58.3
2/5/10	14.0	19.2	19.3	21.8	21.5	58.3
3/5/10	6.4	15.7	17.5	18.7	18.8	48.4
4/5/10	9.6	15.4	16.8	18.3	18.6	50.4
5/5/10	12.0	16.7	17.7	19.8	19.9	55.7
6/5/10	10.4	16.1	17.4	19.6	19.6	58.6
7/5/10	9.7	16.7	17.5	19.5	20.0	53.0
8/5/10	8.1	15.0	17.1	18.9	18.9	58.8
9/5/10	9.6	16.1	17.7	18.8	19.0	58.2
10/5/10	6.4	14.2	16.7	18.5	18.6	58.2
11/5/10	8.3	15.5	16.4	18.0	18.3	54.4
12/5/10	8.3	16.4	16.9	18.4	18.8	59.6
13/5/10	9.1	16.5	17.1	18.8	19.2	56.0
14/5/10	10.7	16.9	17.2	19.7	19.7	54.7
15/5/10	12.4	18.3	18.0	20.7	20.8	54.0
16/5/10	11.2	18.5	18.4	20.9	21.3	51.3
17/5/10	12.9	19.0	18.9	21.0	21.5	51.6
18/5/10	14.2	18.8	19.3	21.9	22.1	55.0
19/5/10	15.9	19.4	19.7	22.2	22.1	58.2
20/5/10	19.5	21.5	20.9	23.6	23.6	61.3
21/5/10	20.1	22.5	22.2	25.1	25.2	59.1
22/5/10	20.4	23.0	22.6	25.5	25.6	51.6
23/5/10	21.8	25.5	23.6	27.1	27.2	51.5
24/5/10	19.3	24.9	24.4	27.5	27.6	50.3
25/5/10	13.7	20.8	22.4	24.9	24.9	49.4
26/5/10	11.2	18.0	21.1	22.5	22.3	50.6
27/5/10	11.8	17.8	19.8	21.3	21.7	48.2
28/5/10	13.9	19.2	19.6	21.6	21.8	47.3
29/5/10	11.9	17.7	19.4	21.3	21.6	50.4
30/5/10	14.0	19.1	19.6	21.4	21.7	53.4
31/5/10	14.3	18.9	19.8	21.7	21.9	57.1
Monthly Max	**6.37**	**14.22**	**16.40**	**17.99**	**18.25**	**61.32**
Monthly Average	**12.75**	**18.47**	**19.17**	**21.31**	**21.46**	**54.29**
Monthly Min	**21.76**	**25.46**	**24.38**	**27.55**	**27.56**	**47.28**



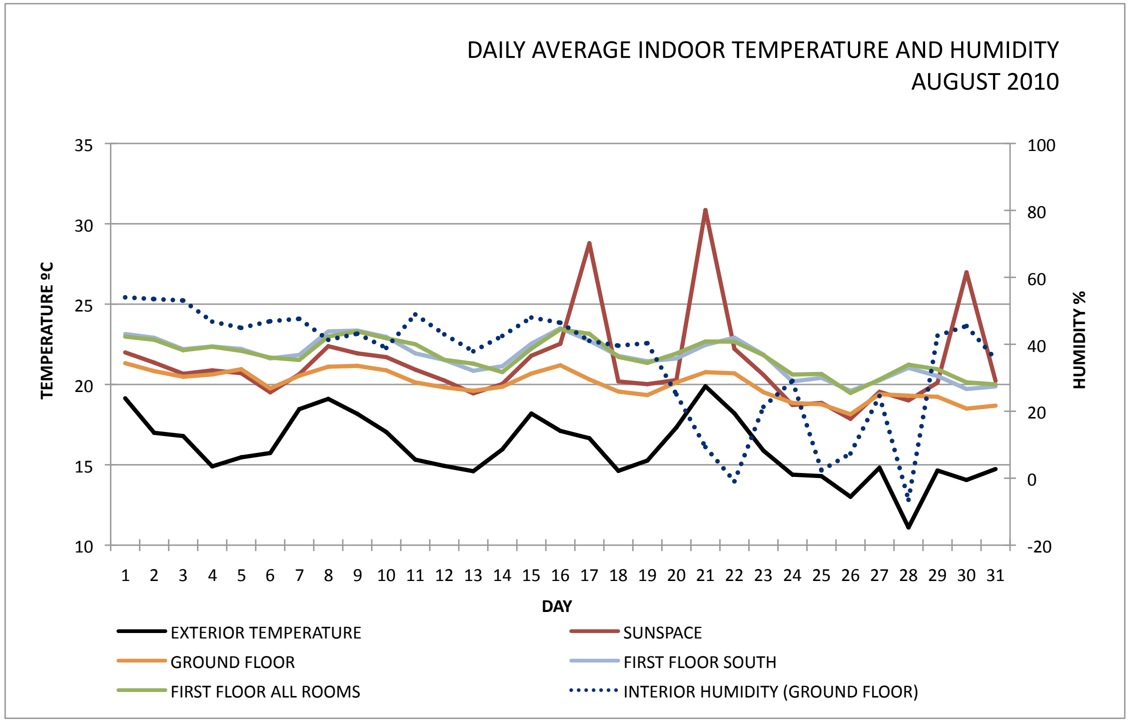
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/6/10	12.1	18.3	20.6	22.0	21.9	63.2
2/6/10	15.3	19.9	20.3	22.6	22.6	40.6
3/6/10	19.1	21.2	21.0	23.9	23.4	54.4
4/6/10	19.4	22.1	21.8	24.8	24.3	54.8
5/6/10	21.5	23.6	22.9	26.2	25.8	55.3
6/6/10	15.5	22.8	22.8	25.9	25.6	55.3
7/6/10	15.8	21.0	22.4	24.5	24.0	55.0
8/6/10	14.4	19.2	21.2	23.1	22.5	60.4
9/6/10	14.7	19.8	21.3	23.6	23.1	67.5
10/6/10	11.1	18.7	20.8	22.7	22.4	57.4
11/6/10	15.1	19.7	20.4	22.1	21.5	59.0
12/6/10	16.5	20.8	20.7	22.7	22.3	52.7
13/6/10	14.7	20.0	20.3	22.6	22.0	52.4
14/6/10	13.9	19.3	20.0	21.6	21.2	59.8
15/6/10	14.3	19.4	19.8	21.5	21.2	49.4
16/6/10	16.3	21.2	20.0	22.6	22.0	54.9
17/6/10	17.3	22.3	20.6	23.8	23.2	50.6
18/6/10	14.2	20.6	20.7	23.7	23.2	50.0
19/6/10	12.4	19.6	20.4	22.6	22.1	55.2
20/6/10	15.4	21.0	20.2	22.8	22.2	54.8
21/6/10	20.5	23.6	20.9	24.5	23.9	57.2
22/6/10	21.6	25.1	22.1	26.3	25.7	52.2
23/6/10	20.2	24.2	21.6	24.1	24.2	52.5
24/6/10	18.8	23.3	21.4	23.7	23.2	50.2
25/6/10	18.9	22.4	20.8	22.6	22.1	46.5
26/6/10	21.3	23.6	21.4	23.7	23.2	58.5
27/6/10	22.8	24.4	22.3	24.9	24.4	54.5
28/6/10	20.7	23.5	21.7	23.9	23.4	51.0
29/6/10	20.4	23.1	22.1	24.3	23.7	54.5
30/6/10	23.2	24.6	23.5	26.4	25.8	59.8
Monthly Max	**11.13**	**18.33**	**19.78**	**21.51**	**21.15**	**67.49**
Monthly Average	**17.25**	**21.61**	**21.21**	**23.66**	**23.21**	**54.66**
Monthly Min	**23.21**	**25.12**	**23.53**	**26.39**	**25.85**	**40.64**



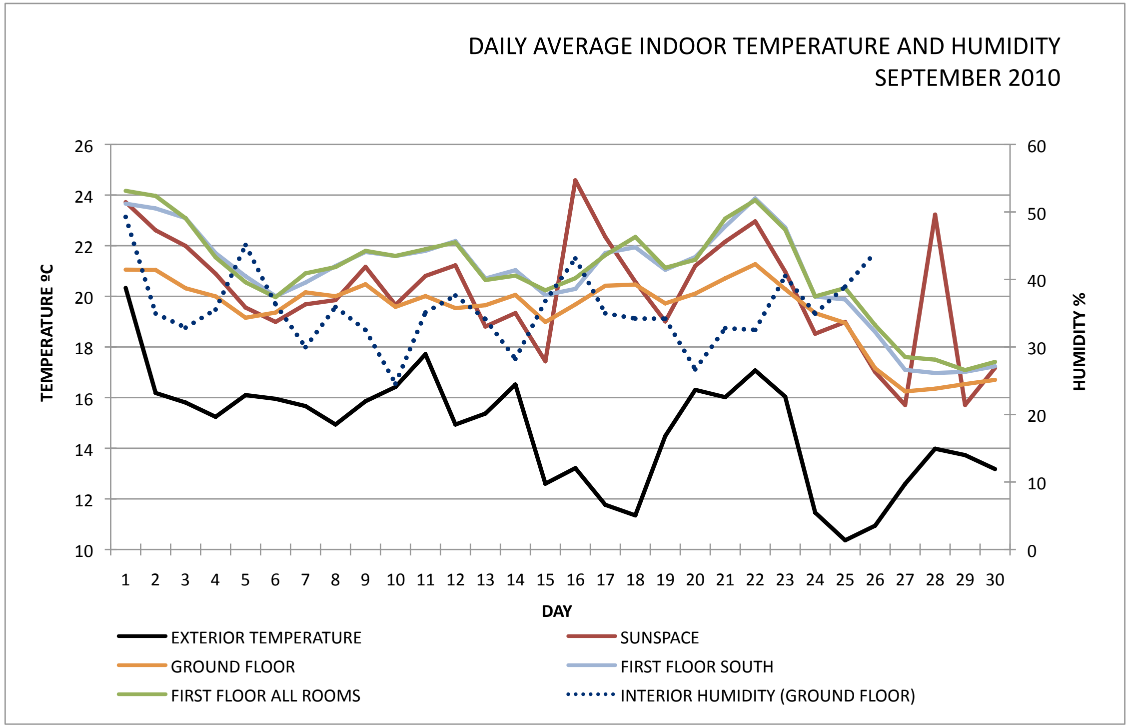
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/7/10	21.6	22.8	22.7	23.3	23.3	54.5
2/7/10	19.9	22.3	22.3	23.1	23.2	41.6
3/7/10	19.7	22.7	23.0	23.4	23.5	48.0
4/7/10	18.1	22.3	21.9	23.6	23.4	52.5
5/7/10	17.5	22.4	22.0	23.3	23.2	49.3
6/7/10	18.3	21.6	21.4	22.5	22.2	47.3
7/7/10	19.9	21.6	21.7	23.1	22.8	57.1
8/7/10	19.6	22.1	21.6	23.2	22.9	50.4
9/7/10	20.9	23.8	22.9	24.6	24.7	54.0
10/7/10	21.8	24.7	23.7	25.6	25.5	50.8
11/7/10	20.2	24.5	23.5	25.5	25.3	42.7
12/7/10	14.3	21.3	22.4	24.1	23.9	34.3
13/7/10	14.3	19.4	21.4	22.1	22.1	24.4
14/7/10	16.8	19.9	21.2	21.9	21.8	41.0
15/7/10	17.0	20.1	21.2	21.8	21.7	39.6
16/7/10	16.4	19.7	20.8	21.4	21.3	34.5
17/7/10	16.3	20.6	21.0	21.9	21.8	43.2
18/7/10	16.7	19.9	20.4	21.5	21.4	43.3
19/7/10	21.2	22.3	21.4	23.2	23.1	37.6
20/7/10	20.3	22.7	22.2	24.3	24.2	49.7
21/7/10	19.6	22.7	22.2	24.2	24.1	40.0
22/7/10	16.0	21.9	21.7	23.7	23.4	36.9
23/7/10	16.0	20.7	20.9	22.4	22.2	48.8
24/7/10	17.8	21.0	20.3	22.4	22.1	50.0
25/7/10	18.5	22.1	21.5	23.2	23.0	54.0
26/7/10	18.4	21.8	21.8	23.1	23.0	46.5
27/7/10	18.8	21.8	21.7	23.2	23.1	40.2
28/7/10	15.9	20.4	20.5	22.2	22.1	46.4
29/7/10	16.4	20.8	20.7	22.2	22.0	42.5
30/7/10	16.1	20.4	20.8	22.3	22.1	40.9
31/7/10	17.4	20.7	20.9	22.2	22.1	41.5
Monthly Max	**14.31**	**19.38**	**20.27**	**21.39**	**21.34**	**57.10**
Monthly Average	**18.13**	**21.64**	**21.67**	**23.04**	**22.92**	**44.63**
Monthly Min	**21.81**	**24.68**	**23.74**	**25.61**	**25.48**	**24.36**



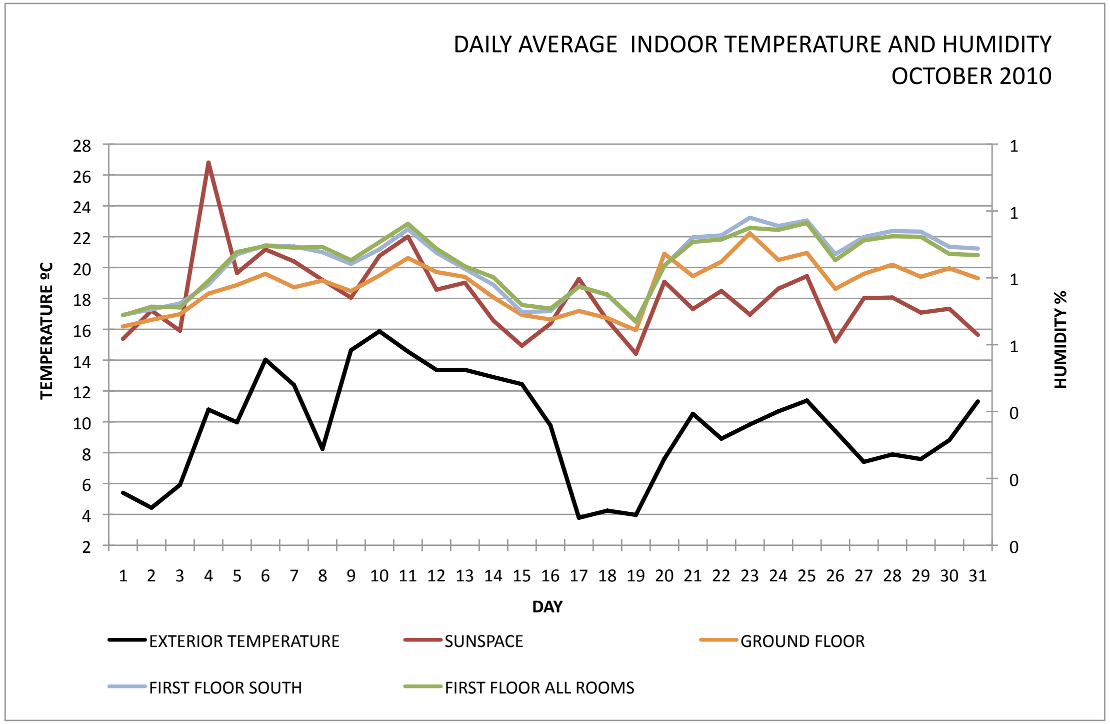
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/8/10	19.1	22.0	21.3	23.1	23.0	54.0
2/8/10	17.0	21.4	20.8	22.9	22.8	53.5
3/8/10	16.8	20.7	20.5	22.2	22.1	53.1
4/8/10	14.9	20.9	20.6	22.4	22.3	46.8
5/8/10	15.5	20.7	21.0	22.2	22.1	44.9
6/8/10	15.7	19.5	19.8	21.6	21.7	46.9
7/8/10	18.5	20.6	20.5	21.8	21.5	47.6
8/8/10	19.1	22.4	21.1	23.3	23.0	41.3
9/8/10	18.2	21.9	21.2	23.4	23.3	43.2
10/8/10	17.0	21.7	20.9	23.0	22.9	38.9
11/8/10	15.3	20.9	20.1	21.9	22.5	48.9
12/8/10	14.9	20.2	19.8	21.5	21.5	43.0
13/8/10	14.6	19.4	19.6	20.9	21.3	37.9
14/8/10	16.0	20.0	19.9	21.1	20.8	42.5
15/8/10	18.2	21.8	20.7	22.5	22.2	48.0
16/8/10	17.1	22.5	21.2	23.5	23.4	46.4
17/8/10	16.7	28.8	20.3	22.7	23.2	41.0
18/8/10	14.6	20.2	19.6	21.8	21.7	39.6
19/8/10	15.3	20.0	19.3	21.4	21.3	40.3
20/8/10	17.3	20.3	20.1	21.6	21.9	25.0
21/8/10	19.9	30.9	20.8	22.5	22.7	9.3
22/8/10	18.2	22.2	20.7	22.9	22.7	-0.9
23/8/10	15.9	20.6	19.5	21.9	21.8	21.3
24/8/10	14.4	18.7	18.9	20.2	20.6	29.1
25/8/10	14.3	18.9	18.8	20.4	20.7	2.3
26/8/10	13.0	17.9	18.1	19.6	19.5	7.4
27/8/10	14.8	19.5	19.4	20.3	20.3	24.6
28/8/10	11.1	19.0	19.3	21.0	21.2	-6.4
29/8/10	14.6	20.1	19.2	20.5	20.9	42.6
30/8/10	14.1	27.0	18.5	19.7	20.1	45.5
31/8/10	14.7	20.2	18.7	19.9	20.0	35.6
Monthly Max	**11.10**	**17.86**	**18.14**	**19.61**	**19.47**	**54.02**
Monthly Average	**16.03**	**21.32**	**20.00**	**21.73**	**21.78**	**35.26**
Monthly Min	**19.89**	**30.86**	**21.33**	**23.49**	**23.43**	**-6.45**



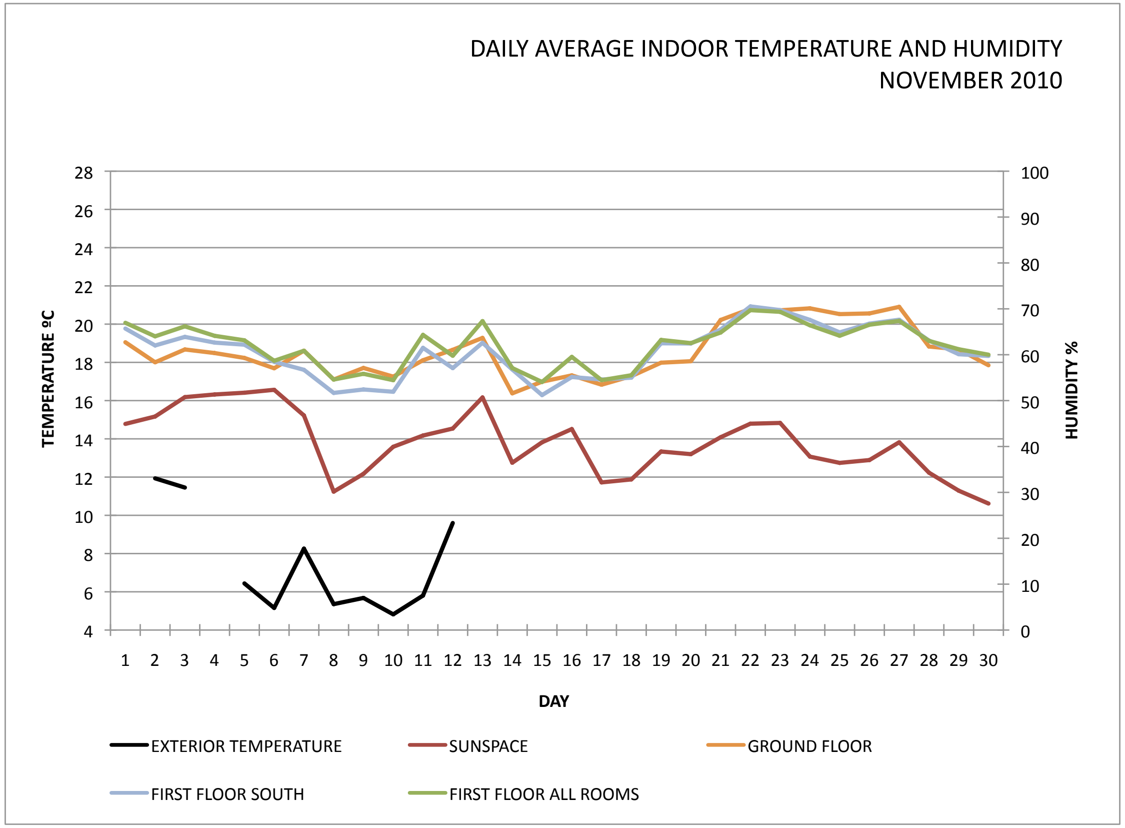
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/9/10	20.3	23.7	21.1	23.7	24.2	49.3
2/9/10	16.2	22.6	21.0	23.5	24.0	35.0
3/9/10	15.8	22.0	20.3	23.1	23.1	32.9
4/9/10	15.2	20.9	20.0	21.7	21.5	35.5
5/9/10	16.1	19.6	19.2	20.8	20.6	45.1
6/9/10	16.0	19.0	19.4	20.0	20.0	36.3
7/9/10	15.7	19.7	20.2	20.5	20.9	30.0
8/9/10	14.9	19.9	20.0	21.2	21.2	35.9
9/9/10	15.9	21.2	20.5	21.8	21.8	32.5
10/9/10	16.4	19.7	19.6	21.6	21.6	24.6
11/9/10	17.7	20.8	20.0	21.8	21.9	35.1
12/9/10	14.9	21.2	19.5	22.2	22.1	37.6
13/9/10	15.4	18.8	19.6	20.7	20.6	34.1
14/9/10	16.5	19.3	20.1	21.0	20.8	28.2
15/9/10	12.6	17.4	19.0	20.1	20.2	36.8
16/9/10	13.2	24.6	19.7	20.3	20.7	43.1
17/9/10	11.8	22.3	20.4	21.7	21.6	35.0
18/9/10	11.3	20.6	20.5	21.9	22.3	34.2
19/9/10	14.5	19.0	19.7	21.0	21.1	34.2
20/9/10	16.3	21.2	20.1	21.6	21.4	26.7
21/9/10	16.0	22.2	20.7	22.8	23.1	32.8
22/9/10	17.1	23.0	21.3	23.9	23.8	32.5
23/9/10	16.0	21.0	20.3	22.7	22.6	40.5
24/9/10	11.5	18.5	19.3	20.0	20.0	34.9
25/9/10	10.4	19.0	18.9	19.9	20.3	38.9
26/9/10	10.9	17.0	17.2	18.6	18.9	44.0
27/9/10	12.6	15.7	16.2	17.1	17.6	
28/9/10	14.0	23.2	16.4	17.0	17.5	
29/9/10	13.7	15.7	16.5	17.0	17.1	
30/9/10	13.2	17.2	16.7	17.2	17.4	
Monthly Max	**10.36**	**15.71**	**16.25**	**16.97**	**17.09**	**49.26**
Monthly Average	**14.74**	**20.20**	**19.44**	**20.88**	**21.00**	**35.61**
Monthly Min	**20.33**	**24.58**	**21.27**	**23.87**	**24.17**	**24.58**



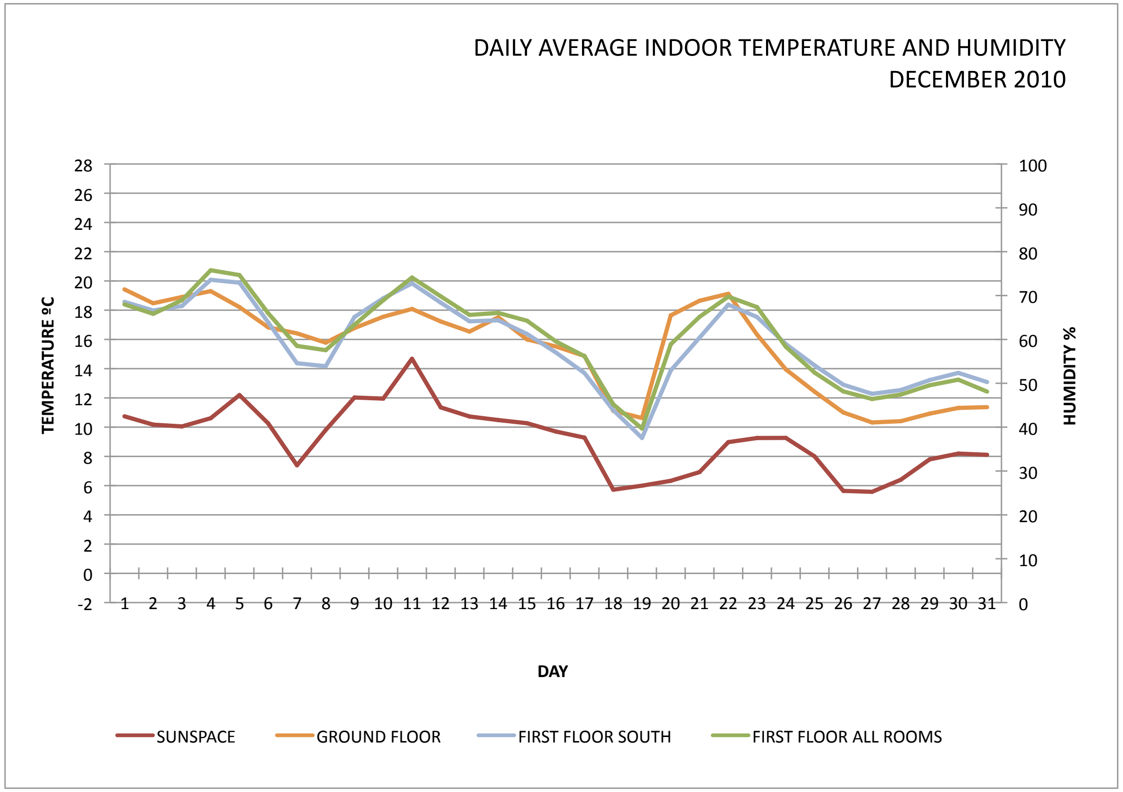
DATE	EXTERIOR	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/10/10	5.4	15.4	16.2	16.9	16.9	
2/10/10	4.4	17.2	16.6	17.3	17.5	
3/10/10	5.9	15.9	17.0	17.7	17.4	
4/10/10	10.8	26.8	18.3	18.9	19.1	
5/10/10	10.0	19.6	18.9	20.9	21.0	
6/10/10	14.0	21.2	19.6	21.4	21.4	
7/10/10	12.4	20.4	18.7	21.4	21.3	
8/10/10	8.2	19.2	19.2	21.0	21.3	
9/10/10	14.6	18.0	18.5	20.2	20.5	
10/10/10	15.9	20.8	19.5	21.2	21.7	
11/10/10	14.6	22.0	20.6	22.5	22.8	
12/10/10	13.4	18.6	19.7	21.0	21.2	
13/10/10	13.4	19.0	19.4	19.9	20.1	
14/10/10	12.9	16.6	18.1	18.9	19.4	
15/10/10	12.4	14.9	16.9	17.1	17.6	
16/10/10	9.8	16.4	16.6	17.2	17.3	
17/10/10	3.8	19.3	17.2	18.8	18.8	
18/10/10	4.2	16.6	16.7	18.2	18.3	
19/10/10	4.0	14.4	15.9	16.5	16.5	
20/10/10	7.6	19.1	20.9	20.1	20.1	
21/10/10	10.5	17.3	19.4	22.0	21.7	
22/10/10	8.9	18.5	20.4	22.1	21.8	
23/10/10	9.8	17.0	22.2	23.2	22.6	
24/10/10	10.7	18.6	20.5	22.7	22.4	
25/10/10	11.4	19.4	20.9	23.0	22.9	
26/10/10	9.4	15.2	18.6	20.9	20.5	
27/10/10	7.4	18.0	19.6	22.0	21.8	
28/10/10	7.9	18.1	20.2	22.4	22.0	
29/10/10	7.6	17.1	19.4	22.3	22.0	
30/10/10	8.8	17.3	20.0	21.3	20.9	
31/10/10	11.3	15.6	19.3	21.2	20.8	
Monthly Max	**3.78**	**14.42**	**15.94**	**16.47**	**16.52**	
Monthly Average	**9.72**	**18.18**	**18.87**	**20.33**	**20.31**	
Monthly Min	**15.87**	**26.80**	**22.23**	**23.23**	**22.89**	



DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/11/10		14.78	19.05	19.77	20.07	
2/11/10	11.93	15.17	18.01	18.88	19.36	
3/11/10	11.45	16.18	18.68	19.33	19.88	
4/11/10		16.32	18.49	19.03	19.39	
5/11/10	6.44	16.41	18.23	18.93	19.15	
6/11/10	5.16	16.57	17.69	18.03	18.08	
7/11/10	8.26	15.22	18.61	17.61	18.61	
8/11/10	5.35	11.24	17.10	16.40	17.10	
9/11/10	5.68	12.17	17.71	16.58	17.40	
10/11/10	4.82	13.59	17.25	16.46	17.07	
11/11/10	5.80	14.17	18.11	18.76	19.44	
12/11/10	9.60	14.54	18.66	17.70	18.35	
13/11/10		16.17	19.28	19.03	20.16	
14/11/10		12.75	16.38	17.63	17.70	
15/11/10		13.82	16.99	16.29	16.97	
16/11/10		14.51	17.32	17.23	18.29	
17/11/10		11.72	16.83	17.10	17.07	
18/11/10		11.88	17.28	17.20	17.33	
19/11/10		13.34	17.98	19.00	19.17	
20/11/10		13.20	18.06	18.99	19.01	
21/11/10		14.08	20.22	19.72	19.56	
22/11/10		14.79	20.80	20.93	20.73	
23/11/10		14.83	20.72	20.73	20.64	
24/11/10		13.07	20.83	20.22	19.94	
25/11/10		12.74	20.52	19.57	19.39	
26/11/10		12.89	20.56	20.03	19.97	
27/11/10		13.82	20.90	20.23	20.17	
28/11/10		12.23	18.83	19.14	19.13	
29/11/10		11.29	18.68	18.43	18.69	
30/11/10		10.62	17.85	18.34	18.40	
Monthly Max	**11.93**	**16.57**	**20.90**	**20.93**	**20.73**	
Monthly Average	**7.45**	**13.80**	**18.59**	**18.58**	**18.87**	
Monthly Min	**4.82**	**10.62**	**16.38**	**16.29**	**16.97**	

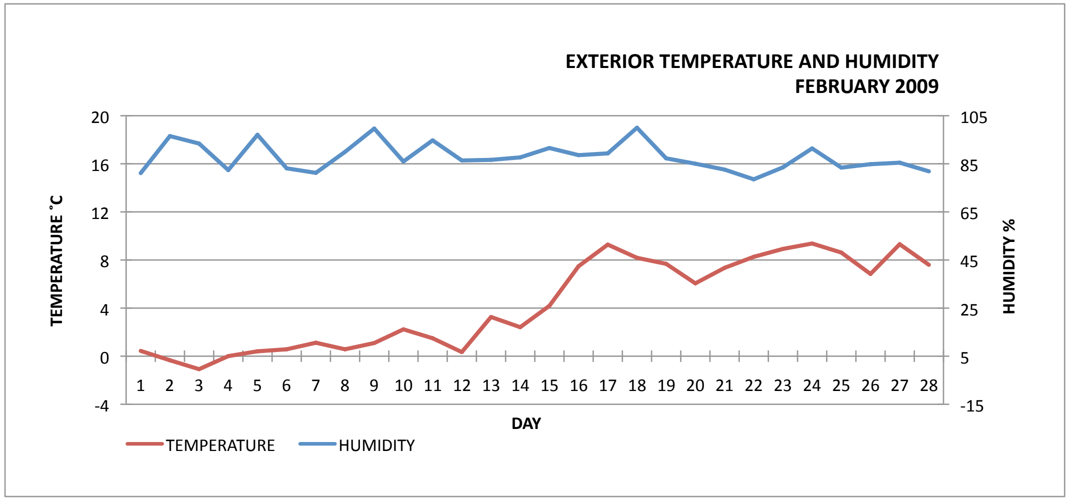


DATE	EXTERIOR TEMPERATURE	SUNSPACE	GROUND FLOOR	FIRST FLOOR SOUTH	FIRST FLOOR ALL ROOMS	INTERIOR HUMIDITY (GROUND FLOOR)
1/12/10		10.74	19.42	18.57	18.39	
2/12/10		10.17	18.47	17.98	17.75	
3/12/10		10.05	18.90	18.29	18.68	
4/12/10		10.61	19.30	20.08	20.73	
5/12/10		12.19	18.21	19.88	20.40	
6/12/10		10.25	16.82	17.16	17.79	
7/12/10		7.39	16.41	14.37	15.55	
8/12/10		9.81	15.78	14.17	15.26	
9/12/10		12.03	16.78	17.53	17.00	
10/12/10		11.95	17.55	18.81	18.68	
11/12/10		14.68	18.08	19.83	20.23	
12/12/10		11.35	17.23	18.51	18.95	
13/12/10		10.73	16.54	17.24	17.68	
14/12/10		10.48	17.51	17.31	17.81	
15/12/10		10.27	16.00	16.37	17.28	
16/12/10		9.70	15.52	15.11	15.87	
17/12/10		9.28	14.87	13.70	14.85	
18/12/10		5.72	11.11	11.16	11.56	
19/12/10		6.00	10.63	9.26	9.91	
20/12/10		6.33	17.65	13.88	15.67	
21/12/10		6.92	18.64	16.12	17.54	
22/12/10		8.97	19.12	18.38	18.93	
23/12/10		9.26	16.33	17.53	18.21	
24/12/10		9.26	13.95	15.69	15.50	
25/12/10		8.00	12.43	14.23	13.73	
26/12/10		5.64	11.00	12.90	12.44	
27/12/10		5.58	10.32	12.28	11.93	
28/12/10		6.40	10.41	12.54	12.23	
29/12/10		7.79	10.92	13.22	12.86	
30/12/10		8.19	11.31	13.71	13.25	
31/12/10		8.11	11.37	13.08	12.43	
Monthly Max		**14.68**	**19.42**	**20.08**	**20.73**	
Monthly Average		**9.16**	**15.44**	**15.77**	**16.10**	
Monthly Min		**5.58**	**10.32**	**9.26**	**9.91**	

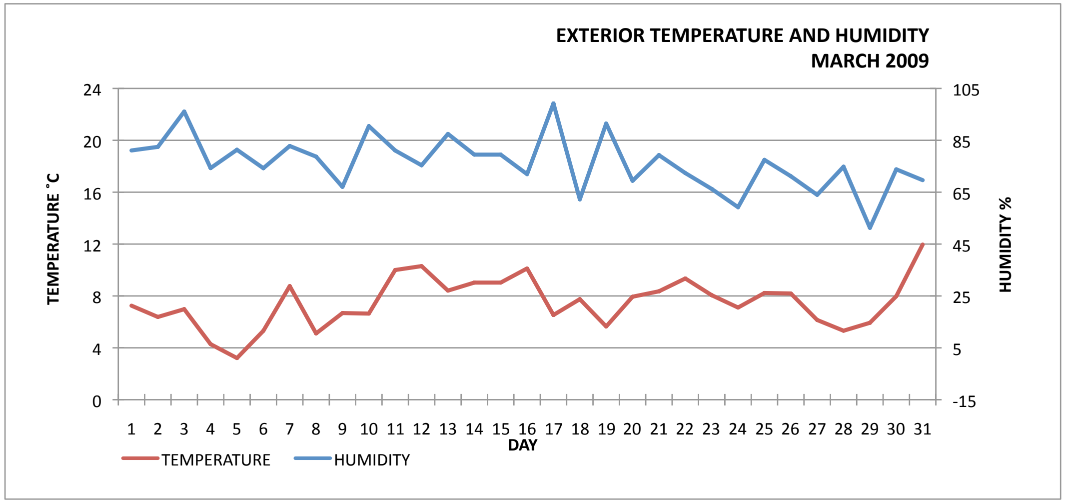


ENVIRONMENTAL CONDITIONS FOR THE BASF HOUSE
UNIVERSITY OF NOTTINGHAM, WEATHER STATION OF THE DEPARTMENT OF THE BUILT ENVIRONMENT
NOTTINGHAM, UNITED KINGDOM
LATITUDE: 52.94˚ North
LONGITUDE: -1˚
ALTITUDE: 66 m

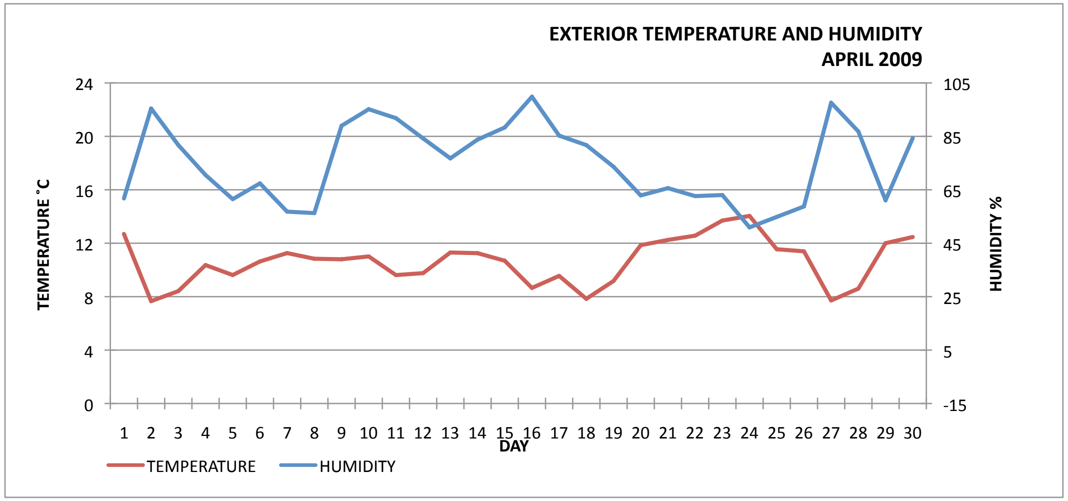
FEBRUARY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Feb	0.44	81.12	3.62	81.08	E	0	
2-Feb	-0.34	96.52	2.78	77.50	E	0	
3-Feb	-1.08	93.42	1.03	153.94	SE	0	
4-Feb	0.01	82.38	1.73	85.83	E	0	
5-Feb	0.41	97.06	2.10	145.53	SE	1	
6-Feb	0.57	83.11	2.07	232.60	SW	0	
7-Feb	1.12	81.24	1.35	275.14	W	0	
8-Feb	0.57	89.96	0.49	219.79	SW	0	
9-Feb	1.09	99.66	1.01	156.84	SE	2	
10-Feb	2.23	85.96	2.57	261.66	W	1	
11-Feb	1.49	94.75	1.28	243.14	SW	0	
12-Feb	0.34	86.39	0.56	248.82	SW	0	DATA MISSING
13-Feb	3.26	86.64	1.83	236.52	SW	0	
14-Feb	2.41	87.67	0.18	235.79	SW	0	
15-Feb	4.19	91.56	0.39	240.58	SW	0	
16-Feb	7.48	88.60	0.66	246.84	SW	0	
17-Feb	9.28	89.33	0.97	276.95	W	0	
18-Feb	8.18	99.99	0.20	248.79	SW	0	
19-Feb	7.68	87.27	0.37	271.21	W	0	
20-Feb	6.06	85.04	0.30	265.00	W	0	
21-Feb	7.34	82.60	0.96	246.95	SW	0	
22-Feb	8.26	78.55	2.05	263.19	W	0	
23-Feb	8.92	83.52	1.86	286.48	W	0	
24-Feb	9.37	91.40	0.31	249.41	SW	0	
25-Feb	8.62	83.41	1.13	242.73	SW	0	
26-Feb	6.84	84.84	1.19	245.68	SW	0	
27-Feb	9.31	85.46	1.09	245.87	SW	0	
28-Feb	7.60	81.87	0.62	216.97	SW	0	
AVG	4.35	87.83	1.24	221.46		0.14	

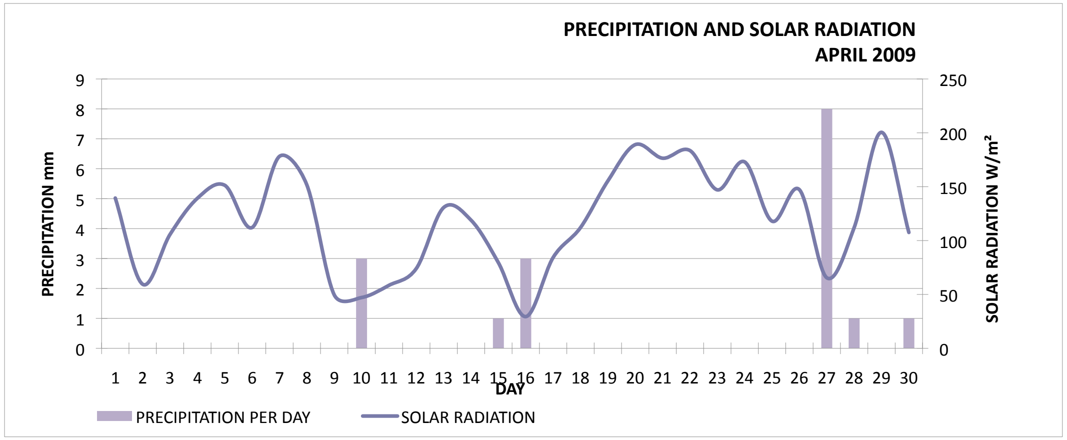


MARCH	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	kW/m²
1-Mar	7.25	81.09	0.58	223.43	SW	0	DATA MISSING
2-Mar	6.38	82.47	1.25	230.92	SW	0	
3-Mar	6.98	96.09	2.41	204.91	SW	4	
4-Mar	4.28	74.29	0.27	226.42	SW	0	
5-Mar	3.21	81.36	0.96	188.11	SW	0	
6-Mar	5.31	74.25	0.57	238.52	SW	0	
7-Mar	8.76	82.81	1.66	222.74	SW	0	
8-Mar	5.11	78.72	2.40	241.68	SW	4	
9-Mar	6.68	67.05	2.36	244.89	SW	0	
10-Mar	6.64	90.48	1.13	246.64	SW	3	
11-Mar	10.00	81.07	0.81	222.70	SW	0	
12-Mar	10.30	75.37	1.53	248.66	SW	0	
13-Mar	8.41	87.47	0.85	209.15	SW	0	
14-Mar	9.03	79.48	1.30	228.38	SW	0	
15-Mar	9.03	79.48	1.30	242.38	SW	0	
16-Mar	10.12	71.95	0.81	250.72	SW	0	
17-Mar	6.53	99.21	1.60	119.65	SE	0	
18-Mar	7.75	62.25	0.26	214.41	SW	10	
19-Mar	5.64	91.47	1.64	119.46	SE	0	79.62
20-Mar	7.94	69.39	0.77	179.61	S	0	112.96
21-Mar	8.36	79.29	0.96	256.04	W	0	119.63
22-Mar	9.35	72.38	1.33	262.83	W	0	108.87
23-Mar	8.06	66.26	3.41	265.06	W	0	52.42
24-Mar	7.11	59.21	2.56	267.90	W	0	118.05
25-Mar	8.23	77.46	2.59	264.25	W	4	96.49
26-Mar	8.19	71.16	2.18	243.43	SW	0	84.98
27-Mar	6.15	63.98	2.27	240.49	SW	0	89.26
28-Mar	5.32	74.83	4.43	257.42	W	0	102.00
29-Mar	5.93	51.27	0.50	246.97	SW	0	137.64
30-Mar	7.98	73.82	0.85	232.25	SW	0	84.52
31-Mar	11.96	69.64	0.41	260.41	W	0	114.20
AVG	7.48	76.29	1.48	229.05		0.81	100.05

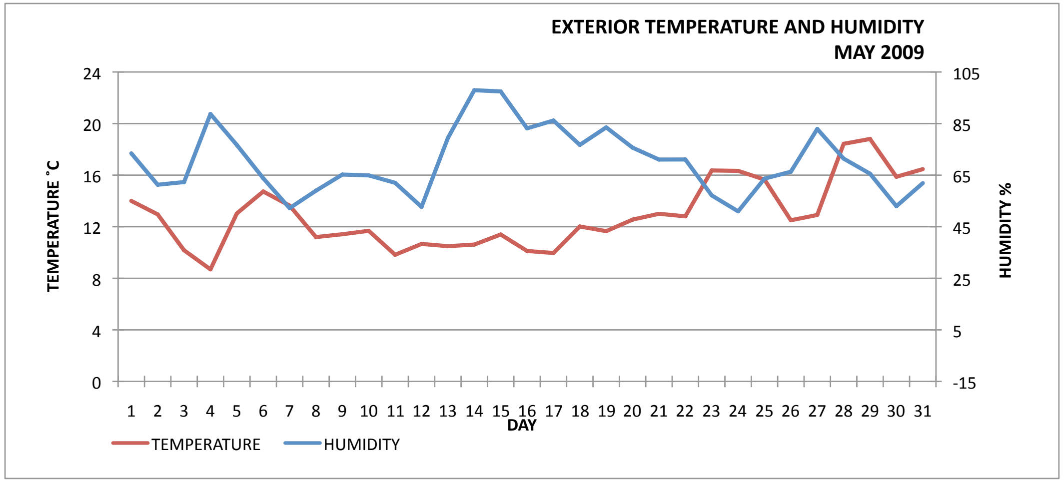


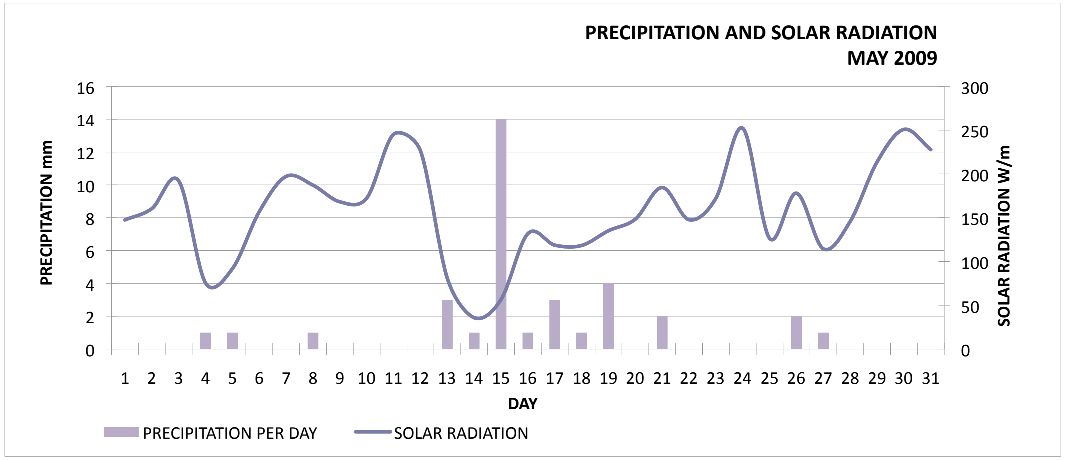
APRIL	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Apr	12.69	61.76	2.05	110.44	SE	0	139.47
2-Apr	7.66	95.43	1.72	75.40	E	0	59.47
3-Apr	8.41	81.75	0.59	171.15	S	0	105.66
4-Apr	10.36	70.54	1.32	237.89	SW	0	139.24
5-Apr	9.62	61.50	0.60	211.54	SW	0	151.32
6-Apr	10.63	67.41	1.24	159.39	SE	0	112.13
7-Apr	11.26	56.82	2.45	213.32	SW	0	178.17
8-Apr	10.84	56.28	2.62	225.81	SW	0	151.67
9-Apr	10.80	88.96	1.63	181.29	S	0	49.67
10-Apr	11.01	95.16	0.65	194.59	S	3	47.13
11-Apr	9.61	91.82	0.31	149.60	SE	0	58.44
12-Apr	9.76	84.23	0.92	147.48	SE	0	74.07
13-Apr	11.30	76.77	0.81	156.10	SE	0	130.67
14-Apr	11.26	83.79	1.97	88.29	E	0	118.96
15-Apr	10.69	88.33	3.20	79.14	E	1	79.47
16-Apr	8.65	99.84	2.90	109.68	E	3	29.42
17-Apr	9.56	85.28	3.20	105.24	E	0	84.28
18-Apr	7.84	81.73	3.07	99.23	E	0	112.02
19-Apr	9.17	73.63	1.72	92.16	E	0	155.35
20-Apr	11.85	62.89	0.49	181.45	S	0	189.03
21-Apr	12.25	65.62	0.69	216.22	SW	0	176.46
22-Apr	12.57	62.64	0.26	196.66	S	0	183.57
23-Apr	13.70	63.03	0.51	197.32	S	0	147.08
24-Apr	14.04	50.94	1.30	175.04	S	0	172.99
25-Apr	11.55	54.85	1.61	160.82	S	0	118.01
26-Apr	11.39	58.75	0.36	193.43	S	0	147.21
27-Apr	7.72	97.60	0.42	211.92	SW	8	65.48
28-Apr	8.60	86.85	0.82	198.63	S	1	111.99
29-Apr	12.00	61.06	0.61	190.61	S	0	200.46
30-Apr	12.47	84.38	0.63	191.25	S	1	107.53
AVG	10.64	74.99	1.36	164.04		0.57	119.88



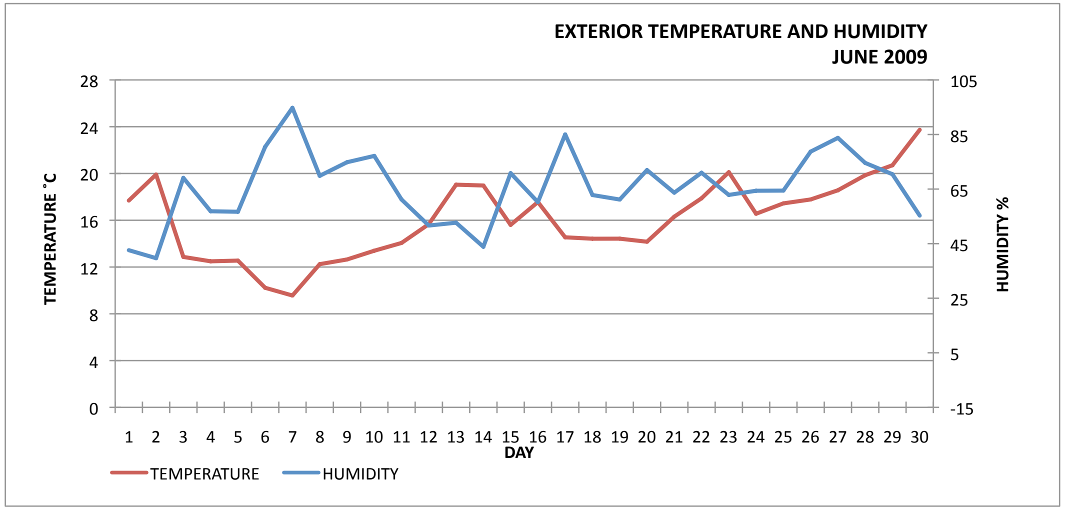


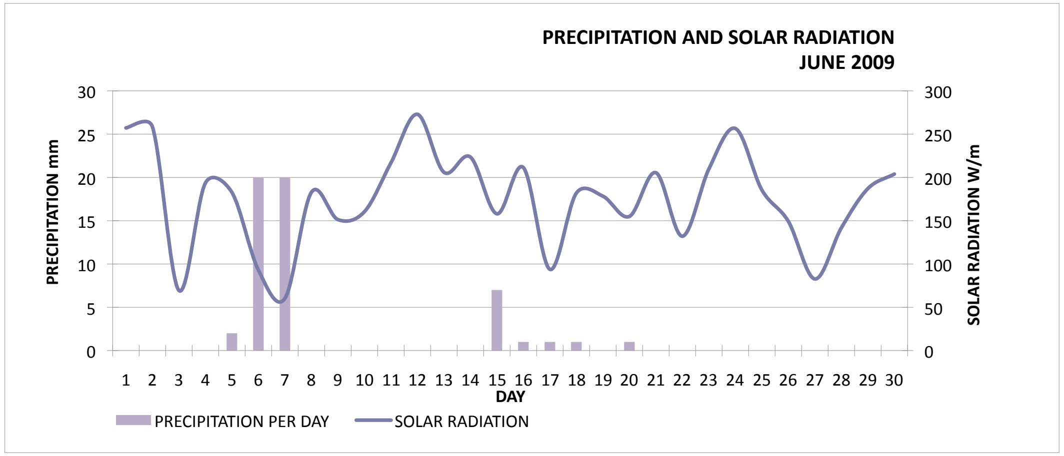
MAY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-May	14.00	73.46	0.53	212.48	SW	0	147.47
2-May	12.96	61.28	0.17	241.11	SW	0	160.36
3-May	10.17	62.32	1.08	250.75	SW	0	192.05
4-May	8.69	88.71	0.71	234.27	SW	1	75.48
5-May	13.03	76.70	1.05	238.74	SW	1	91.79
6-May	14.73	63.81	1.49	237.20	SW	0	156.93
7-May	13.64	52.21	1.31	231.15	SW	0	197.17
8-May	11.20	58.98	1.40	231.82	SW	1	187.13
9-May	11.42	65.23	0.64	228.08	SW	0	168.16
10-May	11.68	64.90	0.97	167.15	S	0	172.41
11-May	9.82	62.03	3.68	87.71	E	0	245.32
12-May	10.66	52.70	3.98	81.41	E	0	226.45
13-May	10.49	79.43	3.02	85.73	E	3	80.71
14-May	10.62	97.93	1.89	92.99	E	1	35.79
15-May	11.40	97.46	0.42	179.25	S	14	56.60
16-May	10.12	83.15	0.79	211.56	SW	1	131.82
17-May	9.96	86.18	1.04	174.80	S	3	118.67
18-May	12.02	76.73	1.34	215.69	SW	1	118.29
19-May	11.66	83.52	0.68	216.67	SW	4	135.11
20-May	12.55	75.65	0.35	211.65	SW	0	148.31
21-May	13.00	71.05	0.45	239.68	SW	2	184.49
22-May	12.81	71.08	0.50	234.46	SW	0	147.71
23-May	16.36	57.15	0.37	223.87	SW	0	172.31
24-May	16.33	50.96	0.25	198.63	S	0	252.14
25-May	15.66	63.65	0.30	156.60	SE	0	126.34
26-May	12.50	66.33	1.30	259.13	SW	2	177.98
27-May	12.91	82.91	0.79	230.86	SW	1	114.45
28-May	18.43	71.41	0.40	233.52	SW	0	145.84
29-May	18.81	65.56	1.70	97.05	E	0	213.76
30-May	15.87	52.97	1.98	93.87	E	0	250.86
31-May	16.47	61.91	2.32	137.11	SE	0	227.73
AVG	12.90	70.24	1.19	191.45		1.13	156.76



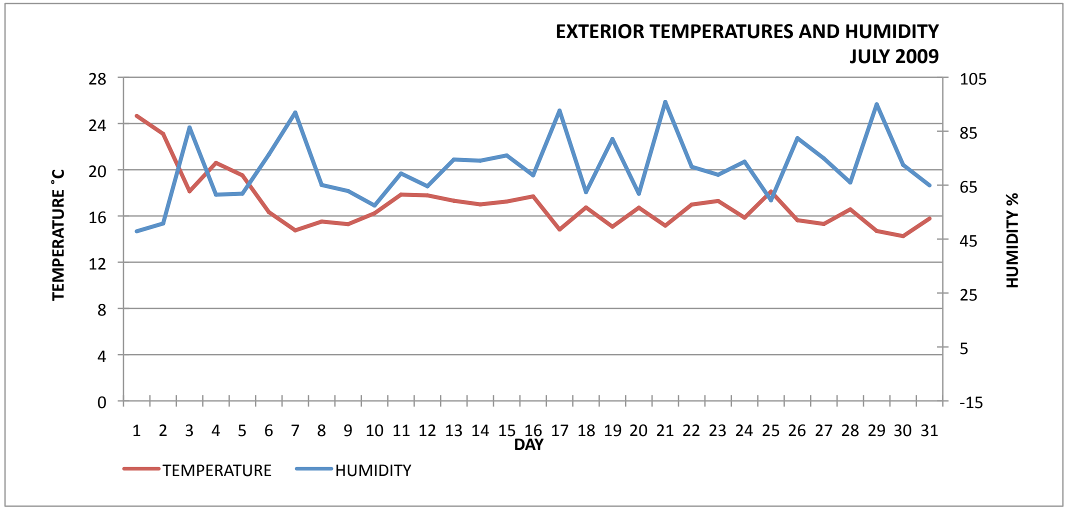


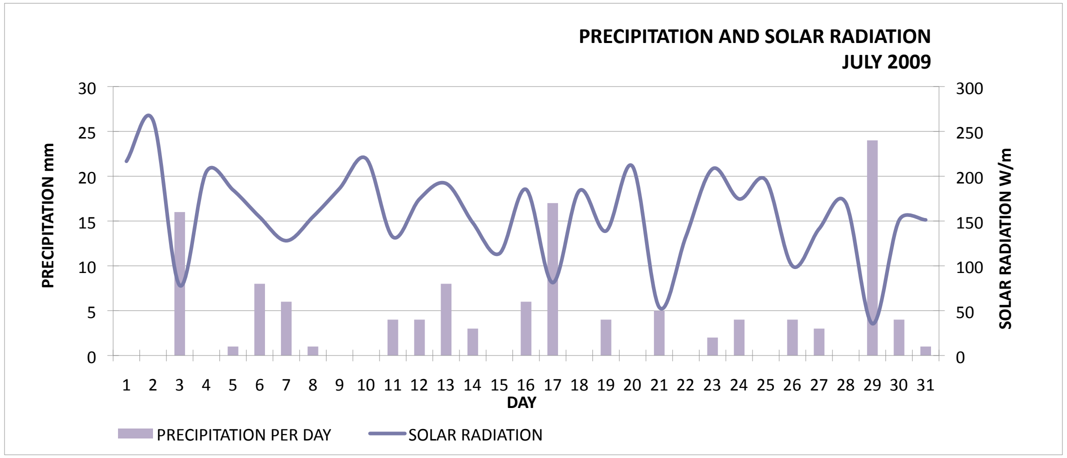
JUNE	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Jun	17.68	42.60	2.18	140.42	SE	0	257.23
2-Jun	19.91	39.67	0.70	185.90	S	0	258.48
3-Jun	12.86	69.10	1.67	100.22	E	0	69.49
4-Jun	12.49	56.88	1.05	183.08	S	0	193.60
5-Jun	12.55	56.68	1.00	125.90	SE	2	182.73
6-Jun	10.22	80.49	2.80	91.00	E	20	92.96
7-Jun	9.56	94.78	2.28	104.82	E	20	60.21
8-Jun	12.25	69.85	2.58	102.22	E	0	182.82
9-Jun	12.64	74.83	2.77	163.37	SE	0	151.32
10-Jun	13.39	77.16	0.99	147.21	SE	0	160.38
11-Jun	14.06	61.18	0.92	267.11	W	0	216.78
12-Jun	15.67	51.63	0.16	209.66	SW	0	272.92
13-Jun	19.04	52.68	0.12	214.30	SW	0	205.99
14-Jun	18.97	43.85	0.39	258.98	W	0	223.56
15-Jun	15.60	70.83	0.86	204.09	SW	7	157.98
16-Jun	17.56	60.22	0.20	225.57	SW	1	211.35
17-Jun	14.54	85.03	0.50	216.68	SW	1	93.83
18-Jun	14.42	62.82	0.61	236.44	SW	1	181.95
19-Jun	14.43	61.17	0.59	238.57	SW	0	178.36
20-Jun	14.16	71.97	0.56	245.32	SW	1	154.95
21-Jun	16.31	63.67	0.42	254.20	W	0	205.48
22-Jun	17.88	70.99	0.18	266.56	W	0	132.10
23-Jun	20.11	62.86	1.35	116.03	SE	0	209.76
24-Jun	16.56	64.39	2.27	89.72	E	0	256.54
25-Jun	17.44	64.43	2.38	90.04	E	0	185.53
26-Jun	17.78	78.72	2.12	111.49	SE	0	149.23
27-Jun	18.56	83.76	0.62	93.81	E	0	82.73
28-Jun	19.85	74.59	0.52	130.60	SE	0	141.75
29-Jun	20.70	70.44	1.32	92.56	E	0	187.13
30-Jun	23.74	55.27	0.49	139.06	SE	0	203.91
AVG	16.03	65.75	1.15	168.16		1.77	175.37



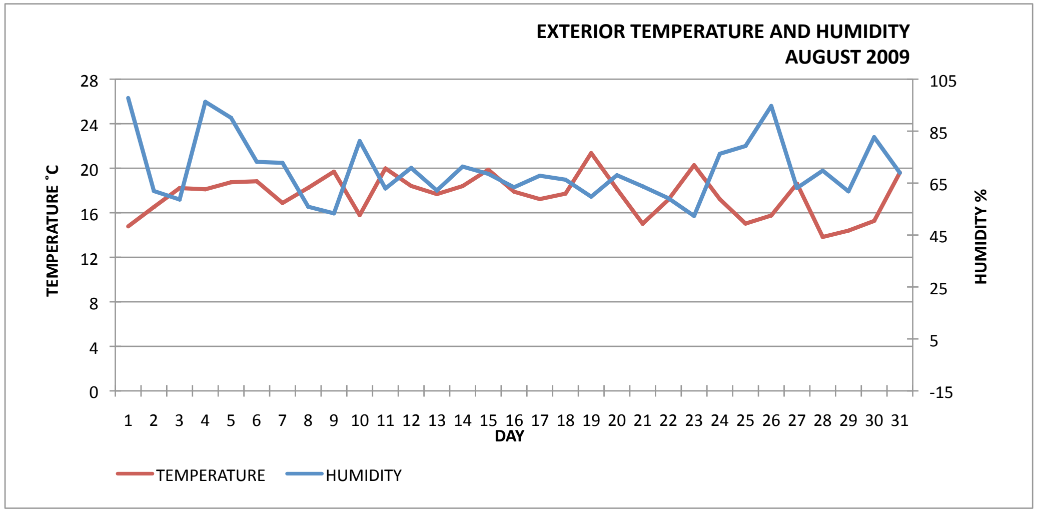


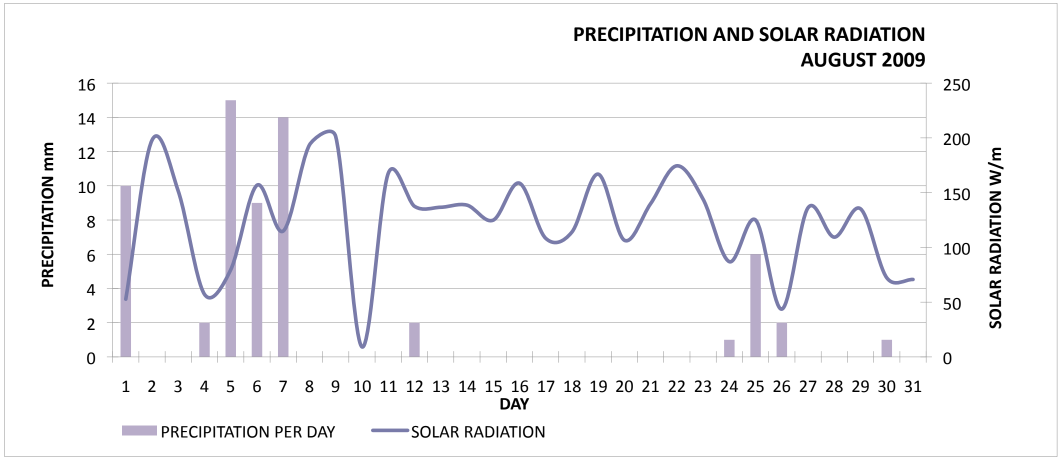
JULY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Jul	24.66	47.88	0.55	136.35	SE	0	216.66
2-Jul	23.10	50.78	1.68	105.04	E	0	262.16
3-Jul	18.14	86.40	0.45	195.80	SW	16	78.15
4-Jul	20.59	61.47	0.15	238.84	SW	0	204.93
5-Jul	19.52	61.84	0.15	241.44	SW	1	184.67
6-Jul	16.33	76.34	0.20	221.39	SW	8	154.47
7-Jul	14.75	91.93	0.23	249.81	SW	6	128.05
8-Jul	15.52	65.06	1.17	267.06	S	1	154.70
9-Jul	15.29	62.82	0.55	241.77	SW	0	186.31
10-Jul	16.23	57.44	0.50	253.71	S	0	219.61
11-Jul	17.85	69.34	0.20	217.98	SW	4	132.16
12-Jul	17.78	64.59	0.41	228.46	SW	4	174.55
13-Jul	17.32	74.50	0.15	212.64	SW	8	191.84
14-Jul	17.00	74.07	0.13	208.29	SW	3	148.12
15-Jul	17.25	76.02	0.35	217.03	SW	0	113.71
16-Jul	17.70	68.66	0.39	216.48	SW	6	185.29
17-Jul	14.83	92.64	1.54	253.15	S	17	81.29
18-Jul	16.74	62.41	0.75	239.28	SW	0	183.79
19-Jul	15.07	82.12	0.29	234.89	SW	4	138.87
20-Jul	16.72	61.82	0.31	231.83	SW	0	210.81
21-Jul	15.16	95.84	0.27	183.68	S	5	53.77
22-Jul	16.99	71.80	0.70	217.54	SW	0	132.68
23-Jul	17.30	68.85	0.35	228.26	SW	2	208.25
24-Jul	15.85	73.71	0.18	234.47	SW	4	174.59
25-Jul	18.11	59.40	0.12	237.28	SW	0	195.61
26-Jul	15.63	82.42	0.26	216.09	SW	4	99.80
27-Jul	15.31	74.92	0.22	230.42	SW	3	141.34
28-Jul	16.57	65.99	0.38	224.73	SW	0	170.27
29-Jul	14.70	94.99	0.15	215.57	SW	24	35.47
30-Jul	14.25	72.51	0.32	238.41	SW	4	150.78
31-Jul	15.78	64.92	0.13	210.14	SW	1	151.28
AVG	17.03	71.40	0.43	220.90		4.03	156.90



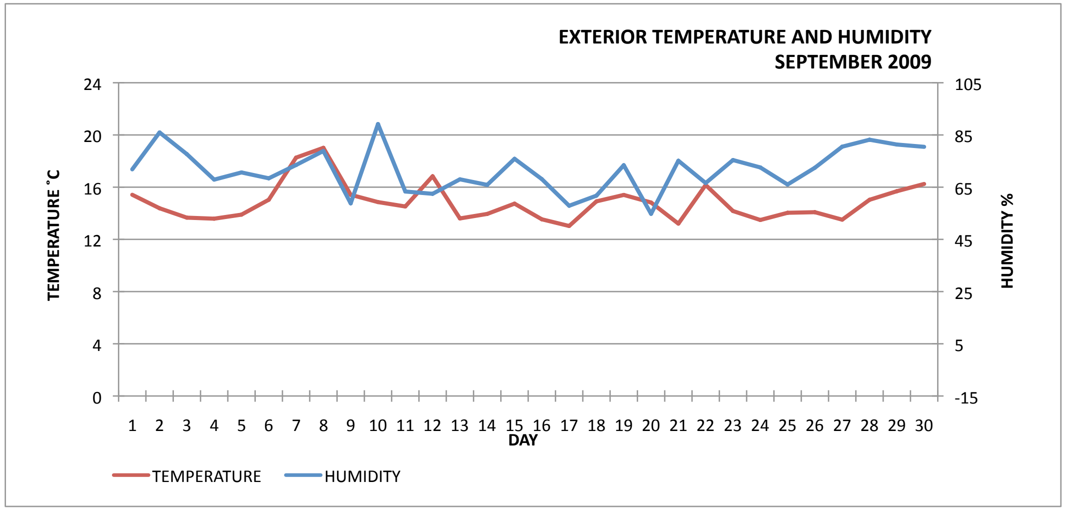


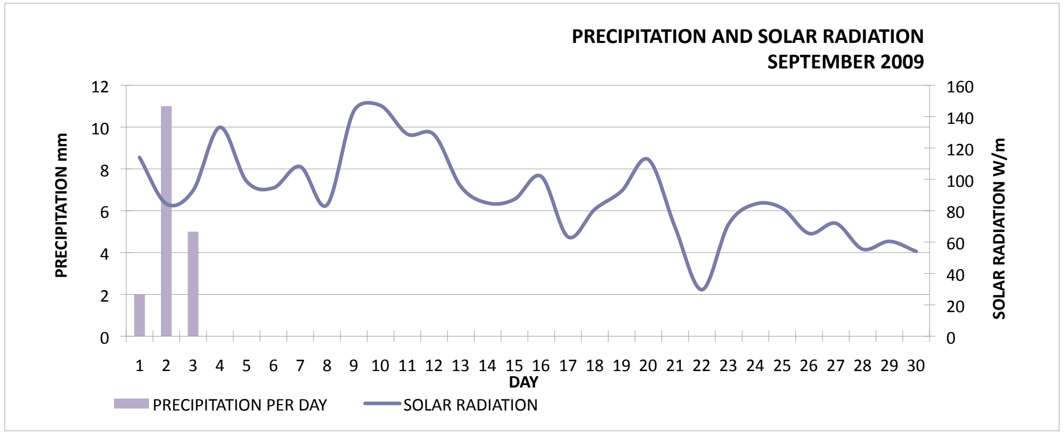
AUGUST	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Aug	14.78	97.75	0.05	202.05	SW	10	52.68
2-Aug	16.52	61.94	0.12	234.93	SW	0	197.86
3-Aug	18.22	58.67	0.30	209.17	SW	0	151.40
4-Aug	18.11	96.27	0.41	203.09	SW	2	57.15
5-Aug	18.74	90.12	0.01	194.99	S	15	79.63
6-Aug	18.83	73.17	0.24	265.18	W	9	156.76
7-Aug	16.88	72.78	0.75	286.45	W	14	114.95
8-Aug	18.24	55.89	0.22	254.46	W	0	193.55
9-Aug	19.70	53.33	0.11	230.40	SW	0	201.21
10-Aug	15.78	81.19	0.02	235.79	SW	0	9.17
11-Aug	19.98	62.92	0.34	276.08	W	0	167.46
12-Aug	18.41	70.84	0.28	260.42	W	2	137.57
13-Aug	17.68	62.15	0.38	204.34	SW	0	136.64
14-Aug	18.39	71.35	0.24	205.53	SW	0	138.60
15-Aug	19.87	68.54	0.52	230.01	SW	0	124.86
16-Aug	17.89	63.37	0.36	235.98	SW	0	158.65
17-Aug	17.23	67.83	0.22	233.94	SW	0	108.35
18-Aug	17.72	66.31	0.09	217.31	SW	0	113.96
19-Aug	21.36	59.75	0.30	215.56	SW	0	166.86
20-Aug	18.13	68.03	0.73	221.30	SW	0	106.53
21-Aug	15.01	63.74	0.27	232.95	SW	0	139.92
22-Aug	17.17	59.17	0.09	222.45	SW	0	174.48
23-Aug	20.27	52.34	0.33	204.94	SW	0	144.01
24-Aug	17.22	76.28	0.05	201.78	SW	1	86.96
25-Aug	15.03	79.28	0.11	221.15	SW	6	124.99
26-Aug	15.76	94.69	0.62	209.74	SW	2	43.65
27-Aug	18.62	63.10	0.40	227.74	SW	0	136.21
28-Aug	13.83	69.80	0.64	237.56	SW	0	109.37
29-Aug	14.39	61.82	0.47	238.57	SW	0	135.19
30-Aug	15.27	82.68	0.25	223.85	SW	1	72.22
31-Aug	19.62	68.93	0.41	217.96	SW	0	70.71
AVG	17.57	70.13	0.30	227.60		2.00	122.95



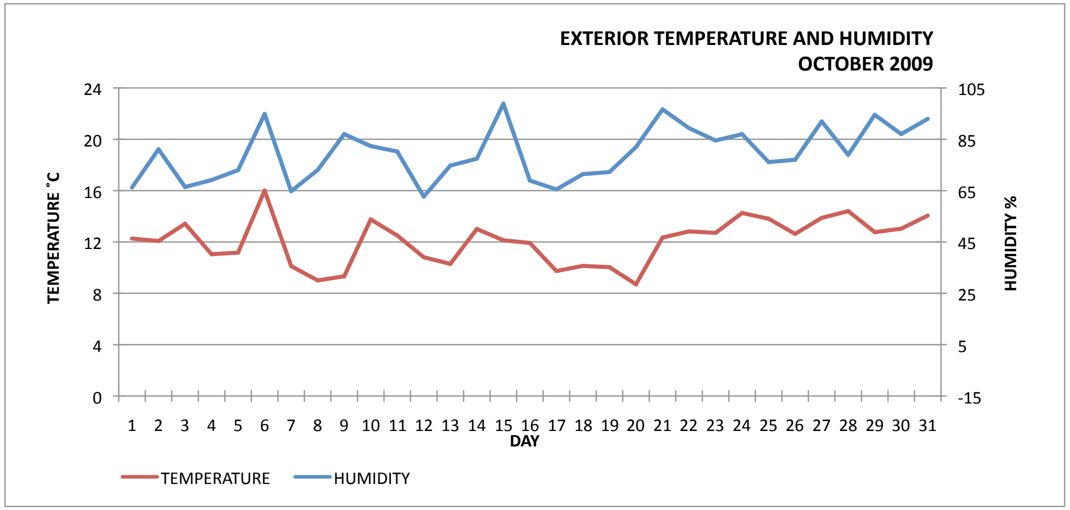


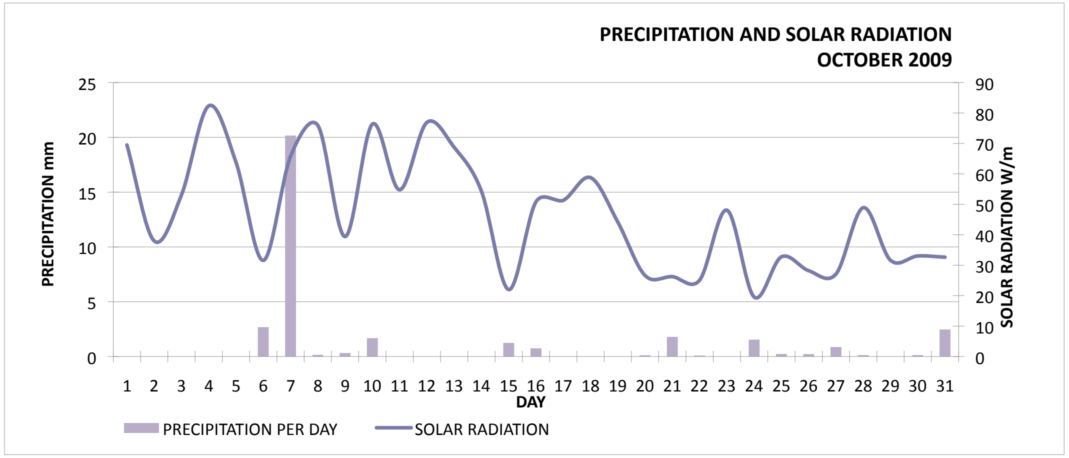
SEPTEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Sep	15.42	71.82	0.37	230.52	SW	2	113.97
2-Sep	14.38	85.97	0.28	210.51	SW	11	84.45
3-Sep	13.66	77.65	0.94	236.29	SW	5	92.89
4-Sep	13.59	67.89	0.90	238.63	SW	0	133.17
5-Sep	13.89	70.64	0.36	238.39	SW	0	98.70
6-Sep	15.04	68.39	0.26	222.33	SW	0	94.57
7-Sep	18.26	73.49	0.13	213.86	SW	0	108.13
8-Sep	19.01	78.86	0.72	235.43	SW	0	83.70
9-Sep	15.42	58.80	1.23	238.38	SW	0	143.49
10-Sep	14.86	89.17	1.06	283.53	W	0	147.07
11-Sep	14.52	63.33	1.46	155.75	SE	0	128.88
12-Sep	16.84	62.46	0.62	305.54	NW	0	128.46
13-Sep	13.60	68.00	2.50	277.92	W	0	95.42
14-Sep	13.95	65.88	2.87	158.21	SE	0	84.92
15-Sep	14.74	75.88	3.34	159.83	SE	0	87.29
16-Sep	13.54	68.08	2.99	70.54	E	0	101.88
17-Sep	13.03	57.88	1.79	115.50	SE	0	63.29
18-Sep	14.91	61.75	1.21	109.17	SE	0	80.92
19-Sep	15.40	73.42	0.43	262.54	W	0	92.58
20-Sep	14.83	54.79	0.67	287.71	W	0	112.63
21-Sep	13.20	75.13	0.32	234.92	SW	0	69.33
22-Sep	16.17	66.58	0.56	238.27	SW	0	29.68
23-Sep	14.17	75.39	0.09	235.48	SW	0	71.54
24-Sep	13.49	72.56	0.19	241.33	SW	0	84.30
25-Sep	14.04	66.01	0.06	235.61	SW	0	81.58
26-Sep	14.08	72.44	0.07	237.87	SW	0	65.50
27-Sep	13.51	80.51	0.17	250.15	SW	0	71.98
28-Sep	15.03	83.17	0.31	241.70	SW	0	55.49
29-Sep	15.69	81.33	0.44	239.29	SW	0	60.48
30-Sep	16.25	80.45	0.22	241.68	SW	0	54.08
AVG	14.82	71.59	0.89	221.56		0.60	90.68



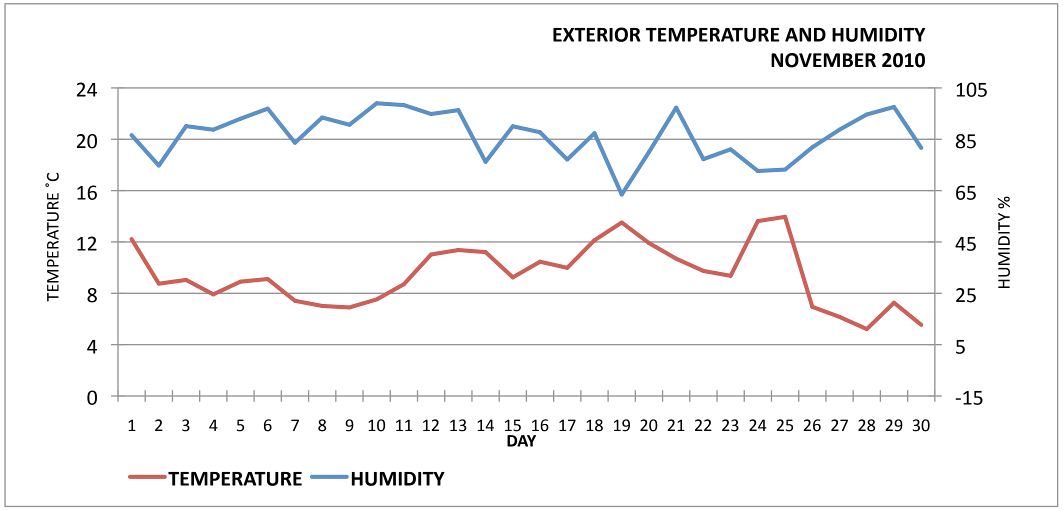


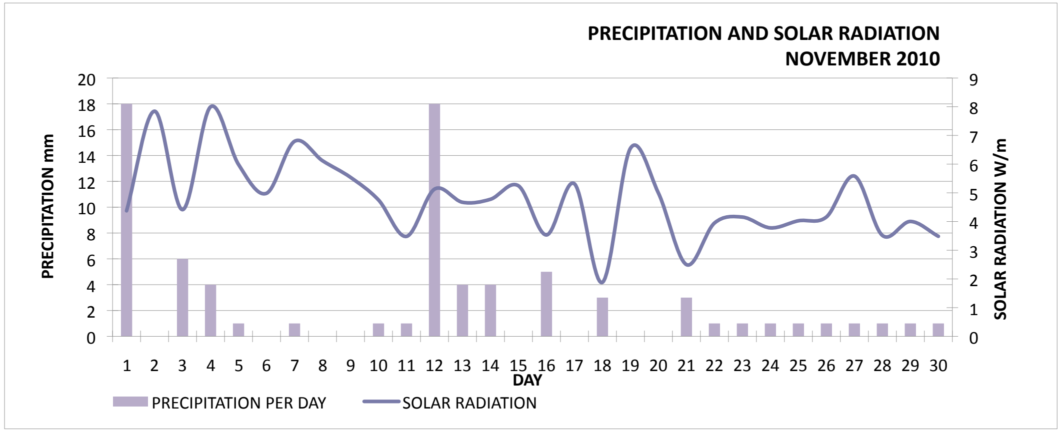
OCTOBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree		mm	W/m²
1-Oct	12.27	66.21	0.67	253.01	W	0	69.50
2-Oct	12.07	81.10	0.27	236.59	SW	0	37.98
3-Oct	13.42	66.41	1.45	234.99	SW	0	53.08
4-Oct	11.04	69.12	0.35	260.49	W	0	82.33
5-Oct	11.17	72.98	0.24	173.83	S	0	63.81
6-Oct	16.00	94.86	0.44	207.77	SW	3	31.59
7-Oct	10.12	64.77	1.32	173.20	S	20	65.75
8-Oct	9.00	73.03	0.71	248.37	SW	0	75.94
9-Oct	9.32	87.01	0.85	124.09	SE	0	39.41
10-Oct	13.76	82.34	0.17	238.92	SW	2	76.33
11-Oct	12.50	80.23	0.95	252.56	SW	0	54.78
12-Oct	10.81	62.66	1.24	272.41	W	0	76.91
13-Oct	10.29	74.75	0.03	237.87	SW	0	68.73
14-Oct	13.01	77.43	0.04	231.21	SW	0	54.32
15-Oct	12.13	98.87	0.01	228.96	SW	1	22.00
16-Oct	11.92	68.90	2.99	241.07	SW	1	50.83
17-Oct	9.74	65.48	1.20	208.35	SW	0	51.31
18-Oct	10.14	71.42	0.09	202.96	SW	0	58.77
19-Oct	10.03	72.23	0.33	208.23	SW	0	44.19
20-Oct	8.70	81.98	1.35	119.77	SE	0	26.62
21-Oct	12.34	96.65	0.50	124.45	SE	2	26.25
22-Oct	12.82	89.34	0.67	144.48	SE	0	25.08
23-Oct	12.71	84.51	0.06	188.83	S	0	48.08
24-Oct	14.26	86.99	0.99	191.95	S	2	19.55
25-Oct	13.81	76.11	1.14	213.45	SW	0	32.75
26-Oct	12.63	77.03	0.34	205.46	SW	0	28.20
27-Oct	13.87	91.96	0.28	171.66	S	1	27.10
28-Oct	14.40	78.95	0.12	236.43	SW	0	48.89
29-Oct	12.76	94.52	0.05	194.75	S	0	31.63
30-Oct	13.03	87.01	0.41	162.69	S	0	33.05
31-Oct	14.06	92.97	0.11	215.05	SW	2	32.64
AVG	12.07	79.61	0.62	206.58		1.12	47.01



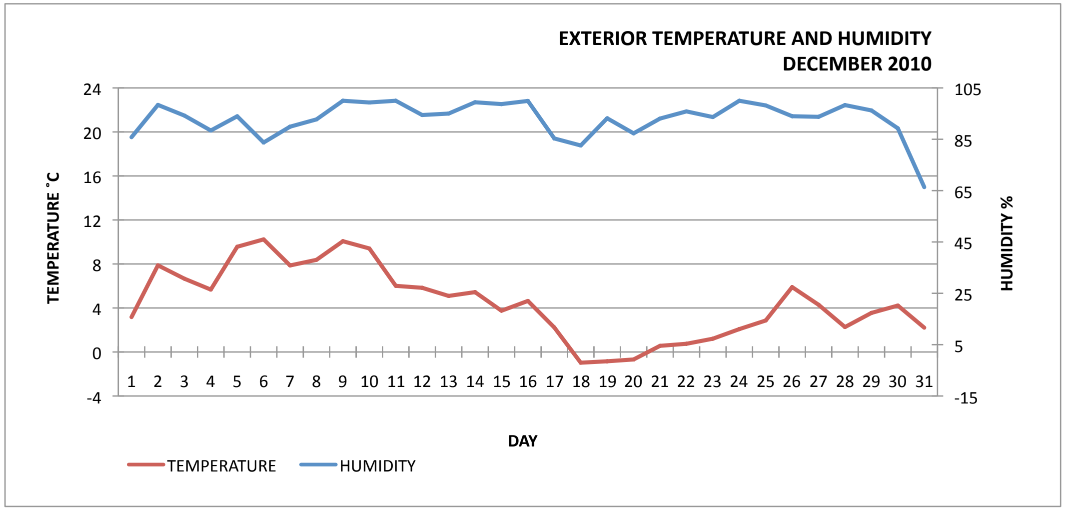


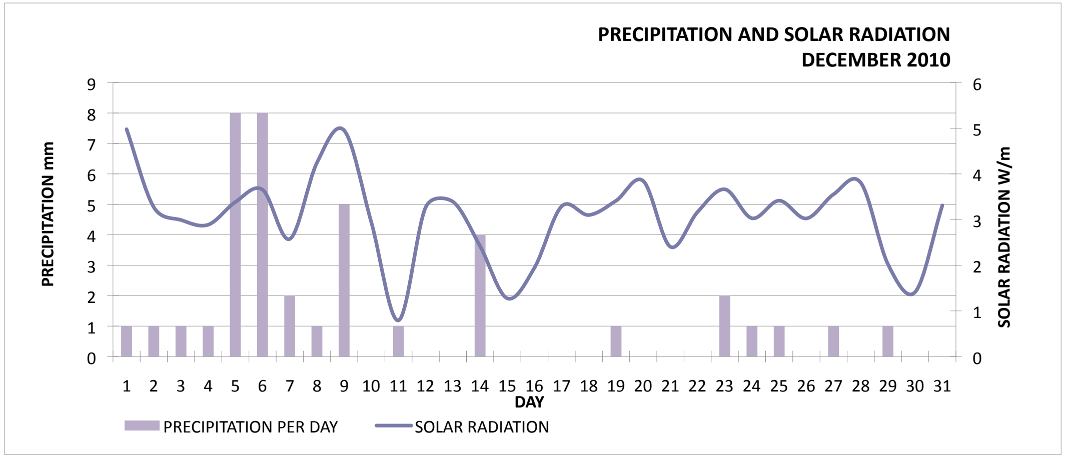
NOVEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Dec	12.22	86.60	3.58	209.98	SW	18	4.37
2-Dec	8.75	74.74	2.52	230.63	SW	0	7.84
3-Dec	9.04	90.11	1.79	219.77	SW	6	4.41
4-Dec	7.92	88.73	1.36	232.71	SW	4	8.00
5-Dec	8.91	93.00	0.85	240.19	SW	1	5.99
6-Dec	9.11	96.93	1.44	240.98	SW	0	4.98
7-Dec	7.42	83.64	1.80	210.91	SW	1	6.79
8-Dec	7.01	93.47	4.06	207.90	SW	0	6.12
9-Dec	6.90	90.65	1.20	255.31	W	0	5.54
10-Dec	7.52	99.01	0.28	216.43	SW	1	4.75
11-Dec	8.71	98.31	1.67	104.02	E	1	3.48
12-Dec	11.02	94.83	1.87	198.75	S	18	5.13
13-Dec	11.37	96.34	2.19	194.29	S	4	4.67
14-Dec	11.21	76.20	4.88	213.02	SW	4	4.78
15-Dec	9.24	90.06	2.02	199.25	S	0	5.24
16-Dec	10.46	87.74	3.66	193.24	S	5	3.53
17-Dec	9.98	77.11	3.67	226.72	SW	0	5.31
18-Dec	12.14	87.35	4.18	224.72	SW	3	1.88
19-Dec	13.51	63.46	5.21	210.65	SW	0	6.55
20-Dec	11.91	79.99	3.77	219.77	SW	0	4.99
21-Dec	10.70	97.31	1.36	177.94	S	3	2.50
22-Dec	9.74	77.25	2.37	210.92	SW	1	3.95
23-Dec	9.36	81.08	2.50	237.58	SW	1	4.16
24-Dec	13.63	72.64	5.71	215.46	SW	1	3.78
25-Dec	13.96	73.19	5.56	226.80	SW	1	4.03
26-Dec	6.94	81.86	3.82	222.24	SW	1	4.16
27-Dec	6.16	88.75	2.93	223.70	SW	1	5.58
28-Dec	5.21	94.66	2.51	170.83	S	1	3.52
29-Dec	7.26	97.58	4.04	88.60	E	1	4.00
30-Dec	5.54	81.65	6.84	231.88	SW	1	3.49
AVG	9.43	86.48	2.99	208.51		2.60	4.78



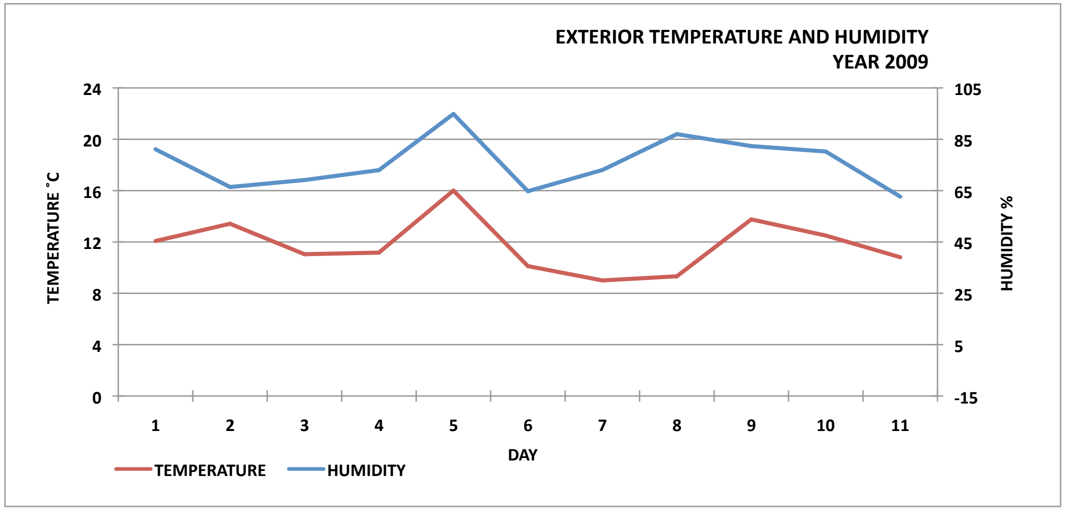


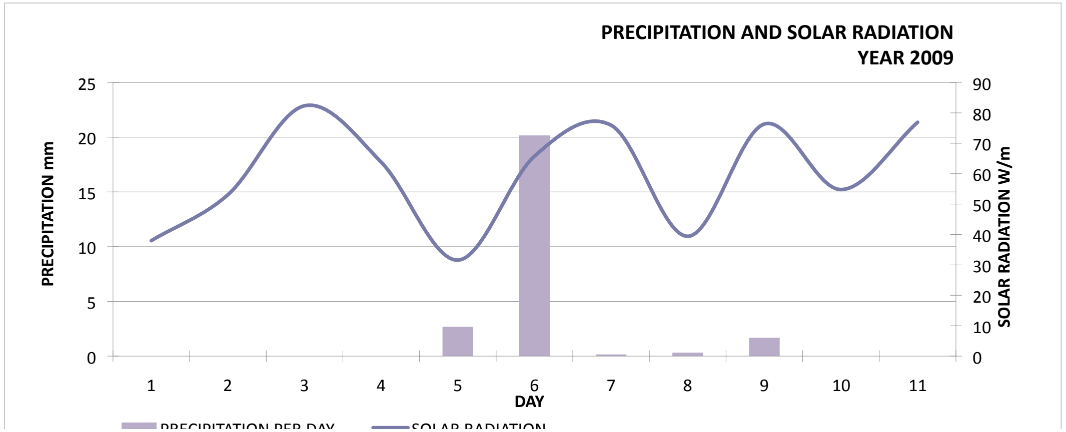
DECEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Dec	3.17	85.80	1.30	207.89	SW	1	4.98
2-Dec	7.88	98.39	0.88	147.13	SE	1	3.27
3-Dec	6.66	94.23	0.66	239.17	SW	1	2.99
4-Dec	5.67	88.41	0.68	216.34	SW	1	2.89
5-Dec	9.56	93.96	1.32	195.29	S	8	3.38
6-Dec	10.23	83.74	2.62	210.77	SW	8	3.65
7-Dec	7.86	89.90	2.07	203.94	SW	2	2.57
8-Dec	8.38	92.74	1.07	209.49	SW	1	4.24
9-Dec	10.07	100.0	0.27	195.94	S	5	4.95
10-Dec	9.41	99.33	0.68	245.86	SW	0	2.94
11-Dec	6.01	100.0	0.61	104.54	E	1	0.79
12-Dec	5.83	94.44	1.68	139.70	SE	0	3.27
13-Dec	5.10	95.00	2.65	200.46	S	0	3.39
14-Dec	5.44	99.41	0.47	244.09	SW	4	2.42
15-Dec	3.75	98.70	0.15	161.57	S	0	1.28
16-Dec	4.64	99.93	0.52	215.83	SW	0	1.94
17-Dec	2.23	85.32	3.83	182.46	S	0	3.29
18-Dec	-0.97	82.58	4.23	192.85	S	0	3.10
19-Dec	-0.84	93.18	1.22	255.39	W	1	3.41
20-Dec	-0.68	87.30	1.05	282.12	W	0	3.85
21-Dec	0.56	93.06	0.41	203.04	SW	0	2.40
22-Dec	0.75	95.86	0.65	232.17	SW	0	3.17
23-Dec	1.21	93.65	0.48	164.98	S	2	3.66
24-Dec	2.08	100.0	0.52	154.03	SE	1	3.03
25-Dec	2.86	98.18	0.56	240.28	SW	1	3.41
26-Dec	5.90	93.98	0.96	208.70	SW	0	3.02
27-Dec	4.29	93.74	1.35	237.77	SW	1	3.55
28-Dec	2.27	98.32	0.30	139.00	SE	0	3.81
29-Dec	3.55	96.23	2.58	75.79	E	1	2.02
30-Dec	4.22	89.26	3.64	68.00	E	0	1.41
31-Dec	2.21	66.35	4.88	93.65	E	0	3.31
AVG	4.49	92.94	1.43	189.30	S	1.29	3.08



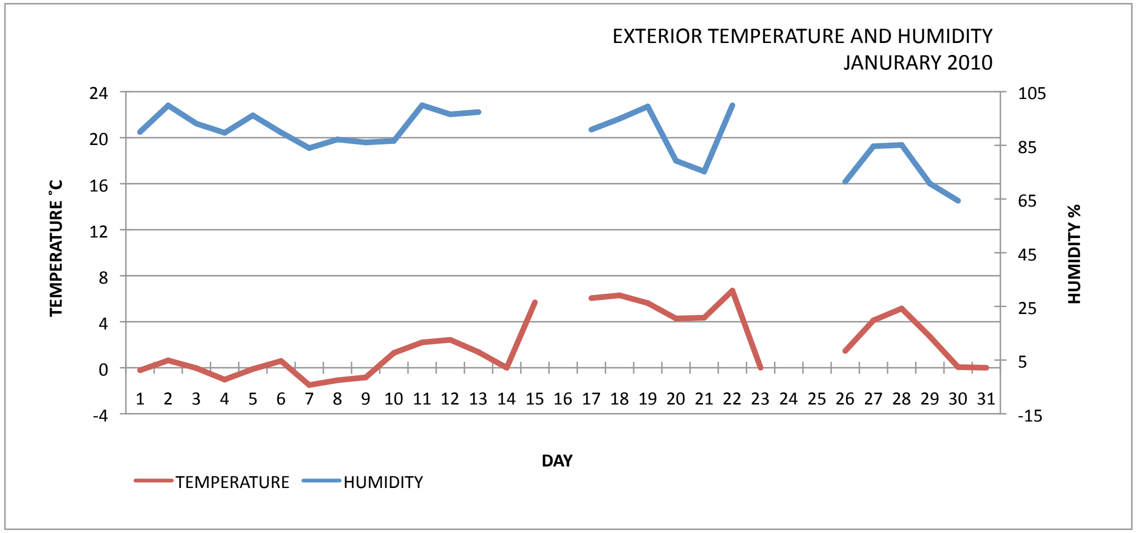


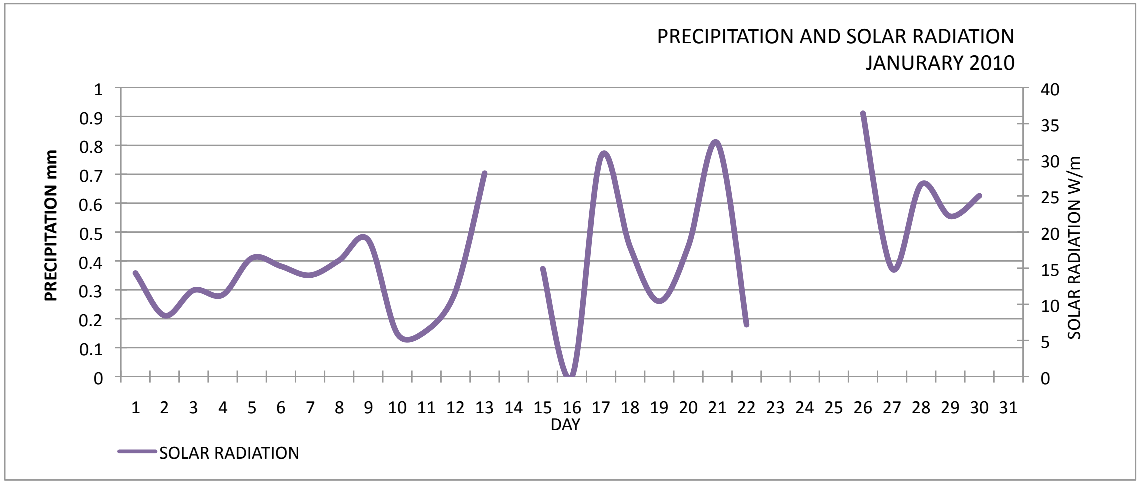
MONTH	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
FEB	12.07	81.10	0.27	236.59	SW	0	37.98
MAR	13.42	66.41	1.45	234.99	SW	0	53.08
APR	11.04	69.12	0.35	260.49	W	0	82.33
MAY	11.17	72.98	0.24	173.83	S	0	63.81
JUN	16.00	94.86	0.44	207.77	SW	3	31.59
JUL	10.12	64.77	1.32	173.20	S	20	65.75
AUG	9.00	73.03	0.71	248.37	SW	0	75.94
SEP	9.32	87.01	0.85	124.09	SE	0	39.41
OCT	13.76	82.34	0.17	238.92	SW	2	76.33
NOV	12.50	80.23	0.95	252.56	SW	0	54.78
DEC	10.81	62.66	1.24	272.41	W	0	76.91
AVG	11.75	75.86	0.73	220.29		2.27	59.81



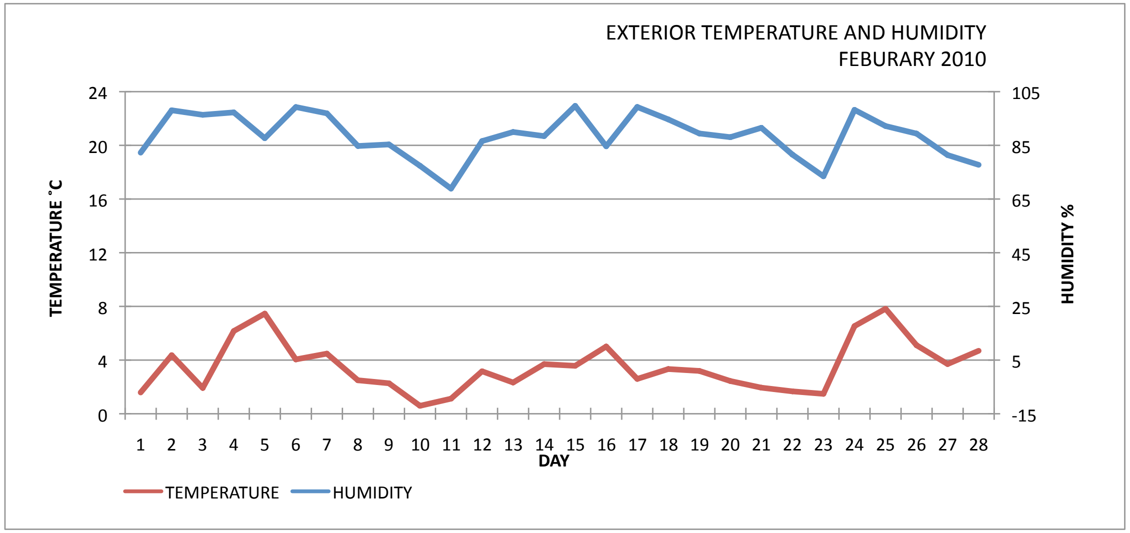


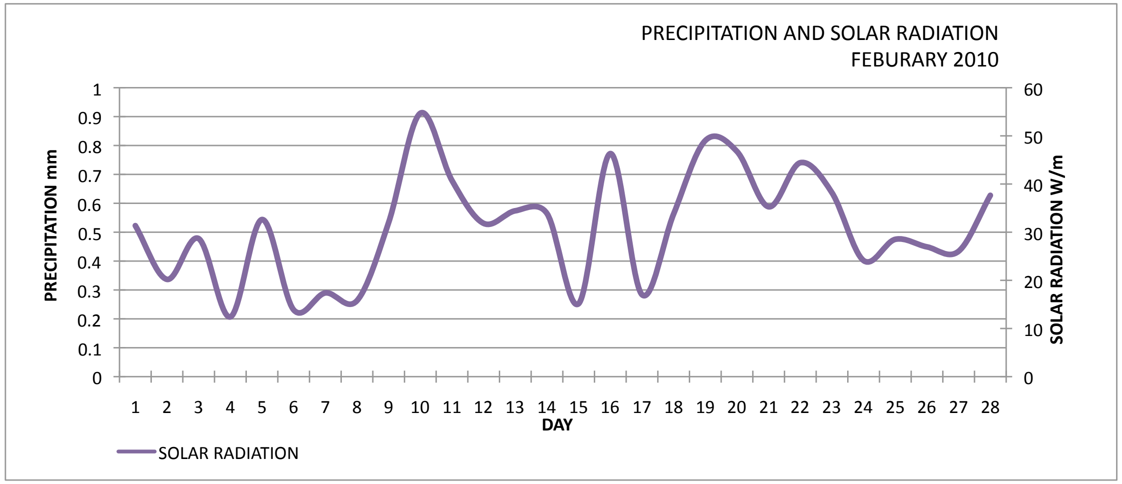
JANURARY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Jan	-0.22	89.97	1.60	246.43	SW	FAULTY DATA	14.32
2-Jan	0.64	99.85	0.68	227.75	SW		8.44
3-Jan	-0.03	93.10	1.13	140.37	SE		11.95
4-Jan	-1.03	89.67	0.39	245.64	SW		11.30
5-Jan	-0.11	96.16	0.54	183.05	S		16.40
6-Jan	0.59	89.80	2.51	138.25	SE		15.27
7-Jan	-1.50	83.99	2.87	263.74	W		14.02
8-Jan	-1.09	87.18	3.02	171.69	S		16.08
9-Jan	-0.84	86.09	3.13	134.89	SE		18.90
10-Jan	1.29	86.65	3.05	79.84	E		5.92
11-Jan	2.21	99.93	2.41	91.37	E		6.35
12-Jan	2.43	96.55	2.22	97.61	E		11.80
13-Jan	1.36	97.40	1.27	73.94	E		28.14
14-Jan	MISSING DATA						
15-Jan	5.69	100.00	2.61	198.87	S	FAULTY DATA	14.91
16-Jan			0.00	0.00	N		0.00
17-Jan	6.05	90.85	0.36	223.16	SW		30.45
18-Jan	6.29	94.92	0.89	212.10	SW		17.90
19-Jan	5.62	99.46	1.80	93.48	E		10.42
20-Jan	4.28	79.26	7.75	89.07	E		18.06
21-Jan	4.35	75.26	0.98	166.46	S		32.29
22-Jan	6.70	99.90	0.65	148.07	SE		7.18
23-Jan	MISSING DATA						
24-Jan							
25-Jan							
26-Jan	1.46	71.42	0.59	131.44	SE	FAULTY DATA	36.44
27-Jan	4.12	84.66	2.16	253.61	W		14.91
28-Jan	5.15	85.14	2.95	253.63	W		26.59
29-Jan	2.71	70.76	4.35	270.53	W		22.17
30-Jan	0.06	64.36	4.75	277.71	W		25.02
31-Jan	MISSING DATA						
AVG	2.25	88.49	2.10	169.72	S		16.74



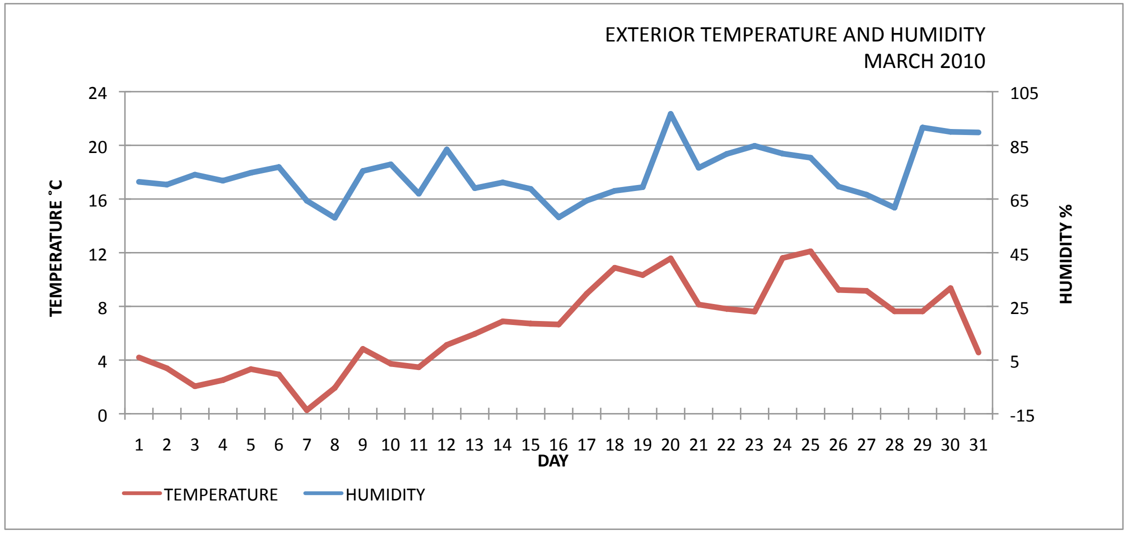


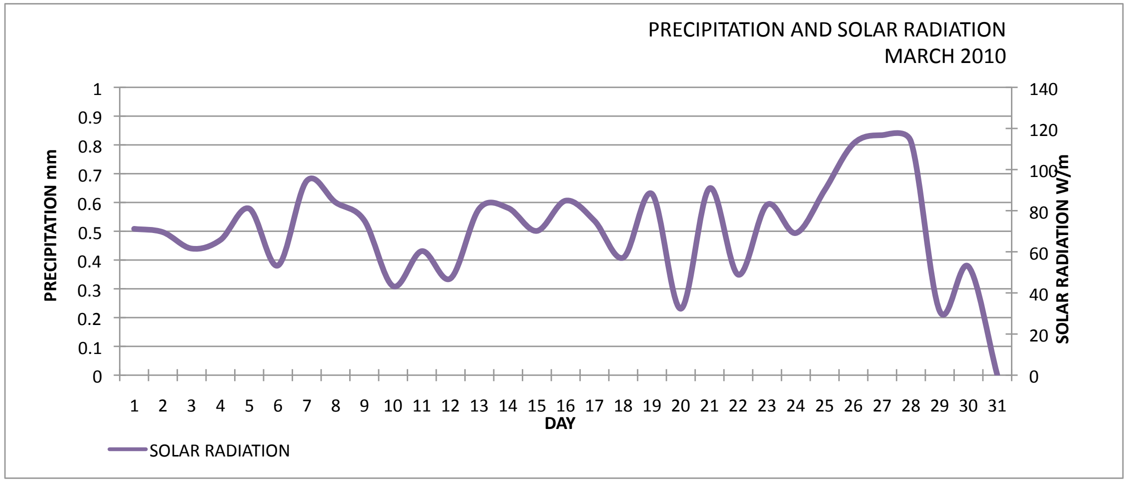
FEBRUARY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Feb	1.59	82.27	0.93	247.63	W		31.36
2-Feb	4.37	98.06	1.59	237.46	SW		20.20
3-Feb	1.92	96.37	0.18	204.87	SW		28.67
4-Feb	6.16	97.27	1.05	187.51	S		12.41
5-Feb	7.46	87.65	0.55	161.36	S		32.63
6-Feb	4.05	99.26	2.09	177.34	S		13.87
7-Feb	4.48	96.92	1.49	196.66	S		17.39
8-Feb	2.49	84.75	6.05	61.98	NE		15.78
9-Feb	2.27	85.33	5.50	145.22	SE		32.02
10-Feb	0.59	77.39	3.10	144.45	SE		54.70
11-Feb	1.12	68.88	2.33	196.92	S		40.73
12-Feb	3.17	86.58	2.96	157.67	S		31.83
13-Feb	2.33	89.97	2.87	205.78	SW		34.44
14-Feb	3.70	88.44	2.08	239.78	SW		33.88
15-Feb	3.57	99.71	1.09	169.93	S		15.16
16-Feb	5.01	84.64	1.63	232.86	SW	FAULTY DATA	46.32
17-Feb	2.60	99.29	0.59	127.34	SE		17.02
18-Feb	3.33	94.66	1.33	129.27	SE		33.80
19-Feb	3.19	89.42	0.61	270.81	W		49.03
20-Feb	2.44	88.04	0.40	249.54	W		46.76
21-Feb	1.94	91.54	0.22	208.31	SW		35.28
22-Feb	1.67	81.55	2.42	88.06	E		44.43
23-Feb	1.48	73.47	3.11	85.49	E		38.19
24-Feb	6.53	98.22	0.59	107.62	E		24.10
25-Feb	7.82	92.20	0.73	154.27	SE		28.52
26-Feb	5.10	89.37	2.03	252.78	W		26.95
27-Feb	3.70	81.38	1.08	94.53	E		26.05
28-Feb	4.69	77.74	2.63	266.06	W		37.65
AVG	3.53	88.58	1.83	178.62	S		31.04



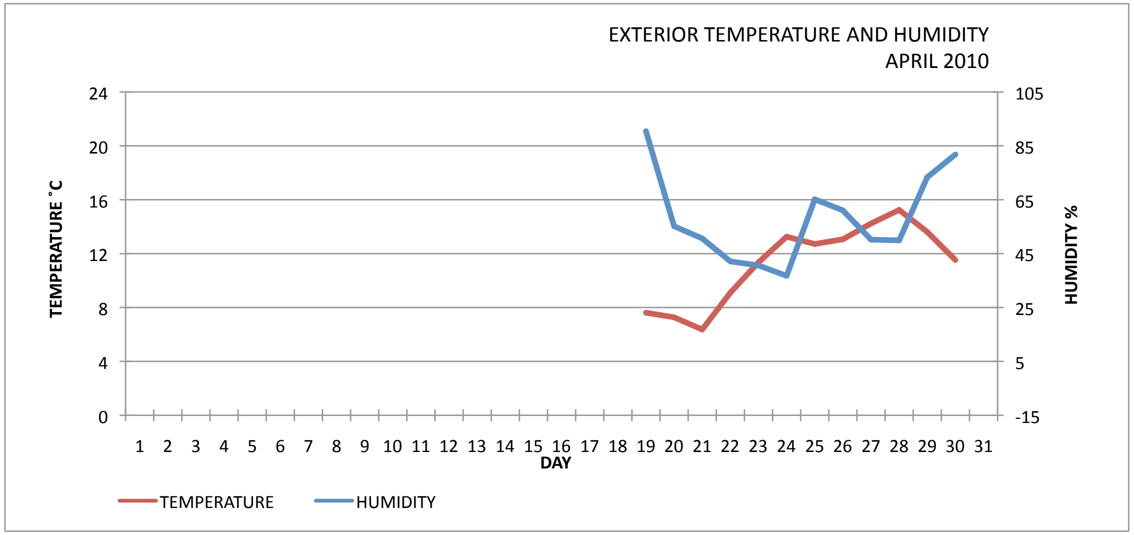


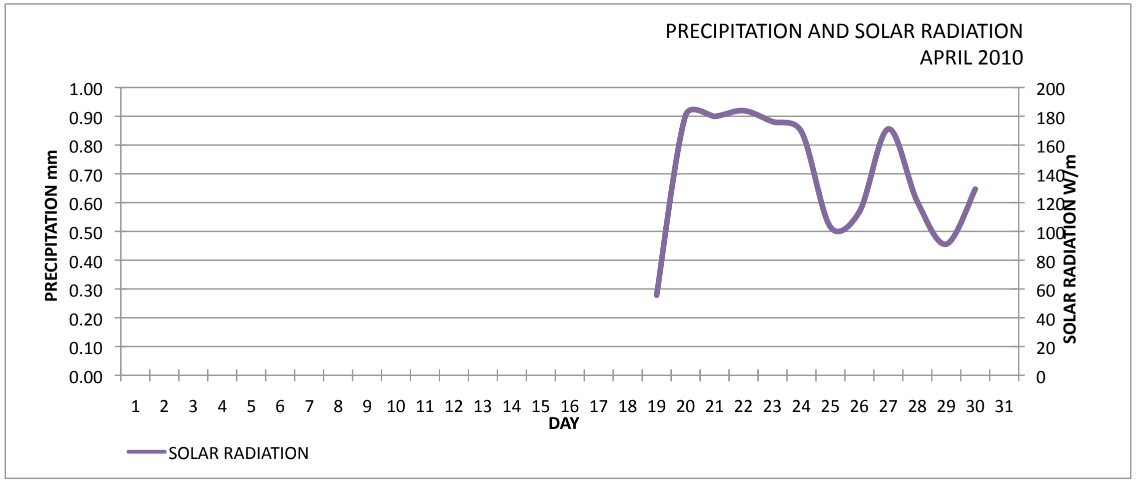
MARCH	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Mar	4.20	71.41	0.61	263.28	W		71.17
2-Mar	3.39	70.37	0.66	187.98	S		69.55
3-Mar	2.05	74.08	1.78	96.13	E		61.58
4-Mar	2.51	71.83	1.39	122.56	SE		65.76
5-Mar	3.33	74.79	1.29	262.75	W		81.02
6-Mar	2.93	76.91	1.80	148.24	SE		53.34
7-Mar	0.27	64.35	1.25	121.11	SE		94.52
8-Mar	1.93	58.01	1.62	173.41	S		84.07
9-Mar	4.83	75.44	2.41	108.52	E		75.27
10-Mar	3.72	77.92	2.26	94.43	E		43.30
11-Mar	3.47	66.97	1.29	242.31	SW		60.34
12-Mar	5.13	83.44	2.52	232.48	SW		47.07
13-Mar	5.95	69.04	1.39	262.15	W		81.07
14-Mar	6.89	71.19	1.82	267.53	W		81.30
15-Mar	6.72	68.77	1.22	250.79	W		70.16
16-Mar	6.65	58.17	0.72	217.11	SW	FAULTY DATA	84.88
17-Mar	8.95	64.40	1.28	218.31	SW		75.08
18-Mar	10.88	68.06	1.83	193.68	S		57.16
19-Mar	10.33	69.42	1.50	203.86	SW		88.17
20-Mar	11.58	96.71	1.89	217.75	SW		32.30
21-Mar	8.14	76.63	0.75	228.74	SW		90.92
22-Mar	7.81	81.78	1.72	209.36	SW		48.84
23-Mar	7.61	84.82	1.32	191.07	S		82.89
24-Mar	11.60	81.91	0.74	173.61	S		69.13
25-Mar	12.11	80.40	1.42	163.04	S		89.96
26-Mar	9.23	69.65	2.44	199.77	S		112.56
27-Mar	9.16	66.61	1.05	245.52	SW		116.74
28-Mar	7.63	61.77	1.56	254.07	W		113.64
29-Mar	7.63	91.63	0.86	161.05	S		31.12
30-Mar	9.36	90.03	1.51	190.37	S		52.83
31-Mar	4.56	89.81	2.30	192.14	S		0.09
AVG	6.47	74.40	1.49	196.55	S		70.51



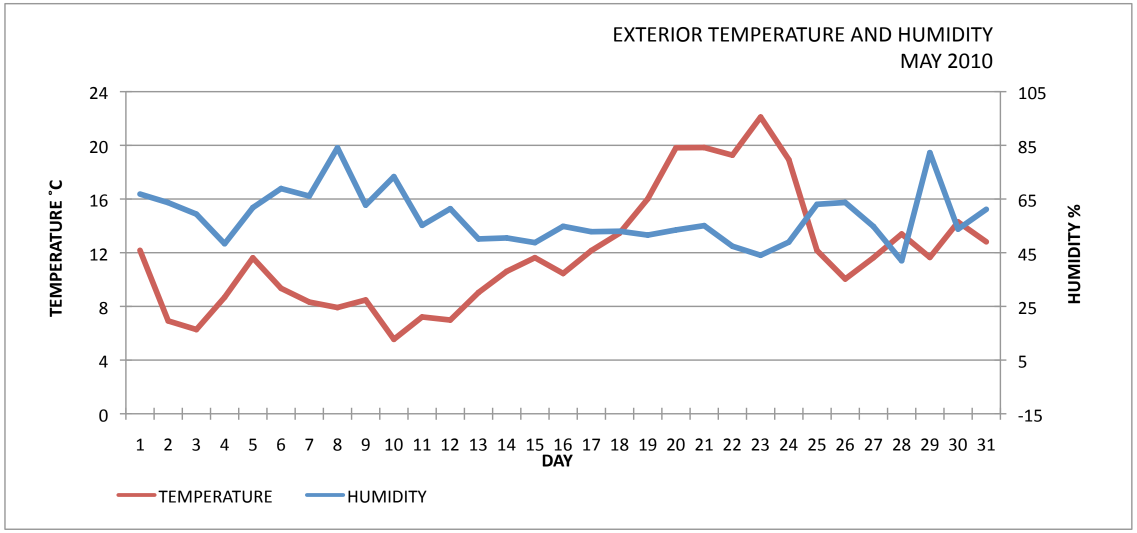


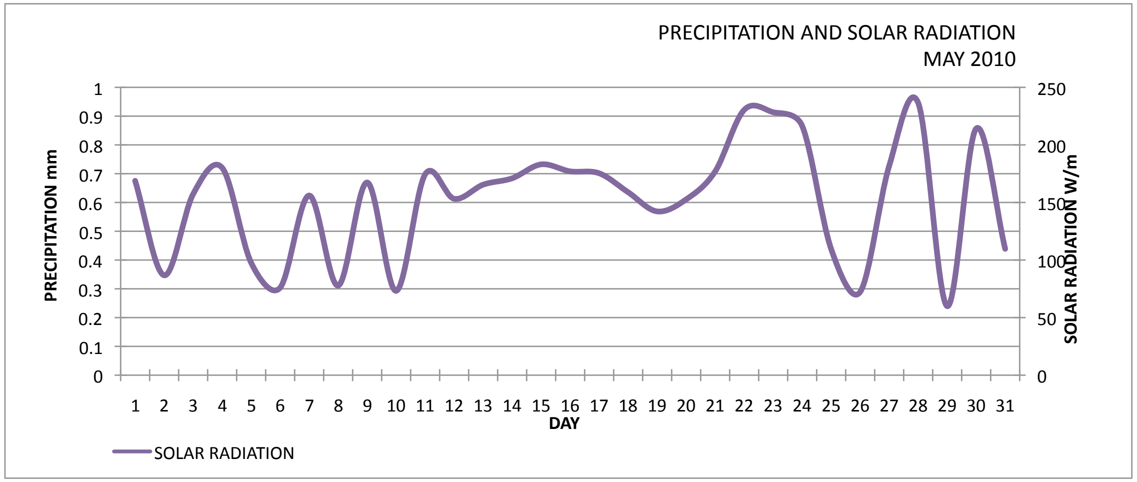
APRIL	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Apr	MISSING DATA						
2-Apr							
3-Apr							
4-Apr							
5-Apr							
6-Apr							
7-Apr							
8-Apr							
9-Apr							
10-Apr							
11-Apr							
12-Apr							
13-Apr							
14-Apr							
15-Apr							
16-Apr							
17-Apr							
18-Apr							
19-Apr	7.61	90.45	1.34	118.87	SE	FAULTY DATA	55.65
20-Apr	7.27	55.16	1.53	262.55	W		180.70
21-Apr	6.37	50.63	1.41	200.01	S		179.92
22-Apr	9.10	42.10	0.73	237.30	SW		183.90
23-Apr	11.35	40.61	0.75	234.05	SW		176.26
24-Apr	13.25	36.77	0.79	183.96	S		169.26
25-Apr	12.71	65.17	0.67	209.34	SW		103.05
26-Apr	13.06	61.05	0.94	257.73	W		113.68
27-Apr	14.23	50.18	0.70	207.83	SW		171.19
28-Apr	15.24	49.91	1.02	199.76	S		120.67
29-Apr	13.61	73.36	0.35	234.48	SW		91.13
30-Apr	11.52	81.81	0.74	238.94	SW		129.40
AVG	11.28	58.10	0.91	215.40	SW		139.57



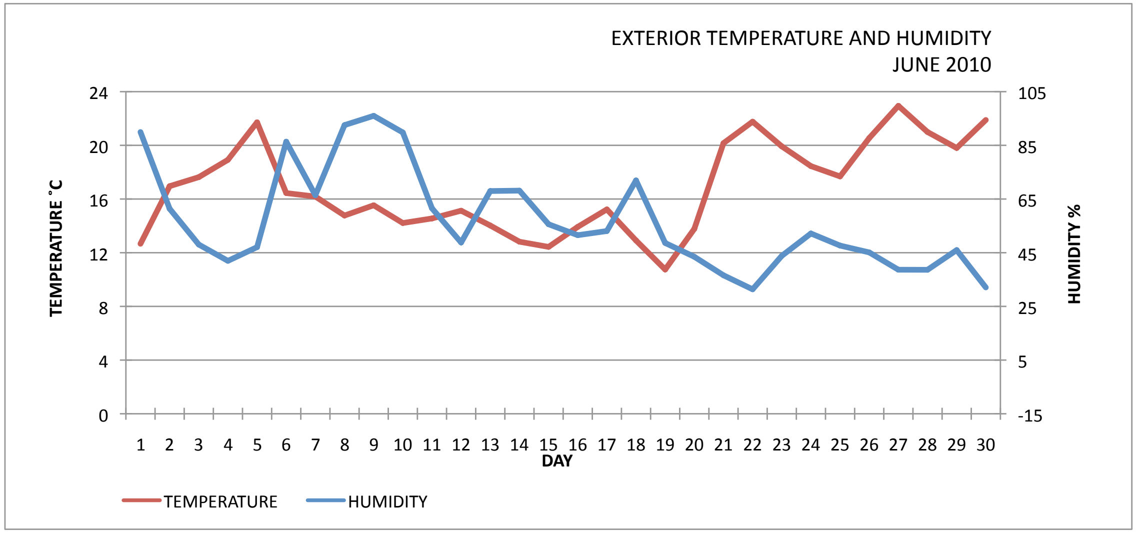


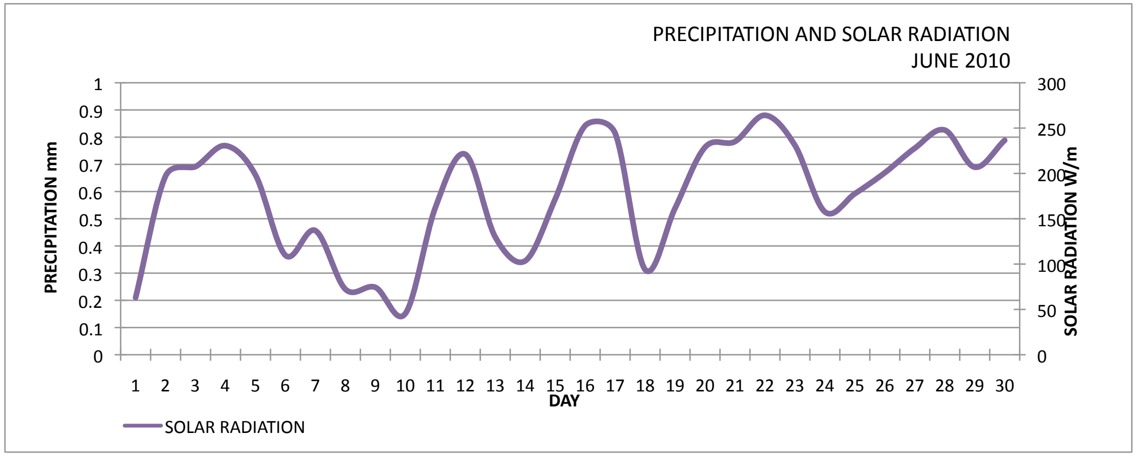
MAY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-May	12.18	66.84	1.44	182.30	S		168.84
2-May	6.92	63.64	3.54	129.53	SE		86.73
3-May	6.28	59.37	3.43	190.05	S		157.28
4-May	8.68	48.34	1.43	210.60	SW		180.14
5-May	11.62	61.80	0.50	214.06	SW		97.66
6-May	9.35	68.89	1.54	88.06	E		75.95
7-May	8.32	66.10	3.07	108.80	E		156.05
8-May	7.92	84.09	3.11	104.59	E		77.79
9-May	8.48	62.72	2.35	129.65	SE		167.37
10-May	5.55	73.34	1.42	147.71	SE		73.21
11-May	7.21	55.21	1.03	157.88	S		174.43
12-May	6.98	61.39	1.37	116.52	SE		153.20
13-May	9.04	50.13	0.36	224.32	SW		165.47
14-May	10.61	50.50	0.51	230.44	SW		170.99
15-May	11.63	48.76	1.00	259.37	W		183.09
16-May	10.45	54.83	0.74	253.68	W	FAULTY DATA	177.04
17-May	12.16	52.82	0.85	206.99	SW		175.36
18-May	13.45	53.01	0.41	173.76	S		158.87
19-May	16.01	51.57	0.15	213.40	SW		142.23
20-May	19.82	53.48	0.28	269.39	W		152.67
21-May	19.84	55.08	0.76	161.95	S		176.96
22-May	19.27	47.42	0.46	125.26	SE		230.42
23-May	22.11	44.05	0.22	231.21	SW		228.38
24-May	18.93	48.95	1.21	200.75	S		216.50
25-May	12.16	63.04	2.16	83.42	E		109.53
26-May	10.04	63.71	1.05	97.83	E		72.30
27-May	11.63	54.77	0.28	262.67	W		181.73
28-May	13.40	42.00	0.30	238.78	SW		236.54
29-May	11.65	82.27	0.11	204.08	SW		59.92
30-May	14.29	53.78	1.89	262.27	W		214.20
31-May	12.81	61.17	2.21	166.60	S		109.73
AVG	11.90	58.16	1.26	182.13	S		152.60



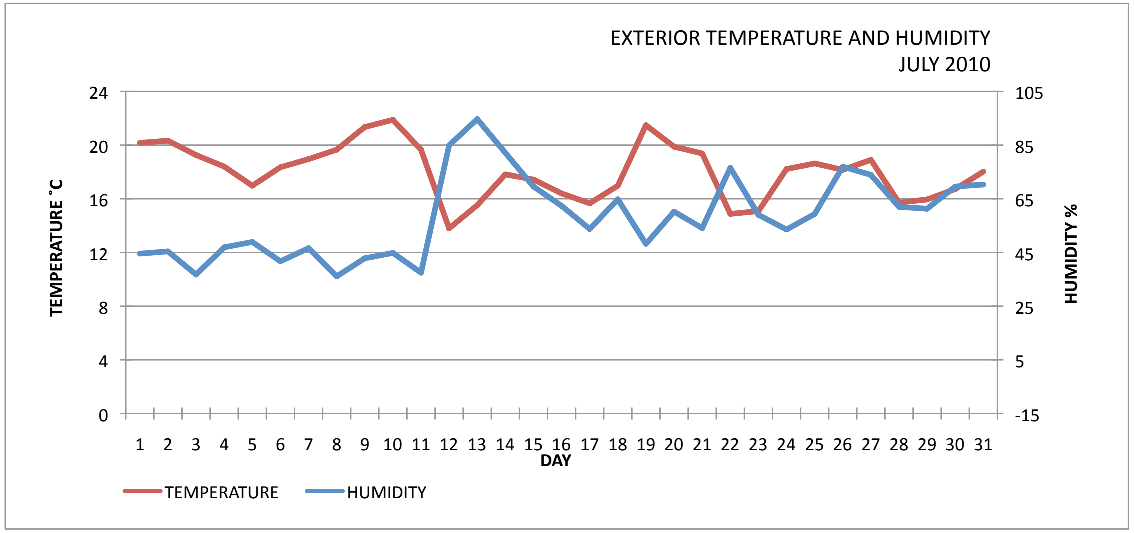


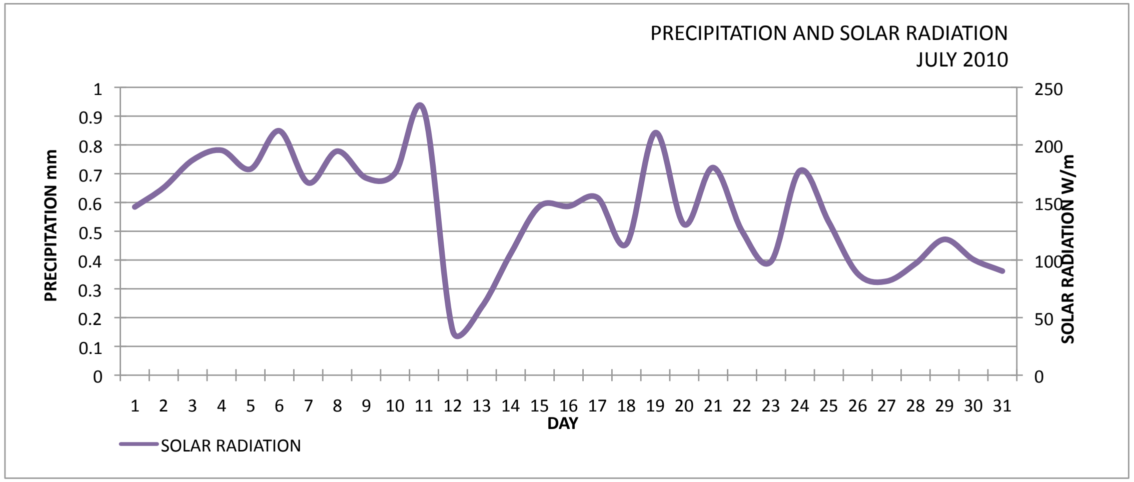
JUNE	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Jun	12.66	89.96	0.14	156.86	SE		63.04
2-Jun	16.96	61.38	0.03	212.28	SW		197.14
3-Jun	17.63	48.04	1.34	128.07	SE		207.54
4-Jun	18.92	41.96	0.57	143.60	SE		230.59
5-Jun	21.72	47.08	0.17	204.86	SW		198.29
6-Jun	16.44	86.37	1.02	220.32	SW		109.62
7-Jun	16.18	66.41	0.06	230.91	SW		136.89
8-Jun	14.77	92.54	1.00	121.57	SE		72.28
9-Jun	15.53	96.00	1.77	119.37	SE		74.35
10-Jun	14.21	89.80	3.09	153.04	SE		45.39
11-Jun	14.55	61.54	1.53	250.75	W		162.12
12-Jun	15.13	48.80	1.23	227.40	SW		221.14
13-Jun	14.03	67.98	0.55	213.35	SW		129.83
14-Jun	12.82	68.12	2.74	123.70	SE		103.55
15-Jun	12.43	55.60	1.97	160.72	S	FAULTY DATA	171.64
16-Jun	13.92	51.53	1.37	151.57	SE		252.67
17-Jun	15.23	53.07	1.33	121.90	SE		244.37
18-Jun	12.91	71.93	1.03	144.25	SE		94.00
19-Jun	10.75	48.63	3.38	241.35	SW		161.55
20-Jun	13.78	43.49	1.51	217.78	SW		228.84
21-Jun	20.16	36.59	0.19	241.41	SW		235.14
22-Jun	21.76	31.36	0.22	257.76	W		264.12
23-Jun	19.93	43.83	0.11	237.57	SW		231.03
24-Jun	18.45	52.16	0.50	251.16	W		157.62
25-Jun	17.68	47.66	0.86	160.77	S		177.66
26-Jun	20.54	45.11	0.53	149.33	SE		200.76
27-Jun	22.94	38.66	0.08	215.92	SW		227.80
28-Jun	20.99	38.63	0.17	227.91	SW		247.79
29-Jun	19.80	45.98	0.74	254.14	W		206.88
30-Jun	21.89	32.06	0.12	237.88	SW		236.54
AVG	16.82	56.74	0.98	192.58	S		176.34



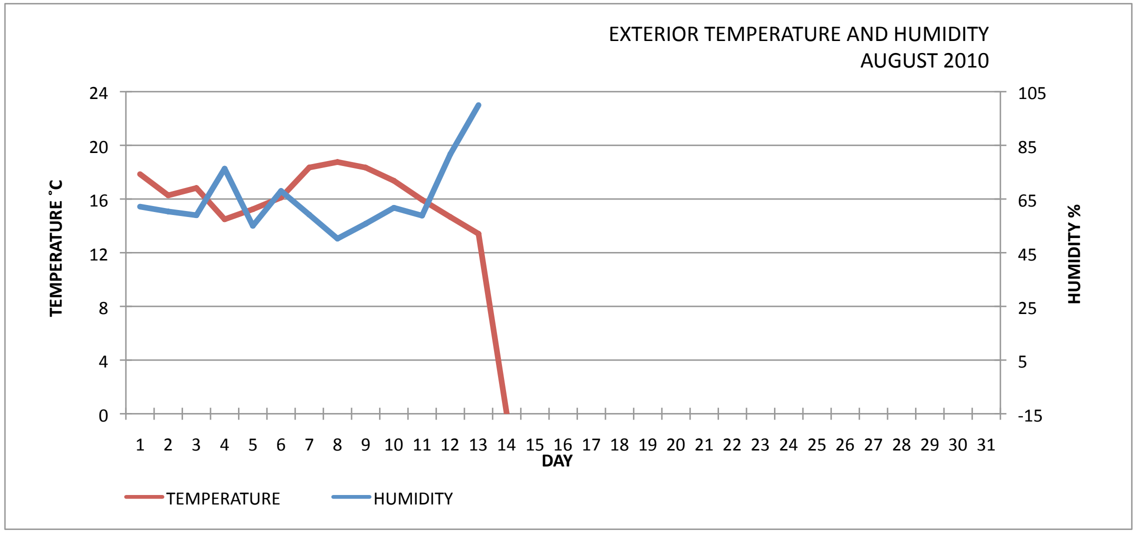


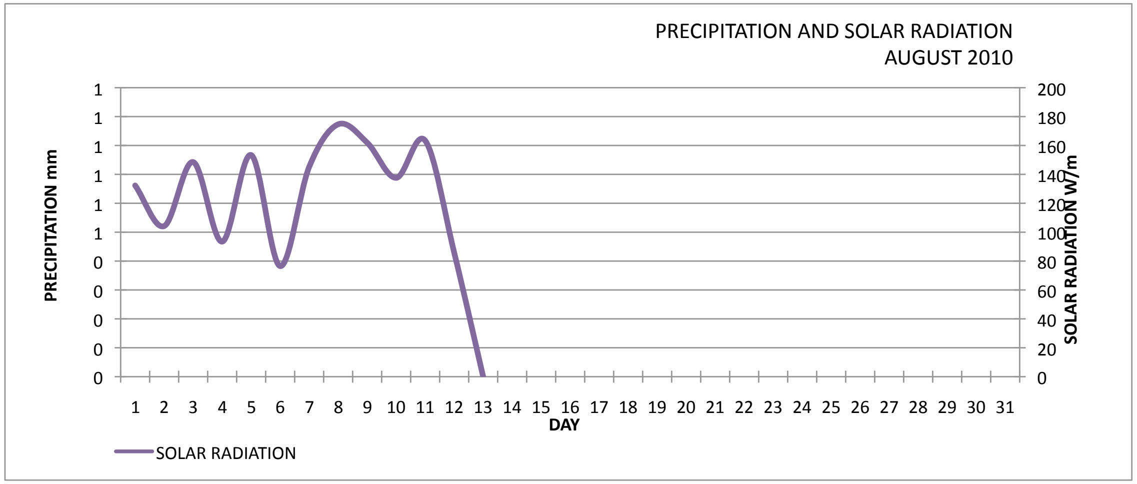
JULY	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Jul	20.17	44.56	0.29	212.09	SW		146.10
2-Jul	20.33	45.40	0.14	222.76	SW		162.90
3-Jul	19.26	36.75	0.18	249.49	W		186.79
4-Jul	18.40	46.92	0.57	253.15	W		195.32
5-Jul	16.98	48.90	0.60	251.03	W		179.00
6-Jul	18.35	41.71	0.23	240.36	SW		212.21
7-Jul	18.95	46.58	0.34	233.60	SW		167.05
8-Jul	19.66	36.08	0.16	221.83	SW		194.57
9-Jul	21.35	42.83	0.18	254.69	W		171.23
10-Jul	21.88	44.83	0.16	236.35	SW		175.42
11-Jul	19.66	37.47	0.96	212.10	SW		229.94
12-Jul	13.80	84.94	2.09	156.09	SE		38.16
13-Jul	15.53	94.68	1.68	105.79	E		59.38
14-Jul	17.82	82.12	0.48	186.59	S		105.60
15-Jul	17.43	69.55	1.00	215.76	SW		146.77
16-Jul	16.40	62.36	0.95	225.32	SW	FAULTY DATA	146.68
17-Jul	15.66	53.75	0.35	235.47	SW		154.16
18-Jul	16.97	64.81	0.42	219.02	SW		113.89
19-Jul	21.48	48.20	0.23	224.25	SW		210.60
20-Jul	19.88	60.23	0.12	209.60	SW		130.79
21-Jul	19.38	54.09	0.24	238.59	SW		180.29
22-Jul	14.87	76.55	1.55	183.25	S		125.05
23-Jul	15.08	59.02	0.88	237.96	SW		98.70
24-Jul	18.21	53.54	0.10	214.91	SW		177.54
25-Jul	18.63	59.33	0.38	246.17	SW		132.91
26-Jul	18.15	76.95	0.51	263.60	W		88.05
27-Jul	18.90	73.90	0.31	247.21	SW		81.58
28-Jul	15.71	61.98	0.31	250.71	W		96.93
29-Jul	15.95	61.30	0.34	259.17	W		117.95
30-Jul	16.73	69.55	0.12	229.30	SW		100.41
31-Jul	18.02	70.30	0.10	235.61	SW		90.40
AVG	18.05	58.36	0.52	224.90	SW		142.46



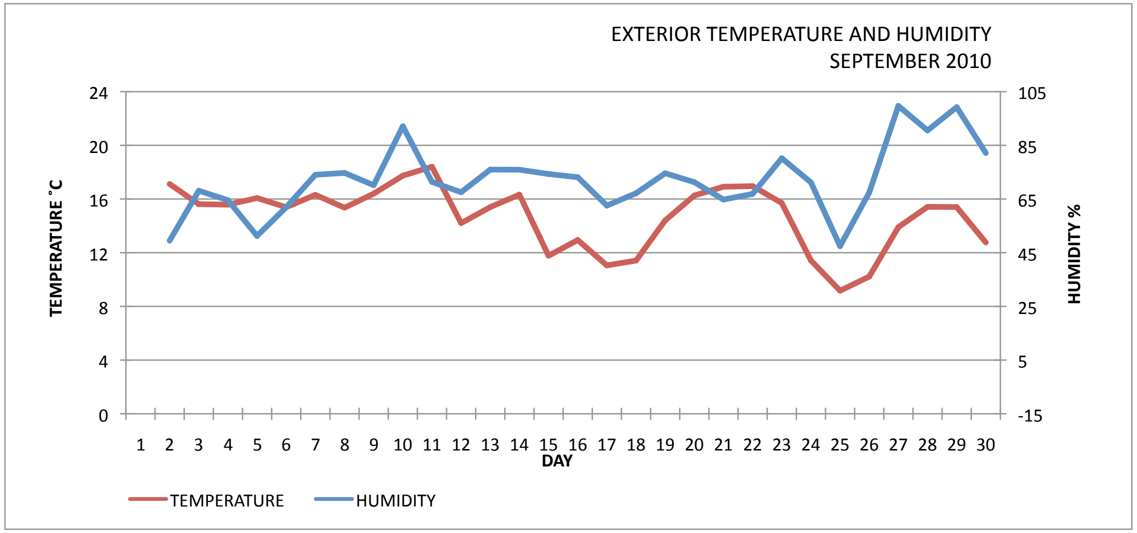


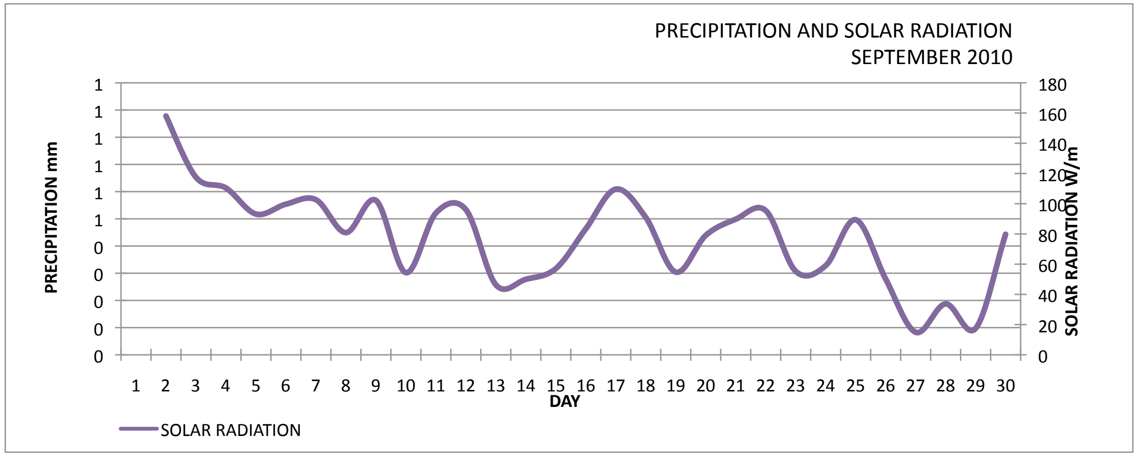
AUGUST	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Aug	17.85	62.16	0.35	239.58	SW	FAULTY DATA	132.34
2-Aug	16.27	60.35	0.76	272.50	W		104.20
3-Aug	16.82	58.95	0.22	244.65	SW		148.53
4-Aug	14.49	76.32	0.47	258.12	W		93.44
5-Aug	15.24	55.01	0.51	245.28	SW		153.41
6-Aug	16.11	68.00	0.39	216.52	SW		76.50
7-Aug	18.35	59.16	0.78	260.41	W		145.12
8-Aug	18.76	50.25	0.62	236.82	SW		174.65
9-Aug	18.34	55.80	0.30	222.19	SW		161.97
10-Aug	17.36	61.74	0.30	243.47	SW		137.58
11-Aug	15.94	58.81	0.30	238.20	SW		163.41
12-Aug	14.66	81.71	0.16	230.39	SW		85.99
13-Aug	13.41	100.00	0.19	241.21	SW		0.03
14-Aug	MISSING DATA						
15-Aug							
16-Aug							
17-Aug							
18-Aug							
19-Aug							
20-Aug							
21-Aug							
22-Aug							
23-Aug							
24-Aug							
25-Aug							
26-Aug							
27-Aug							
28-Aug							
29-Aug							
30-Aug							
31-Aug							
AVG	16.43	65.25	0.41	242.26	SW		121.32



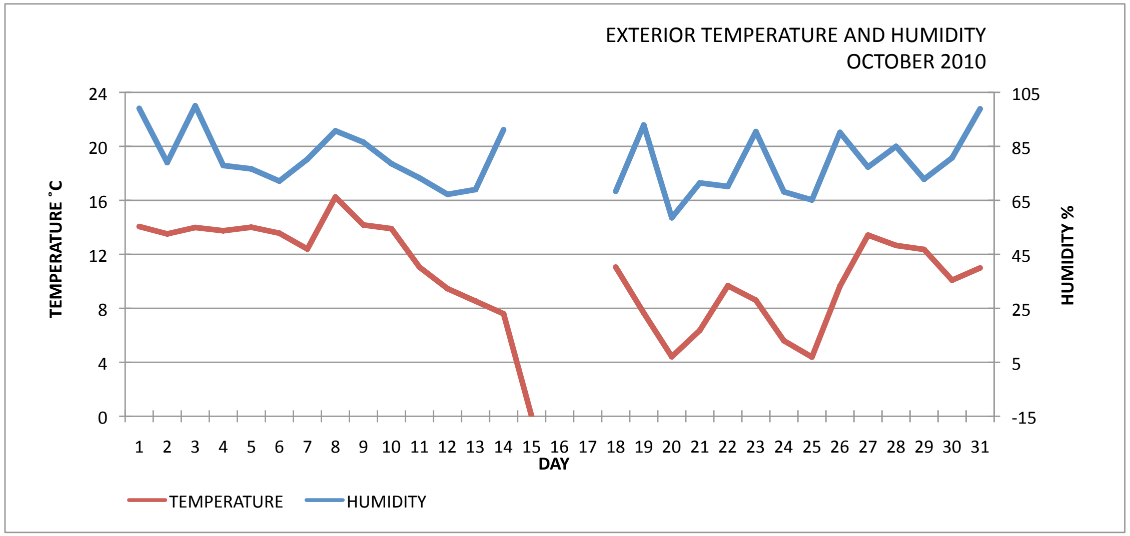


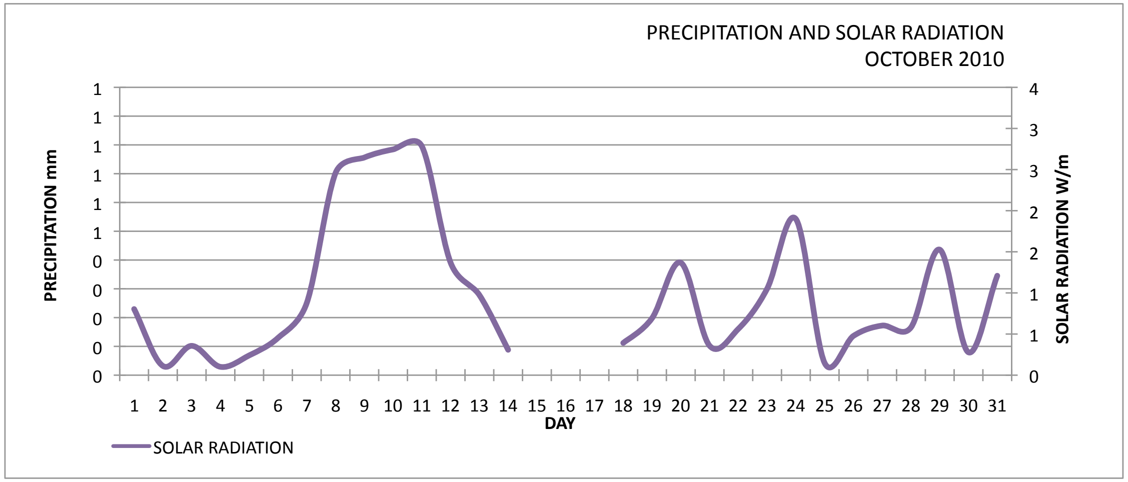
SEPTEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Sep							
2-Sep	17.12	49.49	1.50	95.91	E		158.05
3-Sep	15.62	68.10	0.55	97.60	E		117.51
4-Sep	15.58	64.56	0.50	140.76	SE		110.41
5-Sep	16.07	51.25	1.46	122.86	SE		93.15
6-Sep	15.39	61.95	2.58	115.30	SE		99.69
7-Sep	16.31	74.03	0.19	183.55	S		102.68
8-Sep	15.35	74.72	0.12	210.78	SW		80.86
9-Sep	16.40	70.15	0.19	244.93	SW		102.20
10-Sep	17.74	92.12	0.35	219.06	SW		54.36
11-Sep	18.41	71.38	0.44	227.68	SW		93.82
12-Sep	14.20	67.53	0.47	245.65	SW		96.15
13-Sep	15.40	75.96	0.52	231.16	SW		46.38
14-Sep	16.33	75.92	0.75	235.69	SW		49.97
15-Sep	11.77	74.32	0.56	236.54	SW		57.04
16-Sep	12.95	73.12	0.74	247.67	W	FAULTY DATA	83.38
17-Sep	11.06	62.54	0.65	255.93	W		109.64
18-Sep	11.41	67.15	0.16	231.17	SW		90.92
19-Sep	14.41	74.59	0.53	232.25	SW		54.73
20-Sep	16.26	71.28	0.41	231.22	SW		79.04
21-Sep	16.92	64.80	0.02	206.73	SW		89.75
22-Sep	16.96	66.91	0.13	198.70	S		95.48
23-Sep	15.70	80.19	0.21	223.83	SW		55.29
24-Sep	11.42	71.20	3.74	248.54	W		59.03
25-Sep	9.17	47.44	2.74	283.33	W		89.37
26-Sep	10.22	67.41	3.65	258.02	W		50.20
27-Sep	13.90	99.68	2.08	164.76	S		14.95
28-Sep	15.42	90.54	0.08	121.00	SE		33.74
29-Sep	15.40	99.24	0.20	209.61	SW		17.50
30-Sep	12.76	82.13	0.04	222.70	SW		79.80
AVG	14.68	72.06	0.88	204.93	SW		78.11



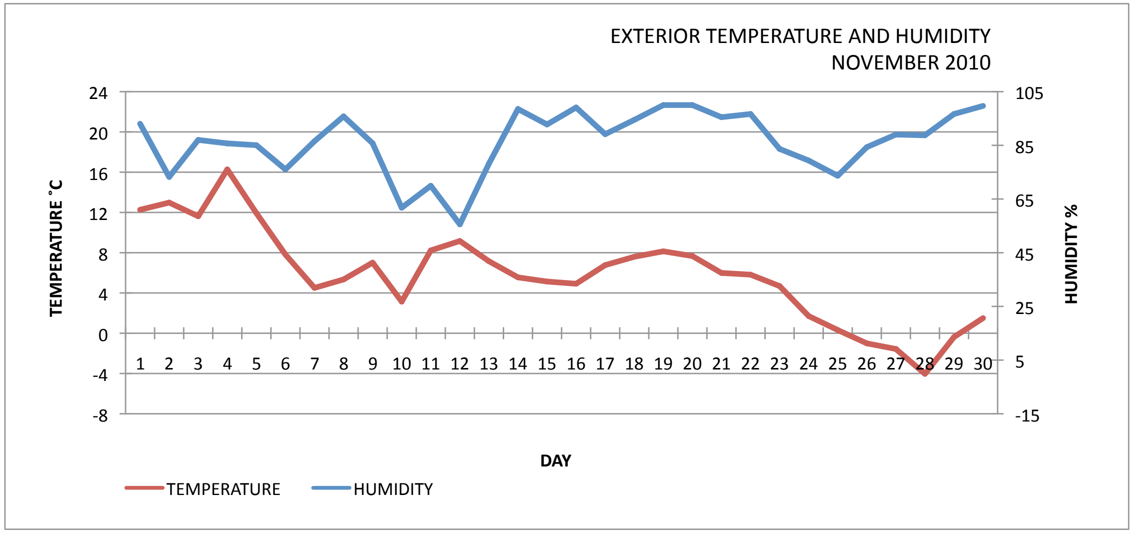


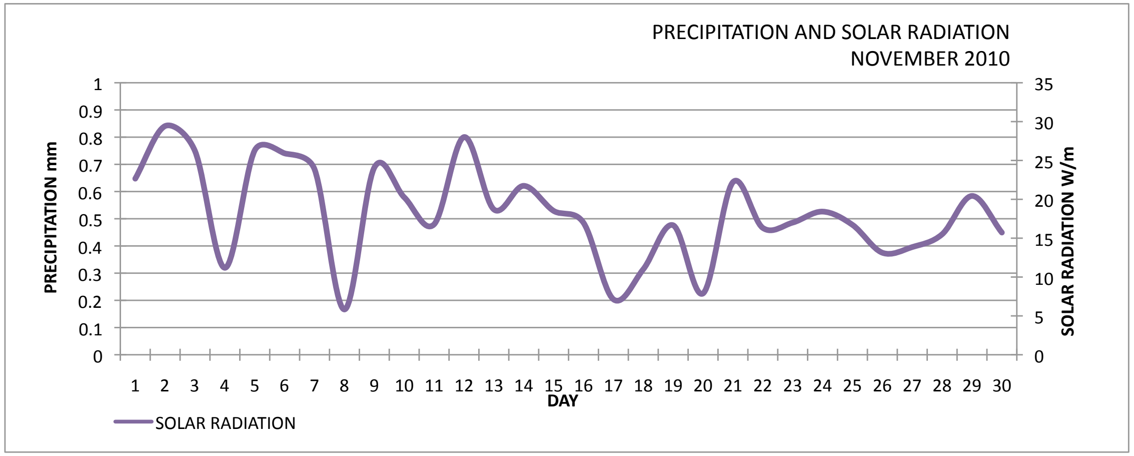
OCTOBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Oct	14.06	99.08	1.79	201.09	S	FAULTY DATA	0.80
2-Oct	13.51	78.99	0.25	204.74	SW		0.11
3-Oct	13.99	100.00	0.80	192.88	S		0.36
4-Oct	13.75	77.91	0.23	211.79	SW		0.10
5-Oct	14.01	76.66	0.54	184.00	S		0.24
6-Oct	13.57	72.13	1.01	214.34	SW		0.45
7-Oct	12.39	80.21	1.96	144.42	SE		0.88
8-Oct	16.25	90.75	5.49	85.47	E		2.46
9-Oct	14.17	86.53	5.91	76.51	E		2.65
10-Oct	13.90	78.57	6.13	101.24	E		2.75
11-Oct	11.05	73.31	6.22	107.19	E		2.78
12-Oct	9.46	67.21	3.05	98.86	E		1.37
13-Oct	8.53	69.00	2.18	187.75	S		0.97
14-Oct	7.60	91.20	0.69	287.82	W		0.31
15-Oct							
16-Oct				MISSING DATA			
17-Oct							
18-Oct	11.06	68.34	0.87	237.26	SW	FAULTY DATA	0.39
19-Oct	7.66	92.91	1.54	254.32	W		0.69
20-Oct	4.41	58.55	3.05	274.40	W		1.37
21-Oct	6.37	71.45	0.80	236.03	SW		0.36
22-Oct	9.67	70.14	1.26	231.72	SW		0.56
23-Oct	8.60	90.47	2.34	262.28	W		1.05
24-Oct	5.60	68.15	4.24	269.44	W		1.90
25-Oct	4.39	65.14	0.33	248.29	W		0.15
26-Oct	9.65	90.15	1.06	221.91	SW		0.48
27-Oct	13.42	77.33	1.35	227.14	SW		0.60
28-Oct	12.66	84.97	1.30	215.55	SW		0.58
29-Oct	12.36	72.82	3.41	211.07	SW		1.53
30-Oct	10.08	80.75	0.62	205.52	SW		0.28
31-Oct	10.99	98.91	2.70	163.60	S		1.21
AVG	10.83	79.70	2.18	198.45	S		0.98



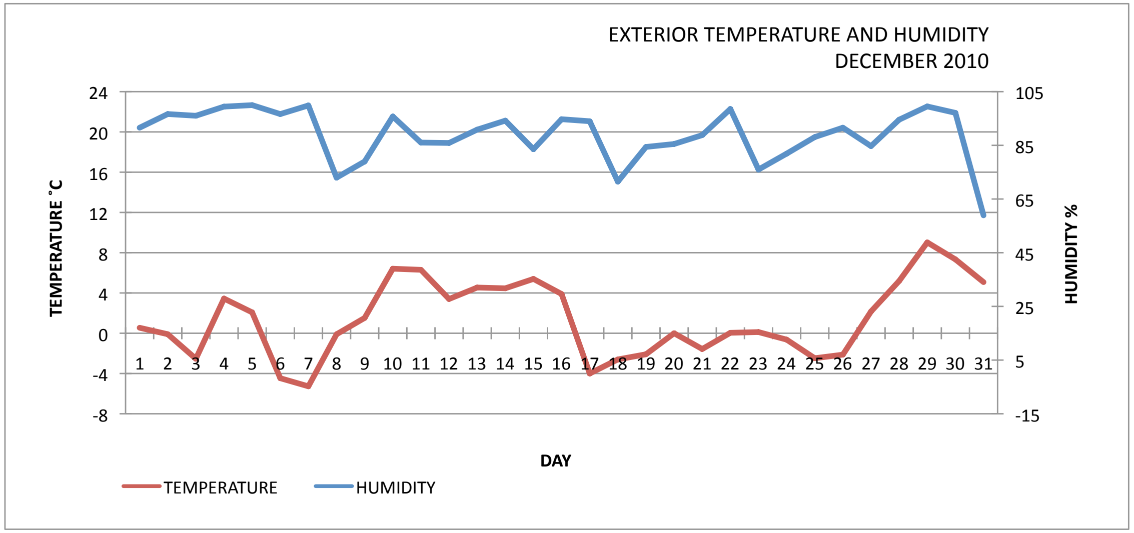


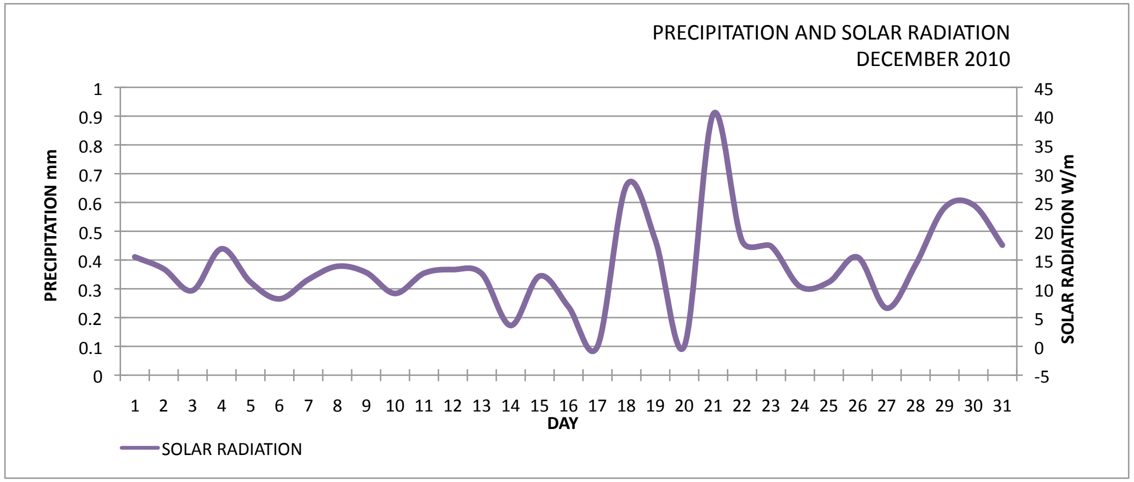
NOVEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Nov	12.27	93.05	0.40	251.85	W		22.66
2-Nov	12.98	73.22	1.27	232.49	SW		29.43
3-Nov	11.62	87.01	0.34	230.56	SW		26.20
4-Nov	16.27	85.72	1.62	234.66	SW		11.18
5-Nov	11.94	85.05	0.45	243.56	SW		26.31
6-Nov	7.81	76.03	0.36	241.10	SW		25.91
7-Nov	4.51	86.54	1.52	171.70	S		23.86
8-Nov	5.34	95.80	3.05	132.07	SE		5.83
9-Nov	7.01	85.75	4.12	103.81	E		24.09
10-Nov	3.14	61.76	1.77	254.45	W		20.26
11-Nov	8.23	69.94	2.70	215.93	SW		16.78
12-Nov	9.16	55.57	2.33	237.96	SW		28.01
13-Nov	7.16	78.17	0.93	215.15	SW		18.70
14-Nov	5.55	98.54	0.16	224.09	SW		21.74
15-Nov	5.14	92.78	0.11	212.11	SW	FAULTY DATA	18.51
16-Nov	4.92	99.09	0.18	186.36	S		16.98
17-Nov	6.77	89.15	1.85	144.38	SE		7.13
18-Nov	7.60	94.48	0.78	157.66	S		11.00
19-Nov	8.14	100.00	0.13	157.56	S		16.66
20-Nov	7.67	100.00	0.81	123.94	SE		7.89
21-Nov	5.99	95.49	2.83	173.52	S		22.21
22-Nov	5.82	96.67	2.30	184.63	S		16.32
23-Nov	4.69	83.67	1.47	281.18	W		17.01
24-Nov	1.71	79.33	1.21	266.66	W		18.42
25-Nov	0.32	73.67	2.98	274.30	W		16.72
26-Nov	-1.00	84.32	0.38	216.50	SW		13.13
27-Nov	-1.56	89.02	2.88	221.77	SW		13.86
28-Nov	-4.04	88.74	0.49	214.28	SW		15.50
29-Nov	-0.38	96.67	2.68	227.27	SW		20.43
30-Nov	1.51	99.69	2.54	76.86	E		15.72
AVG	5.88	86.50	1.49	203.61	SW		18.28



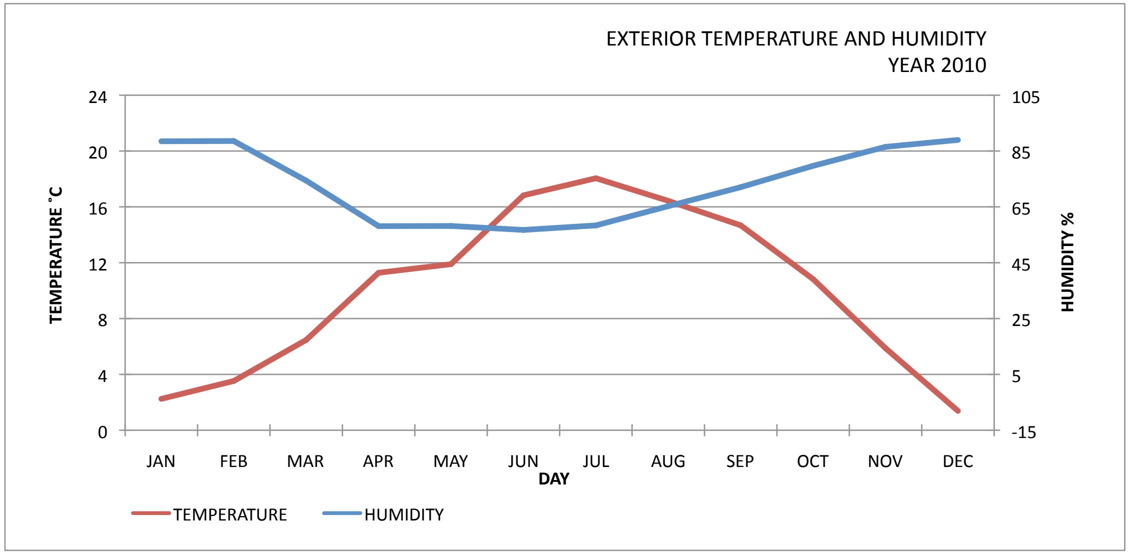


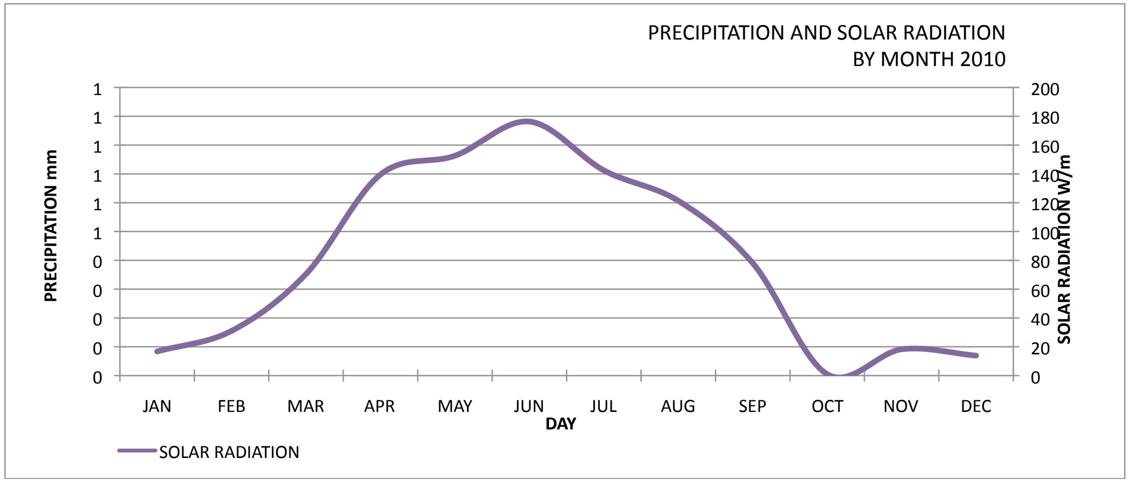
DECEMBER	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
1-Dec	0.54	91.57	2.69	98.89	E		15.54
2-Dec	-0.10	96.66	2.25	147.57	SE		13.46
3-Dec	-2.54	96.02	0.31	218.61	SW		9.71
4-Dec	3.44	99.43	0.03	235.95	SW		16.95
5-Dec	2.07	99.98	0.07	251.57	W		11.17
6-Dec	-4.47	96.65	0.05	228.08	SW		8.25
7-Dec	-5.27	99.86	0.14	228.63	SW		11.61
8-Dec	-0.10	72.96	2.59	245.06	SW		13.90
9-Dec	1.52	78.99	0.99	252.30	W		12.84
10-Dec	6.41	95.75	1.06	237.73	SW		9.19
11-Dec	6.30	86.03	0.97	263.03	W		12.70
12-Dec	3.40	85.88	2.21	222.13	SW		13.34
13-Dec	4.54	90.85	1.38	267.17	W		12.62
14-Dec	4.46	94.20	1.24	184.97	S		3.63
15-Dec	5.40	83.57	1.52	284.61	W		12.22
16-Dec	3.90	94.73	2.95	163.61	S	FAULTY DATA	6.86
17-Dec	-4.00	93.98	0.45	223.39	SW		0.00
18-Dec	-2.60	71.48	2.47	127.06	SE		27.95
19-Dec	-2.09	84.41	1.50	188.00	S		18.46
20-Dec	0.00	85.50	0.00	0.00	N		0.00
21-Dec	-1.57	88.81	0.53	80.92	E		40.32
22-Dec	0.04	98.54	3.03	192.34	S		18.31
23-Dec	0.12	75.98	3.07	173.03	S		17.42
24-Dec	-0.63	81.91	5.04	253.90	W		10.41
25-Dec	-2.48	88.08	1.21	235.53	SW		11.16
26-Dec	-2.13	91.58	0.66	215.67	SW		15.48
27-Dec	2.16	84.71	1.10	181.95	S		6.64
28-Dec	5.19	94.55	0.01	200.57	S		14.18
29-Dec	9.02	99.50	0.01	101.78	E		24.08
30-Dec	7.34	97.10	0.20	172.21	S		24.57
31-Dec	5.08	58.91	0.15	152.14	SE		17.59
AVG	1.39	88.97	1.29	194.46	S		13.89





MONTH	TEMPERATURE	HUMIDITY	WIND SPEED	WIND DIRECTION		PRECIPITATION PER DAY	SOLAR RADIATION
units	˚C	%	m/s	degree			W/m²
JAN	2.25	88.49	2.10	169.72	S	FAULTY DATA	16.74
FEB	3.53	88.58	1.83	178.62	S		31.04
MAR	6.47	74.40	1.49	196.55	S		70.51
APR	11.28	58.10	0.91	215.40	SW		139.57
MAY	11.90	58.16	1.26	182.13	S		152.60
JUN	16.82	56.74	0.98	192.58	S		176.34
JUL	18.05	58.36	0.52	224.90	SW		142.46
AUG	16.43	65.25	0.41	242.26	SW		121.32
SEP	14.68	72.06	0.88	204.93	SW		78.11
OCT	10.83	79.70	2.18	198.45	S		0.98
NOV	5.88	86.50	1.49	203.61	SW		18.28
DEC	1.39	88.97	1.29	194.46	S		13.89
AVG	10.66	71.53	1.20	203.08	SW		85.92





Appendix 7 BASF House questionnaire to visitors

c. general questions

1. Should houses have visible meters to read the energy consumption and the cost of it?

yes	no
☑	☐

2. How do you like the overall appearance of the BASF House?

	dislike				like
2.a. exterior	☐	☐	☐	☑	☐
2.b. interior	☐	☑	☐	☐	☐

3. How much extra are you willing to pay for a Zero Carbon Home?

5-10%	10-15%	15-20%	20-25%
☐	☑	☐	☐

4. If you refurbish your home to improve the energy performance. In how many years will you expect the pay back?

1-5	5-10	10-15
☑	☐	☐

d. additional comments

Very interesting visit. New construction methods particularly significant.

THANK YOU FOR YOUR TIME!

95

BASF HOUSE
VISITORS EXPERIENCE QUESTIONNAIRE

The BASF House is part of the Creative Energy Homes (CEH) Project which is being developed at the School of the Built Environment (SBE), University of Nottingham (*http://www.nottingham.ac.uk/sbe/creative_energy_homes*).

It is part of a research project that involves professors and students towards sustainability and development of energy efficient homes for the future.

This questionnaire is meant to assist a PhD research on Post Occupancy Evaluation of Sustainable Homes in the UK.

15'April'2009

a. personal information

1. Age ☐ 20-35 ☐ 36-50 ☑ 51-65 ☐ 66+

2. Gender ☐ female ☑ male

3. What is your profession? Member of the European Parliament

4. Are you a: ☑ home owner ☐ tenant

5. Do you live in a: ☑ detached house ☐ semi-detached house ☐ terraced house ☐ bungalow ☐ flat

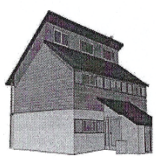
b. BASF House design and technologies

Before your visit, were you aware of any of the passive design strategies and architectural features utilised in the BASF House?
How do you like them?

	awareness yes	no	how do you like them? dislike				like
1. sun orientation	☑	☐	☐	☐	☐	☐	☑
2. sunspace (South facade conservatory)	☑	☐	☐	☐	☐	☐	☑
3. reduced windows size on the North facade	☐	☑	☐	☐	☑	☐	☐
4. natural light quality	☑	☐	☐	☐	☐	☐	☑
5. natural ventilation	☐	☑	☐	☐	☐	☐	☑
6. high ceilings	☐	☑	☐	☐	☐	☐	☑
7. high thermal insulation (floor, walls and roof)	☑	☐	☐	☐	☐	☐	☑
8. airtightness	☐	☑	☐	☐	☐	☐	☑

Please circle your favorite one (from 1 to 8).

East-South Facade



West-North Facade

Before your visit, were you aware of any of the technologies utilised in the BASF House?
How do you like them?

	awareness yes	no	how do you like them? dislike				like
9. passive solar system (solar panels for hot water)	☑	☐	☐	☐	☐	☐	☑
10. biomass boiler	☐	☑	☐	☐	☐	☑	☐
11. roof coating with red pigments for solar heat management	☐	☑	☐	☐	☑	☐	☐
12. water conservation and rainwater harvesting system	☑	☐	☐	☐	☐	☑	☐
13. meters and monitoring system (control system)	☑	☐	☐	☐	☐	☐	☑
14. earth air heat exchanger (EAHE)	☐	☑	☐	☐	☐	☐	☑
15. permeable pavement	☐	☑	☐	☐	☐	☐	☑
16. phase change material (PCM) panels	☐	☑	☐	☐	☐	☐	☑

Please circle your favorite one

Appendix 8 Samples of CEH visit booking calendars

Sample of CEH visit booking calendar 2008

Date	Time	Host	Company/ Group	Contact Details	Group Size	Additional Information
Tuesday 26th August	1pm	Deborah Adkins	Creo Koncept	Colin Waitfield	8	
Thursday 28th August	9am -11am	Claire Farrar			2	VIP visitors
Thursday 11th Sept	11am -3pm	Claire Farrar	RSK	Lucy Speirs	2	(Claire BASF to do tour following on from their meeting with Professor Riffat and will provide her and colleague with lunch at the BASF House)
Monday 15th Sept	TBC	Mark Gillott			8	Mark Gillot with Solar Decathlon group
Tuesday 23rd September	10-12:30pm 1pm- 3pm	Claire Farrar will help of Nina Hormazábal Claire Farrar	Stephen George Taylor Wimpey	Claire Oliver	20	lunch served at 12 no more bookings to be taken for this day...
Wed 24th September	Lunch time (exact timing TBC)	Mark Gillott	Webbrick			Webbrick system training -CANCELLED
Thur 25th September	Lunch time (exact timing TBC)	Mark Gillott	Webbrick			Webbrick system training -CANCELLED
Thurs 2nd October Friday 3rd October	3-5pm					BBC Pre-filming EON house open day
Tuesday 7th October	10am -12pm 1pm -2pm	Claire Farrar Claire Farrar	Brent Teaching PCT CIRIA		7	
Thursday 9th October	TBC	Phil Robinson	BASF		~6	senior managers from the BASF SE Headquarters in Ludwigshafen
Friday 10th October	(exact timing TBC)	Claire Farrar / Mark Gillott	WebBrick		6	WebBrick systems
Tuesday 14th October	11am-1pm	Deborah Adkins	Franklin Ellis Architects	Eleftheria Lohse	10	Confirmed
	1pm-3pm	Deborah Adkins	Single Parties	Rosie Brown	1	
Tuesday 14th October	visit: 9:00-10:00 am meeting: 10:00 to 11:00	Phil Green - Nina Hormazábal Mark Gillott	BASF	Phil Green		senior representative of Blue Scope Steel, meeting with academics with The School of the Built Environment
Tuesday 21st October -	9:30 -10:30am	Deborah Adkins	DMU	Stephen Porritt and Marco Poliafico	2	Maybe Nina can do this one, given the time it is organized at.
Wednesday 22nd October	9:00 -11:30am	Deborah Adkins - Nina Hormazábal	Loughborough University	Monjur Mourshed	35	Confirmed
23rd October	TBC	Phil Robinson	BASF			German organisation representing PVC and Sustainability (the AGPU) -CANCELLED
Wed 29th October	TBC	Phil Robinson	BASF			senior managers from the BASF SE Headquarters in Ludwigshafen -CANCELLED
Thurs 30th	TBC	Phil Robinson	BASF			senior managers from the BASF SE Headquarters in Ludwigshafen-CANCELLED
Thursday 6th November	TBC	Phil Robinson	BASF			German organisation representing PVC and Sustainability (the AGPU) -CANCELLED
Friday 24th October	13:00 -13:15	Nina Hormazábal	UoN Students	Rhoades & Lenard	2	Confirmed
Tuesday 28th October	9:00 - 10:00	Mark Gillot - Nina Hormazábal	E.ON	Allister	20	Confirmed
Wed 29th October	10:00 -11:00	Nina Hormazábal	Arch Firm from Newark	Alvaro Muñoz	5	Confirmed
Wed 29th October	11:30 -12:30	Mark Gillot - Nina Hormazábal	E.ON	Lawrence Kirk	8 to 10	CANCELLED
Monday 10th	all day		WebBrick	Andy Harris		Monitoring system
Thursday 6th November	10:30 - 12:00	Paul Britchford	Corus Group	Paul Britchford	7	Meeting and self-guided group - Confirmed
Thursday 6th November	14:30 - 16:30	Phil Robinson	BASF	Phil Robinson	5	German organisation representing PVC and Sustainability (the AGPU) - Confirmed
Tuesday 11th November	11am - 1pm and 1:30pm -3pm	Claire Farrar	Trelleborg, Rehau, Peak District Housing Association, BRE.	Claire Farrar	15 (3+12 am) 14 (8 + 6 pm)	BASF OPEN DAY
Wednesday 12th November	12:00 -13:00pm	Mark Gillott - Nina Hormazábal	Inbuilt Ltd	Helen Cook		Cancelled
Wednesday 19th November	TBC	Nina Hormazábal	CBP Architects	Gareth Cain	8 to 12	Confirmed
Friday 21st	all day		WebBrick	Andy Harris		Monitoring system

Sample of CEH visit booking calendar 2009

October 2009

Date	Time	Duration	BASF	EON	TARMAC	Host	Host email	Company Name	Sector	Contact's Name	Contact's email	Group size	Notes
06/10/2009	12:45	1.0 hrs	✓	✓	☐	Mark Gillott	mark.gillott@nottingham.ac.uk	Midlands Energy Consortium	Industry	Helen Fletcher	h.fletcher@lboro.ac.uk	50	Part of conference. Final numbers tbc - to pay £3pp. Tom, Ksenia, Kasham agreed to help
07/10/2009	14:00	1.0 hrs	✓	✓	☐	Nina Hormazábal	laxnah@nottingham.ac.uk	WT Partnership	Industry	Steve Brown	steve.brown@wtpartnership.co m	10	Final numbers tbc; agreed to pay £3pp
07/10/2009	14:00	1.0 hrs	✓	✓	☐	Nina Hormazábal	laxnah@nottingham.ac.uk	Nottingham Trent University	Education	Richard Howarth	richard.howarth@ntu.ac.uk	3	Fiona Fuller, Ann McCarthy+ Other colleagues to join tbc; agreed to pay £3pp
07/10/2009	14:00	1.0 hrs	✓	✓	☐	Nina Hormazábal	laxnah@nottingham.ac.uk		Industry	Stephen Moody	Stephen.Moody@boston.gov.uk	1	Interested in the project. To pay £3pp
08/10/2009	13:30	1.0 hrs	✓	✓	✓	Nina Hormazábal	laxnah@nottingham.ac.uk	Oxford Brookes	Education	Fionn Stevenson		30	Mark agreed. Nina and Lucelia guides
12/10/2009	11:00	1.5 hrs	✓	✓	✓	Nina Hormazábal	laxnah@nottingham.ac.uk		Education	Liz Bromley-Smith/Valeria		35	part of teaching
12/10/2009	14:00	1.0 hrs	✓	☐	✓	Ed Cooper	ed.cooper@nottingham.ac.uk		Education	Ed Cooper		9	Part of Ed's teaching and will show the students around. Ed to liaise with Nina.
14/10/2009	15:15	1.0 hrs	✓	✓	✓	Mark Gillott	mark.gillott@nottingham.ac.uk	Nottingham City Councillors	Government	Mariana Castanos	mariana.castanos@nottingham city.gov.uk	20	Mark agreed. Ksenia and Kasham guides
19/10/2009	14:00	1.0 hrs	✓	✓	✓	Nina Hormazábal	laxnah@nottingham.ac.uk		Education	Nina Hormazabal		23	Workshop Group - Architectural Research Methods (S Platt course)
21/10/2009			☐	☐	☐			BASF	Industry	Gill Kelleher			Gill Kelleher looks after the visit
											Monthly total :	181	

Printed : 26/10/2009 13:19:00

Sample of CEH visit booking calendar 2010

September 2010

Date	Time	Duration	BASF	EON	TARMAC	Host	Host email	Company Name	Sector	Contact's Name	Contact's email	Group size	Notes
01/09/2010	11:30	1.0	☐	☐	☐	Valeria Carnevale		Chinese visitors	Industry			7	
01/09/2010	14:00	1.0	☐	☐	☐	Nina Hormazábal	Confirmed	Broxtowe Council Environment	Government	Andrew Pooley, Estates Section	Andrew.Pooley@broxtowe.gov. uk	15	Tel: 0115 9177777, Zr 3742Environment Group, poss up to 20. Need meeting room x 1 hour
09/09/2010	09:00	1.0	✓	✓	✓	Ksenia Chmutina		B&Q	Industry	John Croft	williamjcroft@yahoo.co.uk	3	
09/09/2010	12:00	1.0	✓	✓	✓	Aneel Kilaire		Rehau	Industry	Mike Moseley	Michael.Moseley@rehau.com	3	
09/09/2010	16:30	1.00	✓	✓	✓	Ksenia Chmutina		London School children	Education	Mark Storey, Eng Marktng Team	aaxms1@nottingham.ac.uk	20	Mark Storey been informed no room available in DABE
10/09/2010	14:00		✓	✓	✓	Mark Gillott		Eon UK & Hungary staff visit	Industry	Louise Williams	louise.williams@eon.com	6	
12/09/2010	10:00		✓	✓	✓	Ksenia Chmutina		Business School Alumni Event	Public	Hilary Vaughan Thomas		22	Timing tbc; Hilary tel: 66687 left message re confirmation
14/09/2010	13:30	1.0	✓	✓	✓	Ksenia Chmutina		University of Nottingham-	Education	Tessa Payne	tessa.payne@nottingham.ac.uk	15	Delegates -East Midlands Universities Association's Postgraduate Conference
14/09/2010	15:00		✓	✓	✓	Mark Gillott		Good Homes Alliance	Industry	Simon Corbey/Laura	simon.corby@goodhomes.org.u k	25	Date confirmed; nos. tbc; awaiting Mark to comment on the programme; Ian Gray confirmed to give presentation; (SC: 02078418909)
											Monthly total :	116	

Printed : 08/09/2010 11:08:07

Appendix 9 Analysis of dependence among variables and predictive and segmentation model from the visitor's questionnaires

Analysis of dependence among variables

Taking into consideration the results obtained and trying to understand why people respond one way or another this part of the analysis is to find out the existence of any type of dependence between variables. To do this part of the analysis a non-parametric test of independence called χ^2 (chi square), with a α% of significance (1%) applied.

First, the test was applied to the least popular and least well-known PDS and SET obtained from the results. The objective is to establish the correlation between preference and awareness. Second, the analysis moves on to the relationship between awareness of PDS within the same topics. To do this the PDS were divided into two sets, the first one is related to lighting aspects; sun orientation, reduced window side on the North façade and natural light quality. The second set is related to the airtightness aspect; natural ventilation mechanism, high ceiling, high thermal insulation and airtightness.

The following table 29 depicts the correlation between preference and awareness for the different features analysed. The seven features listed above were the least known and least preferred ones.

Table 29 Dependence correlation between preferences and awareness and the seven least known and least preferred features of the BASF House

CORRELATIONS							
Chi-square	Ceiling	Airtightness	Biomass boiler	Red pigment roof coating	Permeable pavement	Phase change material	Reduced window size (north)
Value	9.941	3.945	9.00	3.736	1.785	2.414	7.704
Degrees of freedom	4	4	4	4	4	4	4
Significance (asymptotic)*	0.041	0.007	0.061	0.443	0.775	0.66	0.103

**. The correlation significance level is 0,05 (*asymptotic*).*

It can be observed in the above table 29 that the two PDS that portray preference and awareness correlations are high ceiling and airtightness. As previously analysed for the case of these two PDS there is not a clear awareness tendency also both PDS are among the least preferred. The other five PDS are independent with a significance of a 5% in regard to a correlation between the two variables after realising the Chi-square analysis.

The following tables 30 and 31 show the dependence correlation in regard to awareness among PDS with lighting and other design features with airtightness respectively; obtained through the Chi-square analysis.

Table 30 Dependence correlation among five passive design features (PDS) with **lighting**

CORRELATIONS						
	Sun Orientation with			Sunspace with		Reduced Window Size (north) with
Chi-square	Sunspace	Reduced Window Size (north)	Natural light quality	Reduced Window Size (north)	Natural light quality	Natural light quality
Value	33.828	37.133	35.384	37.919	46.215	35.528
Degrees of freedom	1	1	1	1	1	1
Significance (asymptotic)*	0.000	0.000	0.000	0.000	0.000	0.000

**. The correlation significance level is 0,05 (*asymptotic*).*

Table 31 Dependence correlation among four features with **airtightness**

CORRELATIONS						
	Natural Ventilation Mechanism with			High Ceiling with		High Thermal Insulation with
Chi-square	High Ceiling	High Thermal Insulation	Airtightness	High Thermal Insulation	Airtightness	Airtightness
Value	23.630	44.212	22.849	7.928	8.830	41.165
Degrees of freedom	1	1	1	1	1	1
Significance (asymptotic)*	0.000	0.000	0.000	0.005	0.003	0.000

*The correlation significance level is 0,05 (*asymptotic*).*

In both analyses depicted in the above tables, as expected, it can be observed that the characteristic association is validated given the existing correlation for all the combinations chosen for these two variables; lighting and airtightness respectively. The variables are dependant for all the pairs of PDS or/and SET with a 5% of significance; i.e. people associated the natural ventilation mechanism with high ceiling or high thermal insulation with airthightness.

Predictive and segmentation model

To analyse questions of section c in the questionnaires, a useful application included within the SPSS software was used. It consisted of a predictive model based on classification trees and the Chaid analysis which helps to study segmentation among variables. For the questions in section c. the variables were considered dependent. The three questions in section c of the questionnaires:

1. How do you like the overall appearance of the BASF House? (interior and exterior)
2. How much extra money are you willing to pay for a Zero Carbon House?
3. If you refurbish your home to improve the energy performance, in how many years will you expect the payback?

For the case of independent variables they were analysed with the independence Chi-square criteria (growing method CHAID), which was applied to all the variables introduced in the survey. Then, the variables with association were considered only. Once the variables with association were picked, the classification tree was introduced and it varied depending on the different 'answer variable'. The questions were analysed in the same order they have in the questionnaires. Question 1 was analysed first, and it was divided into interior and exterior and subsequently Question 2 and Question 3 were analysed.

The main purpose of doing this analysis following all the above procedures, was to establish possible correlations amongst variables when people were asked for the appearance of a sustainable home, based on the BASF House, and which features could be influencing their answers in regard to preferences. For instance, is there any feature that should be considered a key aspect for people when designing a sustainable home. Then, how the different PDS and/or SET, based on the BASF House, might influence the willingness for expending or not on a sustainable home or refurbishing or not their home to convert it into a sustainable home, and which variables could be identified as key ones when people were going to invest on their home.

Classification tree analysis for question 1: How do you like the overall appearance of the BASF House?

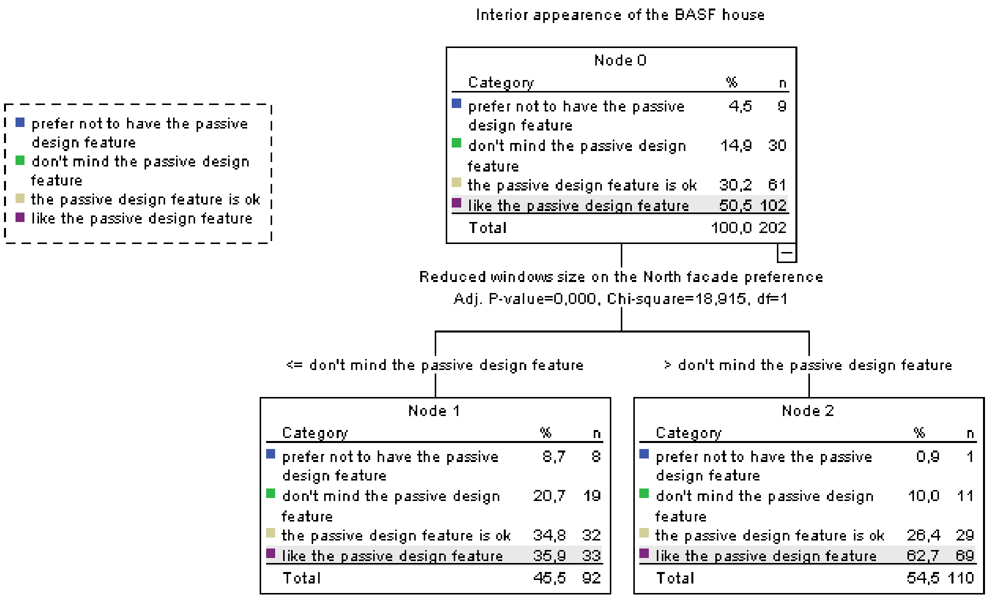


Figure 94 Classification Tree for the analysis of question 1 for the interior appearance.

For the interior appearance of the BASF house, it could be seen on the above classification tree in figure 98 that the only variable that shows some association degree under the chi-square criteria was reduced size windows on the North façade preference. When considering the alternative *don't mind the passive design strategy* as the cutting criteria, 45.5% answered above or equal and 55.5% below to this alternative.

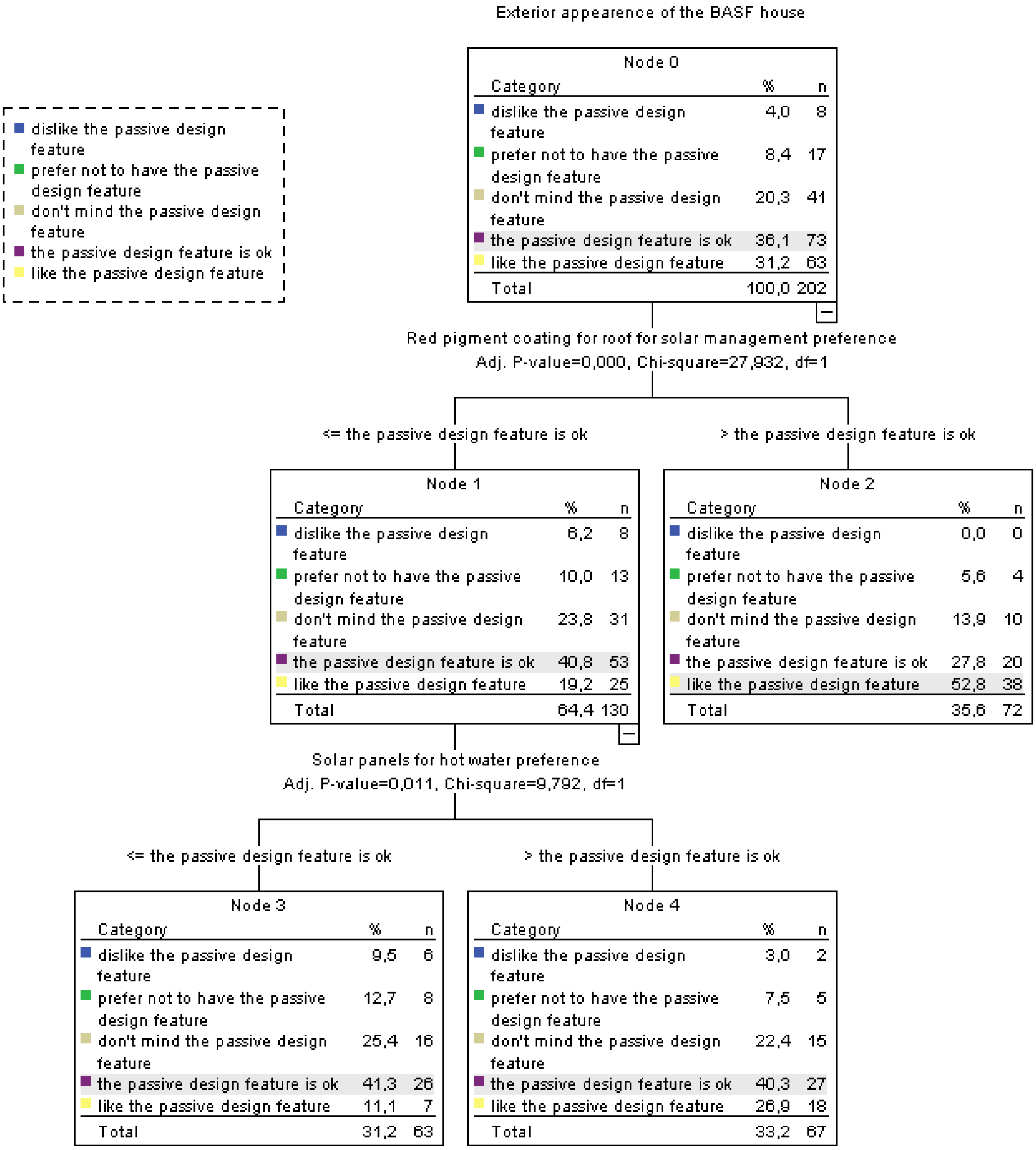


Figure 95 Classification Tree for the analysis of question 1 for the exterior appearance.

For the exterior appearance of the BASF house, it could be seen on the above classification tree in figure 99 that the influential variables for this case are *roof coating with red pigment coating solar heat management* and *solar panels for hot water* preferences**.** The first one has direct association while the second one is dependent of the first when considering answers equal or above to the alternative *don't mind the passive design strategy*.

Classification tree analysis for question 2: How much extra money are you willing to pay for a Zero Carbon House?

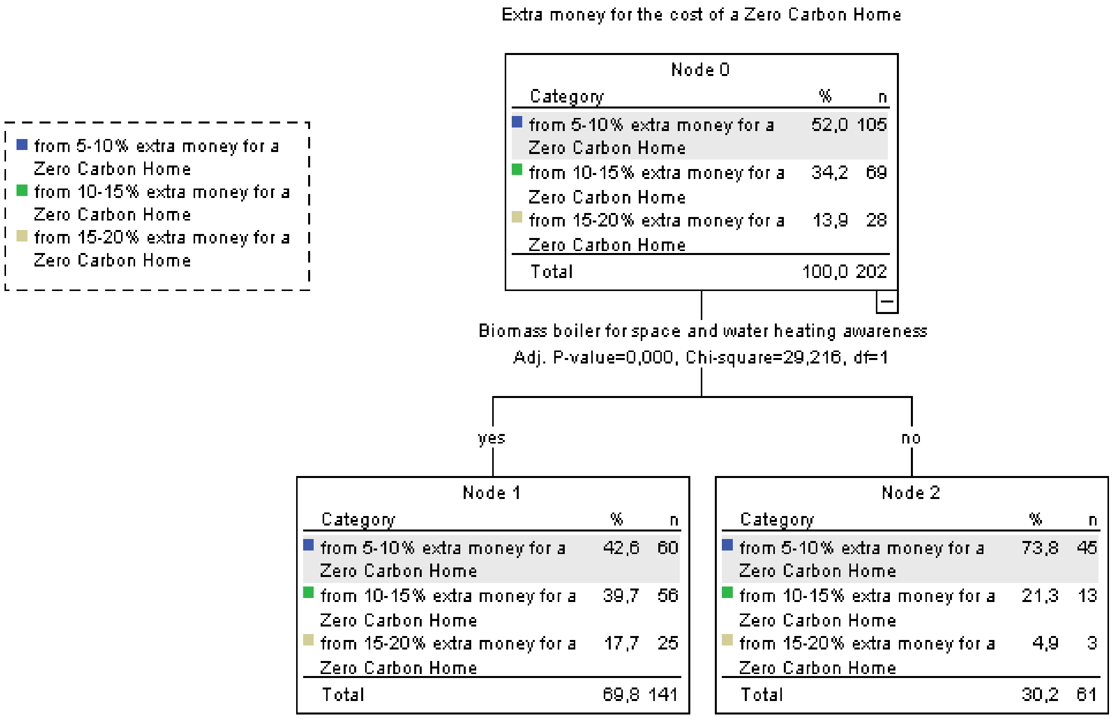


Figure 96 Classification Tree for the analysis of question 2

It could be seen in the above classification tree in figure 100 that the only variable that shows association under the chi-square criteria is the *biomass boiler for space and water heating* awareness. When considering the alternative *don't mind the passive design strategy* as the cutting criteria, 69.8% answered above or equal and a 30.2% below to this alternative.

Classification tree analysis for question 3: If you refurbish your home to improve the energy performance, in how many years will you expect the payback?

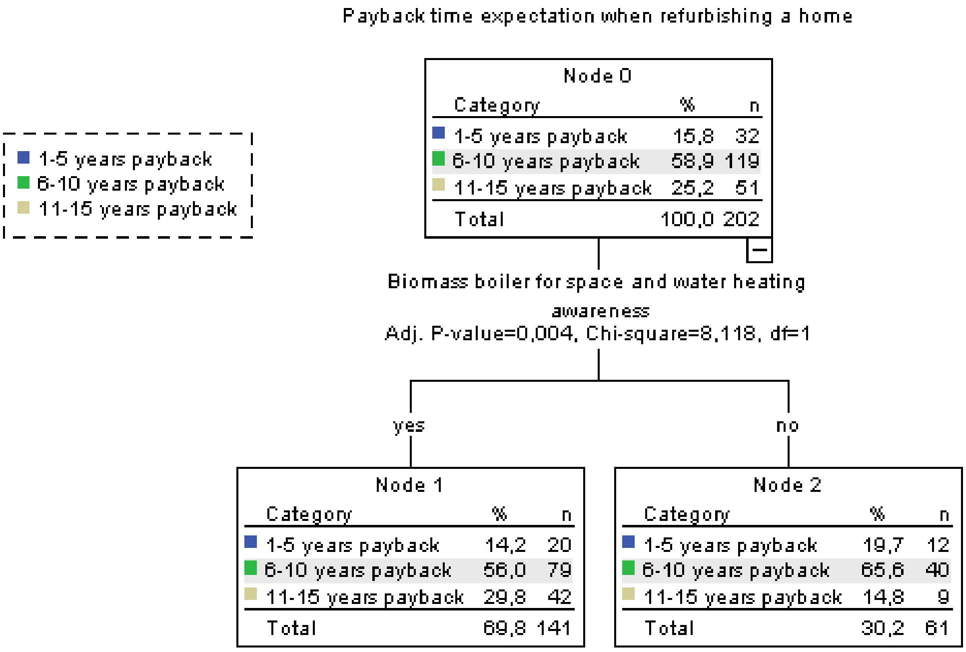


Figure 97 Classification Tree for the analysis of question 3

It could be seen on the above classification tree in figure 101 exactly the same result to the question 2. The only variable that shows association under the chi-square criteria is the *biomass boiler for space and water heating* awareness. When considering the alternative *don't mind the passive design strategy* as the cutting criteria, 69.8% answered above or equal and a 30.2% below to this alternative.

Appendix 10 Samples of BASF House questionnaires

Example of BASF house full ocupant's questionnaire including pages 5, y and 11 with answers from one of the occupants

BASF House Occupant's Questionnaire 2010

The University of Nottingham

Nottingham, 13 August, 2010.

Dear BASF house former or current occupant,

All of you have the opportunity to live in the BASF house for at least a month or longer. In my own case after living in and studying the house for the last two years I have found so much information to be drawn and learnt from this real-life research energy home, becoming a mesmerising task.

As you might know I am starting my writing up period of my PhD thesis. I'm currently at the last bit of my third year and soon I'll move back home to complete this stage.

At this point I would be delighted if all of you could devote part of your time to respond to this survey questionnaire with the memories of your personal experience, perceptions and expectation of the BASF house.

The survey is part of the qualitative analysis chapter on the BASF House, which is the most important case study I'm analysing among the several affordable sustainable homes I'm working with. I have already completed the analysis of the monitored data for the last 2 years obtaining some interesting results that will be enriched by this questionnaire. I also managed to collect 480 questionnaires from the people who have visited the house on open days, over 2,500.

The survey consists of A questionnaire, based on the same one I gave to visitors, with addition of specific questions for occupants, related to the experience of living in the BASF house. All the information is for academic research purposes and it will remain fully anonymous. Later, if you would like to find out some of the results, I'll be more than happy to share them with you as well as sharing possible publications on the research.

Finally, I really appreciate the time with which you will contribute to my work, I'm looking forward to receive your replies and it has been a great experience to share the house with all of you at a certain point.

THANK YOU VERY MUCH – MUCHISIMAS GRACIAS!

Nina Hormazábal

GENERAL INSTRUCTIONS

BASF House. Occupant's Questionnaire

This questionnaire is to evaluate the performance of the BASF house. The purpose of this evaluation is to assess how well the house performs for all you in terms of health, safety, functionality and psycho-physiological comfort/well-being.

Your answers will help to learn from this building and to understand better the aspects related to sustainable homes.

It is necessary to identify successes and failures in the house by responding to these broad categories. Please answer all questions that you are able to by clicking on the circles, writing in boxes, marking the appropriated box on tables with an 'X' or leave them blank when questions are not applicable to you or they don't make sense for the particular feature being evaluated.

Sections:

a. Demographic information
b. Period of occupancy of the BASF house
c. BASF house usage of spaces by occupants, typical week routine
d. Adequacy of space in the BASF house:
   - Distribution, size and spatial relationships
   - Heating/cooling and ventilation (temperature and air quality)
   - Lighting and acoustics
   - Plumbing/electrical
   - Finishing materials, floor, walls, ceiling, colours, etc.
e. Adequacy of passive design features and low to zero carbon technologies applied to the BASF house
f. Other

The University of Nottingham

a. Demographic information

1. Age

☒ 20-30 ☐ 31-40 ☐ 41-50

2. Gender

☒ Female ☐ Male

3. What is your profession? Consultant

4. Are you a:

☐ Home owner ☒ Tenant

5. Are you currently living in a:

☒ Detached home
☐ Semi-detached home
☐ Terrace home
☐ Bungalow
☐ Flat

b. Period of occupancy of the BASF house

5. How long did you live in the BASF house?

☐ About a month
☐ 2-6 months
☐ 6-8 months
☐ 9-12 months
☐ 13-15 months
☒ Over 15 months

6. In which period did you live in the BASF house and in which position?

From:

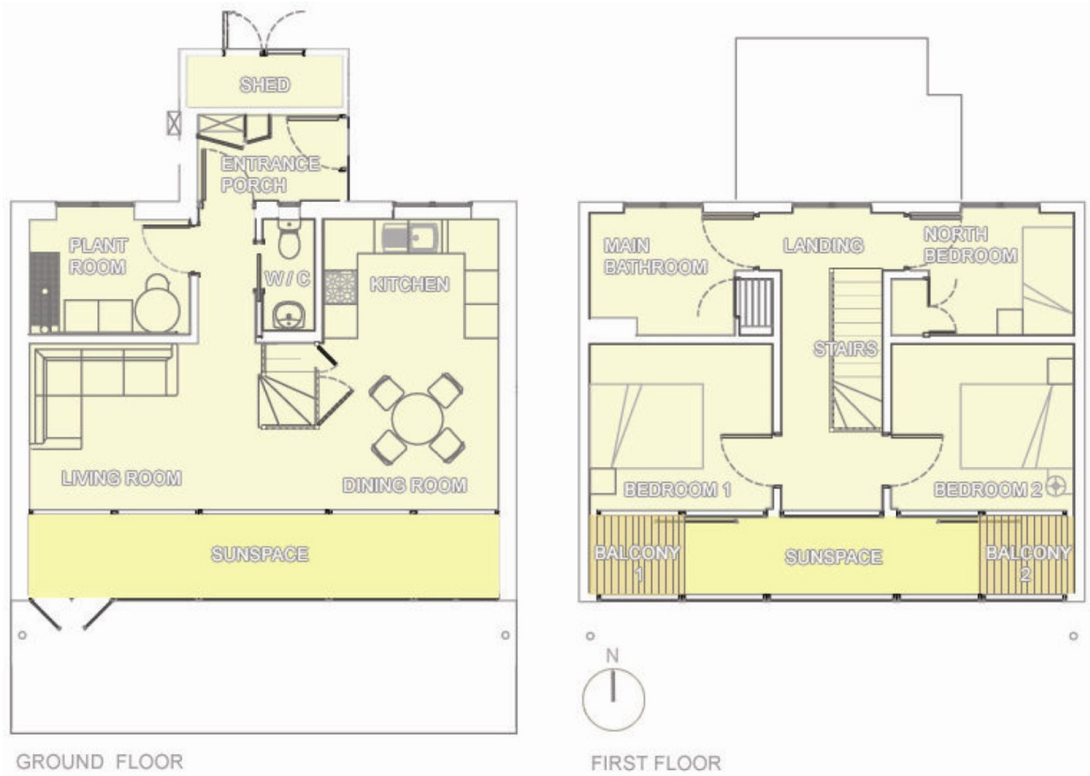
To:

☒ Regular tenant ☐ Temporary stay ☐ Visit

c. BASF House usage of spaces

Please make an effort to recompose the past and remember your average routine when you were living in the BASF house.

A typical week routine: Please indicate the amount of hours you spent typically in the different areas of the BASF house, during work days on Table 1 and on weekends on Table 2. If your summer routine differs much from your winter one (for example you went on summer vacation), please fill in both columns, winter (W) and summer (S). Use the following plan view as a reference if you need it.



For all the following questions please indicate your answers by marking the appropriated blank with an 'X', if a question is not applicable to you or it doesn't make sense for the particular feature is been rated leave the box blank.

7. In an average work week, how many hours did/do you spend in the following spaces of the BASF house?

Table 1: work day routine

SPACES	GROND FLOOR AREAS														FIRST FLOOR AREAS											
N° Hours	Kitchen		Dining room		Living room		Sunspace		Ground-floor toilet		Plant room		Shed		Bedroom 1		Balcony Bedroom 1		Bedroom 2		Balcony Bedroom 2		North Bedroom		Main bathroom	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
0-5					X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X		
6-10			X	X																						
11-15	X	X																								
16-20																										
21-25																										
26-30																										
31-35																										
35-40																										
41-45																										
46-50																										
51+																			X	X						

8. In an average weekend, how many hours did/do you spend in the followings spaces of the BASF house?

Table 2: weekend routine

SPACES	GROND FLOOR AREAS													FIRST FLOOR AREAS										
N° Hours	Kitchen		Dining room		Living room		Sunspace		Ground-floor toilet		Plant room		Shed		Bedroom 1		Balcony Bedroom 1		Bedroom 2		Balcony Bedroom 2		North Bedroom		Main bathroom	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	S	S	W	S	W	S	W	S	W	S	W	S
0-5					X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X		
6-10			X	X																						
11-15	X	X																								
16-20																										
21-25																										
26-30																										
31+																			X	X						

d. Adequacy of space in the BASF House

Key for the following quality ratings:

Ex = Excellent quality = very comfortable (when applicable)
G = Good quality
F = Fair quality
P = Poor quality = uncomfortable (when applicable)

9. Please evaluate the overall quality of the following spaces of the BASF house

Table 3: general space quality of the BASF house

	SPACES	RATING			
GROND FLOOR AREAS	**Kitchen**	**Ex**	**Good**	**Fair**	**Poor**
	Dining room		/		
	Living room			/	
	Sunspace				/
	Ground- floor toilet			/	
	Plant room				/
FIRST FLOOR AREAS	**Bedroom 1**			/	
	Balcony Bedroom 1				/
	Bedroom 2			/	
	Balcony Bedroom 2				/
	North Bedroom				/
	Main Bathroom		/		
CIRCULATION AREAS	**Stairs**		/		
	Landings		/		
	Entrance Porch		/		
	Shed			/	

10. Please evaluate the overall quality of the following spaces of the BASF house individually, considering your personal comfort.

Table 4: quality of individual spaces on ground floor of the BASF house

GROND FLOOR AREAS																								
SPACES	Kitchen				Dining room				Living room				Sunspace				Ground- floor toilet				Plant room			
RATING	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P
Adequacy of Space		/				/						/				/			/					/
Lighting in winter		/				/				/				/						/			/	
Lighting in summer		/				/				/				/						/			/	
Acoustics / noise			/			/						/				/			/				/	
Temperature		/				/				/					/				/				/	
Air freshness (odours)		/				/				/					/				/				/	
Air movement		/				/				/					/				/					/
Flexibility of use		/					/				/					/			/					/
Furniture		/				/						/				/			/					/
Privacy			/				/					/				/			/				/	
Safety		/				/				/						/			/				/	
Size/area (m^2)		/				/						/				/			/				/	
Height		/				/				/				/					/				/	
Maintenance		/				/					/			/					/				/	
Storage		/					/					/				/			/				/	
Aesthetics quality of interior design		/				/					/				/				/				/	

11. Please evaluate the overall quality of the following spaces of the BASF house individually, considering your personal comfort.

Table 5: quality of individual spaces on first floor of the BASF house

FIRST FLOOR AREAS																								
SPACES	Bedroom 1				Balcony Bedrm 1				Bedroom 2				Balcony Bedrm 2				North Bedroom				Main bathroom			
RATING	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P
Adequacy of Space		/						/		/						/			/			/		
Lighting in winter		/				/				/				/				/				/		
Lighting in summer		/				/				/				/				/				/		
Acoustics / noise		/					/			/					/			/				/		
Temperature		/				/				/				/				/				/		
Air freshness (odours)		/				/				/				/					/			/		
Air movement		/				/				/				/					/				/	
Flexibility of use			/				/				/				/				/			/		
Privacy		/						/		/						/			/			/		
Furniture		/						/		/						/			/			/		
Safety		/					/								/				/			/		
Size/area (m²)			/					/			/					/			/			/		
Height		/				/				/				/					/			/		
Maintenance		/				/				/				/					/				/	
Storage space		/						/		/						/			/				/	
Aesthetics quality of interior design		/				/				/				/					/			/		

12. Please evaluate the overall quality of the design of the BASF house?

Table 6: general design quality of the BASF house

DESIGN ASPECTS	RATING			
RATING	**Ex**	**Good**	**Fair**	**Poor**
Aesthetics quality of exterior			✓	
South façade (sunspace)		✓		
North facade				✓
Geometric form				✓
Aesthetics quality of interior design		✓		
Volumetric distribution			✓	
Environmental quality - comfort		✓		
Lighting in winter		✓		
Lighting in summer		✓		
Acoustics				✓
Temperature		✓		
Ventilation		✓		
Air quality		✓		
Adaptability				✓
Security				✓
Privacy				✓
Maintenance			✓	
Relationship of spaces / layout			✓	
Quality of building materials		✓		
floors		✓		
walls		✓		
ceilings		✓		
colours			✓	
textures			✓	
windows		✓		
pavement			✓	
Entrance porch			✓	
Shed			✓	
Quality of building installations			✓	
Plumbing			✓	
Electrical			✓	
Appliances			✓	
Technologies			✓	

e. Adequacy of passive design features and LZC technologies in the BASF house

For all the following questions please indicate your answers by marking the appropriated box with an 'X', if a question doesn't make sense for the particular feature please leave the box blank.

Please select and rank by personal preference from 1 (most favourite feature) to 7 (least favourite feature) and explain (below) why or describe any particular experience you had with it to like it or dislike it.

13. Please evaluate the overall quality of the following passive design features of the BASF house

Table 7: Quality of passive design features of the BASF house

PASSIVE DESIGN FEATURES	SUN ORIENTATION				SUNSPACE (South façade conservatory)				REDUDED WINDOW SIZE (on north façade)				NATURAL VENTILATION MECHANISM (remote controlled windows)				HIGH CEILING (Bedrooms)				HIGH THERMAL INSULATION				AIRTIGHTNESS			
RATING	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P
YOUR PREFERENCE																												
Adequacy of design		/					/					/		/				/				/				/		
Integration to design		/				/						/		/				/				/				/		
Aesthetics		/				/						/		/				/				/				/		
Ease of use		/					/				/			/				/				/				/		
Odours		/				/					/			/				/				/				/		
Noise			/				/					/			/			/				/				/		
Safety			/				/					/		/				/				/				/		
Size/area (m^2) &/or volume (m^3)		/						/				/		/				/				/				/		

Favourite passive design feature:

High ceiling

Least favourite passive design feature:

Reduced window size

The University of Nottingham

14. Please evaluate the overall quality of the following low to zero technologies applied to the BASF house

Table 8: Quality LZC technologies quality of the BASF house

LZC TECHNOLOGIES	PASSIVE SOLAR SYSTEM (solar panels/hot water)				BIOMASS BOILER (heating system, water and space)				RED ROOF COATING (solar heat management)				WATER CONSERVATION & RAINWATER HARVESTING				METERS AND MONITORING SYSTEM (kitchen touch panel)				GROUND AIR HEAT EXCHANGE SYSTEM (cooling and ventilation)				PERMEABLE PAVEMENT			
RATING	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P	Ex	G	F	P
YOUR PREFERENCE																												
Adequacy of design		/				/					/			/				/				/					/	
Integration to design			/				/				/			/				/				/						/
Aesthetics			/				/				/				/			/				/						/
Ease of use		/					/			/				/				/					/				/	
Clear User Manual			/				/			/					/				/				/					/
Odours	/						/			/				/				/				/					/	
Noise		/					/				/			/				/				/					/	
Maintenance		/					/				/			/					/				/					/
Safety			/			/				/				/				/				/						/
Size/volume (m³)			/				/				/			/				/				/						/

Favourite LZC technology:

Passive Solar

Least favourite LZC technology:

Permeable paving

f. Other questions and further comments

In your opinion:

15. Was a good experience for you to have visible readings of the energy consumption (W, kW-h)?

☒ Yes ☐ No

Explain why

16. Should all homes have visible energy meters showing consumption (W, kW-h) and cost of it (£)?

☒ Yes ☐ No

17. How much extra money are you willing to pay for a Zero Carbon Home?

☐ 5-10% ☐ 10-15% ☐ 15-20% ☒ 20-25%

18. If you refurbish your home to improve the energy performance, in how many years will you expect the payback?

☐ 1-5 years ☒ 6-10 years ☐ 11-15 years

19. Please make a list of possible suggestions/additions that you think could improve the performance in regard to comfort of the BASF house.

More flexibility in the use of space

20. Would you implement any of the features you experience in the BASF house in your actual/future home?

Yes

BRILLIANT!!!! THANK YOU SO MUCH!!!! I REALLY APPRECIATE YOUR TIME!!!!

Appendix 11 Descriptive analysis on design features

Tables of Occupant's Evaluation of Design Features, Passive Design Strategies (PDS) and Sustainable Energy Technologies (SET) implemented in the BASF House.

Design Features	Evaluation			
	Excellent	Good	Fair	Poor
Aesthetics quality of exterior	0,0 %	12,5 %	62,5 %	25,0 %
South facade (sunspace)	12,5 %	37,5 %	37,5 %	12,5 %
North facade	0,0 %	12,5 %	12,5 %	75,0 %
Geometric form	0,0 %	37,5 %	37,5 %	25,0 %
Aesthetics quality of interior design	0,0 %	50,0 %	12,5 %	37,5 %
Volumetric distribution	0,0 %	50,0 %	12,5 %	37,5 %
Environmental quality-comfort	0,0 %	85,7 %	0,0 %	14,3 %
Lighting in winter	25,0 %	75,0 %	0,0 %	0,0 %
Lighting in summer	25,0 %	62,5 %	12,5 %	0,0 %
Acoustics	12,5 %	37,5 %	25,0 %	25,0 %
Temperature	0,0 %	75,0 %	25,0 %	0,0 %
Ventilation	25,0 %	62,5 %	12,5 %	0,0 %
Air quality	25,0 %	62,5 %	12,5 %	0,0 %
Adaptability	0,0 %	37,5 %	12,5 %	50,0 %
Security	12,5 %	75,0 %	12,5 %	0,0 %
Privacy	0,0 %	12,5 %	12,5 %	75,0 %
Maintenance	12,5 %	75,0 %	12,5 %	0,0 %
Relationship of space /layout	0,0 %	37,5 %	37,5 %	25,0 %
Quality of building materials	25,0 %	75,0 %	0,0 %	0,0 %
Floor	25,0 %	75,0 %	0,0 %	0,0 %
Walls	25,0 %	62,5 %	12,5 %	0,0 %
Ceilings	37,5 %	62,5 %	0,0 %	0,0 %
Colours	12,5 %	37,5 %	37,5 %	12,5 %
Textures	12,5 %	37,5 %	37,5 %	12,5 %
Windows	37,5 %	62,5 %	0,0 %	0,0 %
Pavement	25,0 %	62,5 %	12,5 %	0,0 %
Entrance porch	37,5 %	37,5 %	25,0 %	0,0 %
Shed	0,0 %	62,5 %	12,5 %	25,0 %
Quality of building installations	14,3 %	71,4 %	14,3 %	0,0 %
Plumbing	25,0 %	25,0 %	37,5 %	12,5 %
Electrical	37,5 %	50,0 %	12,5 %	0,0 %
Appliances	25,0 %	62,5 %	12,5 %	0,0 %
Technologies	0,0 %	50,0 %	37,5 %	12,5 %

PDS **Sun Orientation**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	50,0 %	33,3 %	16,7 %	0,0 %
Integration to design	28,6 %	42,9 %	28,6 %	0,0 %
Aesthetics	0,0 %	66,7 %	33,3 %	0,0 %
Ease of use	50,0 %	50,0 %	0,0 %	0,0 %
Size or Volume	0,0 %	0,0 %	100,0 %	0,0 %
PDS **Sunspace**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	25,0 %	37,5 %	37,5 %	0,0 %
Integration to design	25,0 %	62,5 %	12,5 %	0,0 %
Aesthetics	25,0 %	37,5 %	37,5 %	0,0 %
Ease of use	12,5 %	37,5 %	25,0 %	25,0 %
Odours	20,0 %	80,0 %	0,0 %	0,0 %
Noise	16,7 %	33,3 %	16,7 %	33,3 %
Safety	0,0 %	37,5 %	25,0 %	37,5 %
Size or Volume	0,0 %	37,5 %	25,0 %	37,5 %
PDS **Reduced window size**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	14,3 %	57,1 %	14,3 %	14,3 %
Integration to design	28,6 %	14,3 %	42,9 %	14,3 %
Aesthetics	0,0 %	16,7 %	16,7 %	66,7 %
Ease of use	0,0 %	66,7 %	33,3 %	0,0 %
Odours	33,3 %	33,3 %	33,3 %	0,0 %
Noise	20,0 %	60,0 %	0,0 %	20,0 %
Safety	16,7 %	66,7 %	0,0 %	16,7 %
Size or Volume	0,0 %	25,0 %	50,0 %	25,0 %
PDS **Natural Ventilation Mechanism**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	62,5 %	25,0 %	12,5 %	0,0 %
Integration to design	25,0 %	62,5 %	12,5 %	0,0 %
Aesthetics	14,3 %	71,4 %	0,0 %	14,3 %
Ease of use	25,0 %	37,5 %	25,0 %	12,5 %
Odours	25,0 %	75,0 %	0,0 %	0,0 %
Noise	12,5 %	12,5 %	62,5 %	12,5 %
Safety	14,3 %	85,7 %	0,0 %	0,0 %
Size or Volume	16,7 %	66,7 %	16,7 %	0,0 %

PDS **High Ceiling**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	25,0 %	50,0 %	25,0 %	0,0 %
Integration to design	37,5 %	37,5 %	12,5 %	12,5 %
Aesthetics	12,5 %	50,0 %	25,0 %	12,5 %
Ease of use	0,0 %	33,3 %	33,3 %	33,3 %
Odours	0,0 %	50,0 %	50,0 %	0,0 %
Noise	0,0 %	66,7 %	0,0 %	33,3 %
Safety	0,0 %	75,0 %	0,0 %	25,0 %
Size or Volume	28,6 %	42,9 %	0,0 %	28,6 %
PDS **High thermal insulation**	Evaluation			
	Excellent	Good	Fair	Poor
Adequacy of design	50,0 %	50,0 %	0,0 %	0,0 %
Integration to design	50,0 %	50,0 %	0,0 %	0,0 %
Aesthetics	0,0 %	75 %	0,0 %	25 %
PDS	Airtightness			
	Excellent	Good	Fair	Poor
Adequacy of design	50,0 %	37,5 %	12,5 %	0,0 %
Integration to design	33,3 %	66,7 %	0,0 %	0,0 %
Aesthetics	25 %	75 %	0,0 %	0,0 %
Ease of use	25 %	75 %	0,0 %	0,0 %
Odours	0,0 %	60,0 %	20,0 %	20,0 %
Noise	33,3 %	66,7 %	0,0 %	0,0 %
Safety	33,3 %	66,7 %	0,0 %	0,0 %
Size or Volume	0,0 %	100,0 %	0,0 %	0,0 %
SET	Passive solar system			
	Excellent	Good	Fair	Poor
Adequacy of design	25,0 %	50,0 %	25,0 %	0,0 %
Integration to design	12,5 %	62,5 %	25,0 %	0,0 %
Aesthetics	0,0 %	50,0 %	37,5 %	12,5 %
Ease of use	0,0 %	40,0 %	40,0 %	20,0 %
Clear User Manual	0,0 %	40,0 %	40,0 %	20,0 %
Odours	100,0 %	0,0 %	0,0 %	0,0 %
Noise	0,0 %	40,0 %	40,0 %	20,0 %
Maintenance	16,7 %	50,0 %	33,3 %	0,0 %
Safety	0,0 %	60,0 %	40,0 %	0,0 %
Size or Volume	16,7 %	50,0 %	33,0 %	0,0 %

SET	Biomass boiler			
	Excellent	Good	Fair	Poor
Adequacy of design	0,0 %	16,7 %	0,0 %	83,3 %
Integration to design	0,0 %	14,3 %	14,3 %	71,4 %
Aesthetics	0,0 %	0,0 %	16,7 %	83,3 %
Ease of use	0,0 %	0,0 %	14,3 %	85,7 %
Clear User Manual	0,0 %	40,0 %	40,0 %	20,0 %
Odours	0,0 %	0,0 %	16,7 %	83,3 %
Noise	16,7 %	0,0 %	33,3 %	50,0 %
Maintenance	0,0 %	0,0 %	28,6 %	71,4 %
Safety	0,0 %	0,0 %	25,0 %	75,0 %
Size or Volume	0,0 %	16,7 %	16,7 %	16,7 %
SET	Red Roof Coating			
	Excellent	Good	Fair	Poor
Adequacy of design	25,0 %	62,5 %	12,5 %	0,0 %
Integration to design	25,0 %	25,0 %	50,0 %	0,0 %
Aesthetics	0,0 %	37,5 %	37,5 %	25,0 %
Ease of use	0,0 %	100,0 %	0,0 %	0,0 %
Clear use Manual	0,0 %	50,0 %	50,0 %	0,0 %
Odours	0,0 %	100,0 %	0,0 %	0,0 %
Noise	50,0 %	0,0 %	50,0 %	0,0 %
Maintenance	0,0 %	50,0 %	25,0 %	25,0 %
Safety	0,0 %	100,0 %	0,0 %	0,0 %
Size or Volume	0,0 %	50,0 %	50,0 %	0,0 %
SET	Water Conservation and Rainwater Harvesting			
	Excellent	Good	Fair	Poor
Adequacy of design	57,1 %	42,9 %	0,0 %	0,0 %
Integration to design	42,9 %	57,1 %	0,0 %	0,0 %
Aesthetics	14,3 %	28,6 %	57,1 %	25,0 %
Ease of use	57,1 %	42,9 %	0,0 %	0,0 %
Clear user manual	0,0 %	50,0 %	50,0 %	0,0 %
Odours	0,0 %	100,0 %	0,0 %	0,0 %
Noise	0,0 %	33,3 %	33,3 %	0,0 %
Safety	50,0 %	50,0 %	0,0 %	25,0 %
Size or Volume	0,0 %	66,7 %	33,3 %	0,0 %

SET	Meters and Monitoring System			
	Excellent	Good	Fair	Poor
Adequacy of design	37,5 %	50,0 %	0,0 %	12,5 %
Integration to design	50,0 %	25,0 %	25,0 %	0,0 %
Aesthetics	28,6 %	42,9 %	14,3 %	14,3 %
Ease of use	12,5 %	25,0 %	25,0 %	37,5 %
Clear user manual	0,0 %	0,0 %	16,7 %	83,3 %
Odours	0,0 %	100,0 %	0,0 %	0,0 %
Noise	0,0 %	100,0 %	0,0 %	0,0 %
Maintenance	0,0 %	25,0 %	25,0 %	50,0 %
Safety	0,0 %	50,0 %	50,0 %	0,0 %
Size or Volume	66,7 %	33,3 %	0,0 %	0,0 %
SET	Ground Air heat exchange system			
	Excellent	Good	Fair	Poor
Adequacy of design	37,5 %	25,0 %	25,0 %	12,5 %
Integration to design	12,5 %	62,5 %	12,5 %	12,5 %
Aesthetics	14,3 %	57,1 %	28,6 %	0,0 %
Ease of use	0,0 %	71,4 %	28,6 %	0,0 %
Clear user manual	0,0 %	0,0 %	50,0 %	50,0 %
Odours	0,0 %	66,7 %	0,0 %	33,3 %
Noise	0,0 %	75,0 %	25,0 %	0,0 %
Maintenance	16,7 %	33,3 %	33,3 %	16,7 %
Safety	33,3 %	66,7 %	0,0 %	0,0 %
Size or Volume	16,7 %	50,0 %	33,3 %	0,0 %
SET	Permeable Pavement			
	Excellent	Good	Fair	Poor
Adequacy of design	25,0 %	50,0 %	25,0 %	0,0 %
Integration to design	12,5 %	75,0 %	0,0 %	12,5 %
Aesthetics	14,3 %	28,6 %	42,9 %	14,3 %
Ease of use	28,6 %	57,1 %	14,3 %	0,0 %
Clear user manual	0,0 %	33,3 %	33,3 %	33,3 %
Odours	0,0 %	0,0 %	100,0 %	0,0 %
Noise	0,0 %	50,0 %	50,0 %	0,0 %
Maintenance	40,0 %	40,0 %	0,0 %	20,0 %
Safety	66,7 %	0,0 %	0,0 %	33,3 %
Size or Volume	33,3 %	33,3 %	0,0 %	33,3 %

When analysing the rooms and spaces in a more detailed manner, marking one of the four mentioned choices, to qualify each room or space individually on 16 different features, when appropriate, from the best evaluated feature to the least one and combining the two highest options, excellent and good and the two lowest ones, fair and poor respectively, the following information was obtained:

<u>For the ground floor</u>

Kitchen Excellent + good interior quality: aesthetic quality of interior design, adequacy of the space, lighting in winter, and lighting in summer, all these features obtained the maximum, 100%, when adding the two best choices, however if it is just taken the choice *excellent*, the highest punctuation goes to two features equally, adequacy of space and size/area (m^2), with 50% each.

Poor + fair interior quality: privacy, acoustics/noise and storage space, obtaining a big gap from the worst evaluated feature, privacy with 87.5 %, followed by the second worst with 37.5%.

Dining room Excellent + good interior quality: lighting in summer and air movement, both with 100%, however if it is taken just the choice *excellent*, the highest is lighting in winter, with 28.6% and 85.7% when considering the two best choices.

Poor + fair interior quality: privacy with 87.5 %, flexibility of use, furniture and adequacy of space all with 62.5 %.

Sunspace Excellent + good interior quality: lighting in winter, height and maintenance, all with 100%, however if it taken just the choice *excellent*, the highest is lighting in winter, with 57.1%.

Poor + fair interior quality: privacy, furniture and aesthetic quality of interior design all with 100%, being the first two with 71.4% when considering just the worst choice *poor.*

Living room Excellent + good interior quality: lighting in summer, with 100%, however if it taken just the choice *excellent*, the highest is lighting in winter, with 28.6% and 85.7% when considering the two best choices.

Poor + fair interior quality: privacy with 87.5 %, flexibility of use, furniture and adequacy of space all with 62.5 %.

Toilet Excellent + good interior quality: in general it was evaluated very low in regard to quality of its features, safety and height, with 62.5 %, from which only 12.5% was for the choice *excellent*, being higher the temperature feature, with 25% for the same choice.

Poor + fair interior quality: from the worst to the least poor evaluated feature lighting in winter, lighting in summer and size/area (m^2), which is quite predictable, given the location underneath the stairs and the small window facing the South porch.

Plant room Excellent + good interior quality: in general it was evaluated very low as the toilet in regard to quality of its features, temperature, with 50 %, from which half went to each choice.

Poor + fair interior quality: most of the evaluation was concentrated on the choice *fair*, when taking just the choice *poor* only, furniture obtained 71.4 %, but when adding the two worst choices lighting in winter, lighting in summer, flexibility of the space, size/area (m^2) and aesthetic quality of interior design they all obtained 100%. Being the room of the ground floor worst evaluated.

<u>For the first floor</u>

Main bathroom Excellent + good interior quality: it was the best evaluated room of the BASF house, obtaining a 100% on 10 of the 16 features, adequacy of the space, lighting in winter, lighting in summer, acoustics/noise, air freshness, privacy, furniture, safety, size/area (m^2) and height, when taken the choice *excellent* only, adequacy of space received 75% the highest.

Poor + fair interior quality: storage space was the lowest evaluated feature, with 12.5% for the choice poor and 75% with both choices, poor + fair.

Balconies of bedroom 1 (south west) and bedroom 2 (south east) Excellent + good interior quality: both balconies are very similarly evaluated, lighting in winter, lighting in summer, air freshness, air movement and aesthetic quality of interior design, with 100%. For balcony 2 size/area (m^2) height, also obtained 100%, while for balcony 1 these two features received a 75%. Adequacy of the space, also received a 75% for both balcony, in the case of balcony 1, this feature was evaluated with 75% entirely for the choice *excellent*.

Poor + fair interior quality: privacy was the lowest evaluated feature, with 100% for the choice *poor* entirely for both balconies. When combining *poor + fair* the feature storage space obtained 100% and for the feature furniture the balcony 1 obtained 100%, while balcony 2 obtained 75%.

Bedroom 1 (south west) This room was evaluated by two occupants only, most of the time it was occupied by the main author, who is not considered for this questionnaire. Nevertheless, the evaluations for both bedrooms differ slightly.

Excellent + good interior quality: lighting in winter, lighting in summer, acoustics/noise, air freshness, air movement, safety and height with 100%. The next two features were furniture and aesthetic quality of interior with 66.7%

Poor + fair interior quality: size/area (m^2) with 100% for the choice *fair* entirely. Flexibility of use and privacy obtained a 66.7% for the first feature it was equally distributed between the two choices, while for the second it was concentrated all in the choice *fair.*

Bedroom 2 (south east): this bedroom was evaluated by two occupants only, most of the time it was occupied by the main author, who is not considered for this questionnaire. Nevertheless, the evaluations for both bedrooms differ slightly.

Excellent + good interior quality: lighting in winter, acoustics/noise, air freshness, air movement, furniture, height and aesthetic quality of interior with 75%, the next feature was safety with 66.7%

Poor + fair interior quality: size/area (m^2) with 75% for the choice *fair* entirely. Then, seven features obtained 50% adequacy of the space, lighting in summer, temperature, flexibility of use, privacy, maintenance and storage space.

When comparing the best evaluated features for the two south bedrooms, lighting in summer obtained half of the score of bedroom 1, which is probably related to the sun orientation. Also the majority of the higher values were 100% for bedroom 1, while 75% for bedroom 2, which is probably related to the amount of answers obtained for each case.

Appendix 12 Tracking devices and info-graphics to analyse the interior space usage

This section shows the pattern and time spent by the occupants in the different rooms and spaces in the BASF house, at the time they were living in it. It also presents the resulting mapping of the ground floor (public space) usage recorded by the tracking devices mentioned in chapter 3 on other methodological tools, during three weeks of wintertime in 2008.

A typical working week (from Monday to Friday)

Figure 98 depicts the amount of hours spent in the different spaces of the ground floor during summertime (S) versus wintertime (W). The ground floor is the most public space of the house, while the first floor is very private; given the fact the occupants are not members of the same family, but that they share meal times.

As can be seen in figure 98, the ground floor was not widely used; the mean per week was between 6 and 10 hours. The most used space was the dining room and in wintertime, 14.3% of the occupants used it between 31 to 35 hours per week, while in summertime usage was never over 15 hours.

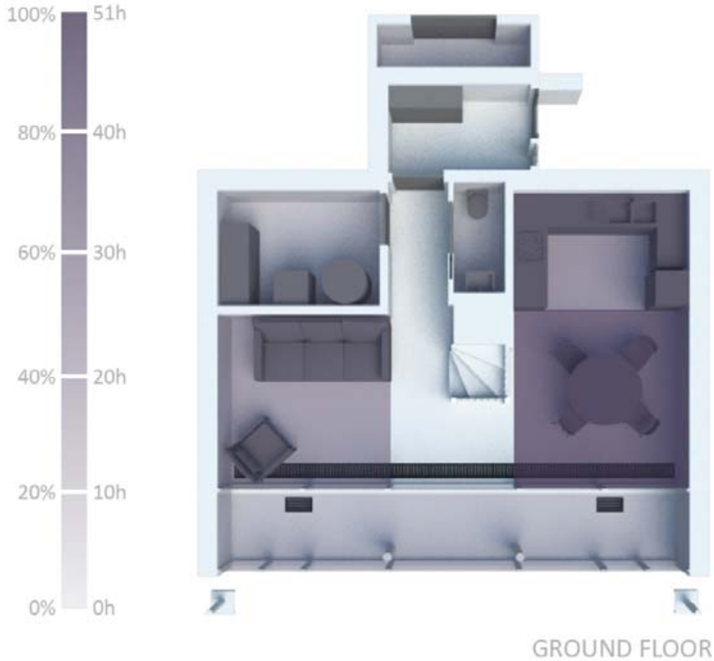


Figure 98 Example of ground floor usage of the BASF house in hours.

Images like that in figure 98 are helpful to visualise the way the shared spaces or public spaces of a home are used. However this will vary so much depending on the occupants and their habits. An analysis of the results shows an interesting correlation between the length of time spent in certain spaces of the BASF House and the space/room preferences.

The first floor comprised of the bedrooms and main bathroom, they were typically occupied and they were more private spaces. All occupants had more or less similar sleeping habits. Therefore, this floor was used much more than the ground floor, which is to be expected given that all the occupants worked/studied during working hours. The occupants spent an average of 40 hours in their bedrooms between Monday and Friday. The most relevant result obtained was that in wintertime the occupants spent 25% more time in their bedrooms than they did in summer.

A typical weekend (Saturday and Sunday)

The trend at the weekend was similar to that for working days. The dining room was the space most occupied in the house, from 16 to 20 hours, but at the weekend the average number of hours per day was higher. Meanwhile, the first floor occupancy pattern was almost the same as that for working days. The average number of hours per day spent in the bedrooms was slightly higher at weekends and obviously varied a little between the different occupants.

Usage of the space analysed by the tracking devices

The following image, figure 99 is the plan view of the tracking system in the BASF house, and it shows the location of the five sensors, the location of the master sensor and the time source, which was directly connected to the computer that was recording the readings. Also the consumption zones are identified in lighter purple and occupants in magenta purple. Both images were for the 8th of May after supper time, 20:23 hrs. Millions of points are recorded to show location and length of stay in space by each occupant. Also by analysing the length of time occupants spend in a specific space within a period of time, it could be deduced that the occupant was comfortable in that particular space and that could be contrasted with the room preferences, then the same variables can be analysed with more than one tool. This is the case for the dining room for instance versus the living room.

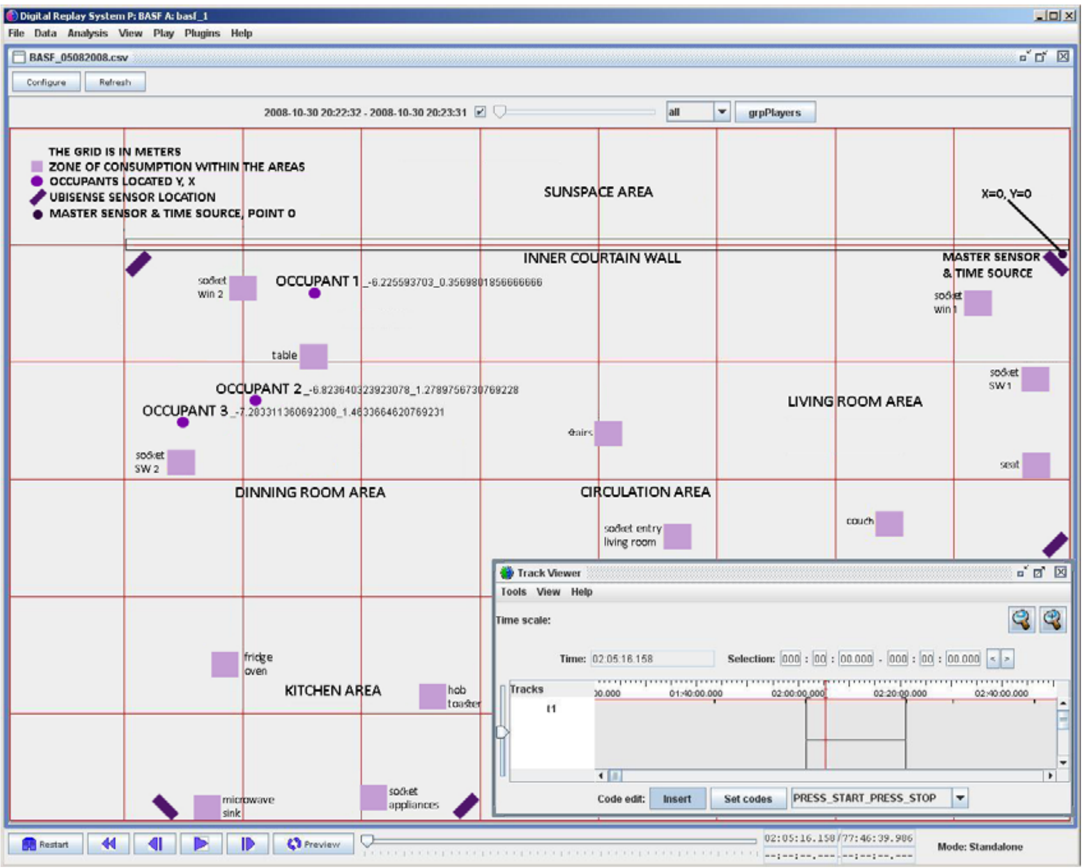


Figure 99 Plan reading of the tracking system to analyse occupation of public spaces in the BASF House

In the next figure 100 the points indicate the location of the occupants recorded by the readings through their tags, and by adding one reading to another over the plan view, the density of the points shows the length of permanence in each area, the dining room and the living room have sitting places and a desk area by the southwest sliding door, while the kitchen has shorter permanence, therefore is less dense. It can be noticed that there is a very dense population of readings at the bottom of the stairs as well. That was the main access to the first floor, bedrooms and main bathroom, and every time the occupants passed by it will be registered. The same happened for the two sliding doors that access the sunspace (inner curtain wall). On the southwest side of the sunspace is the line for clothing, and on the southeast is the place to go out when cleaning up after eating, and it was normally used to access to the south terrace.

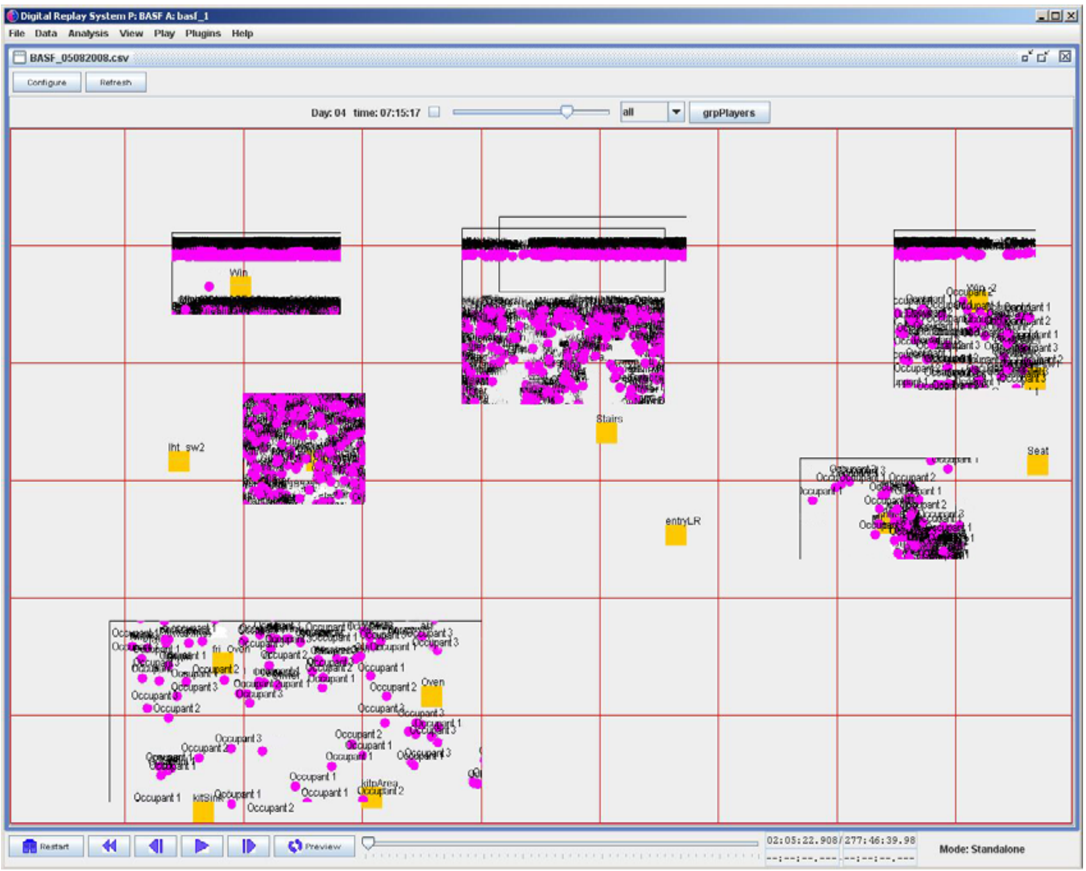


Figure 100 Plan reading of the tracking system to analyse occupant's frequency and permanence in the public spaces in the BASF House through dots

The following graphs in figures 101 and 102 show the comparison in percentage of the time spent in the public spaces of the BASF house, kitchen, dining and living rooms, by the three occupants in one typical working day of spring. These graphs were created from the above information that measures in dots marked every minute the occupant enter in the specific zone while wearing the tag. This was a typical working day routine during that time, occupant 1 worked at home while the other two occupants did not. Occupant 1 and 2 used to lunch at home together, and occupant 3 usually used the living room in the evening for yoga training. These measurements helped to distribute the individual energy consumption among occupants.

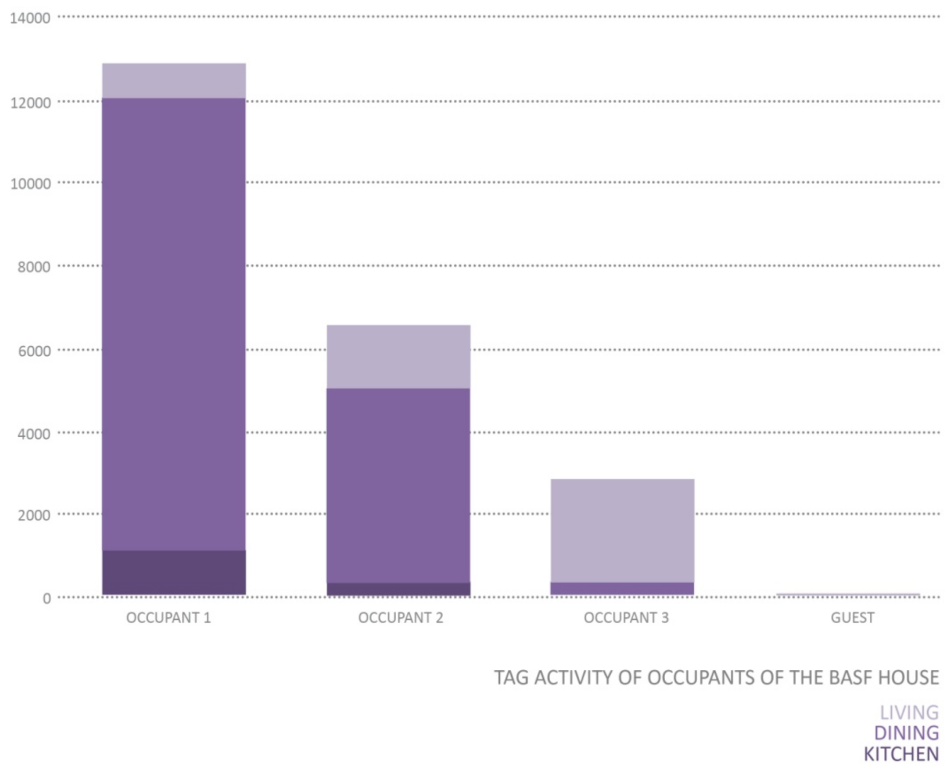


Figure 101 Graphs depicting the percentage of permanence distributed among the three occupants and one guest in the public spaces in the BASF House in a typical working day

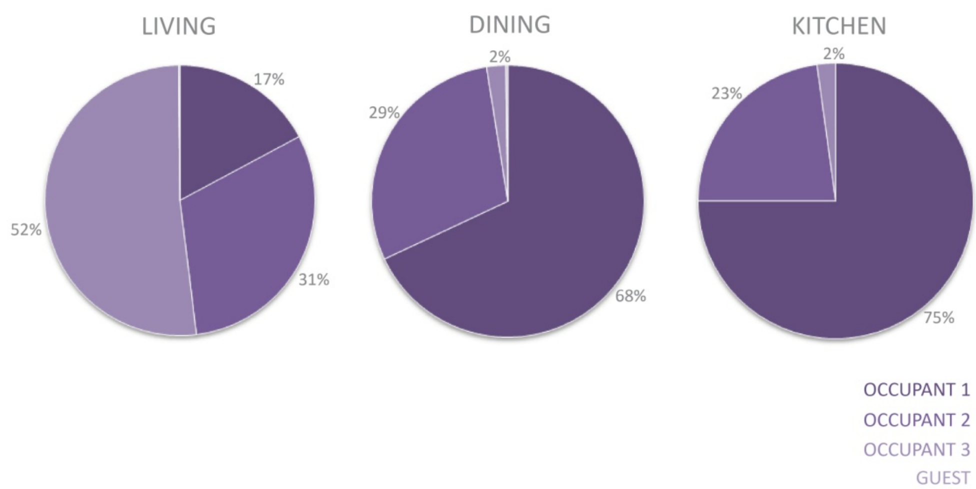


Figure 102 Set of graphs comparing the percentage of permanence in the different public spaces (kitchen, dining room and living room) of the ground floor on the BASF House in a typical working day, by the three occupants and one guest, during a tracking device measurement period.

Appendix 13 BASF House Occupant's questionnaire (written comments for open questions)

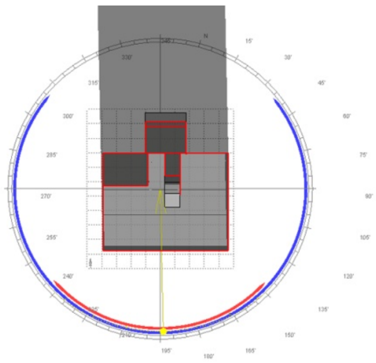
occupant	favourite passive design feature	least favourite passive design feature	comments on passive design features	favourite LZC technology	least favourite LZC technology	comments on LZC technology	possible suggestions and/or additions	features of Basf house in yours in the future	
1	High Ceiling	Reduce Window Size		Passive Solar System	Permeable Paving		more flexibility in the use of space	**Yes**	
2	Sun Orientation, air tightness	Reduce Window Size, natural ventilation mechanism	SO: the house is always full of light and when the sun is not covered with clouds, the house receives the sun heat perfectly, and besides there is a beautiful view	Water Conservation & Rain Water Harvesting, passive solar system	Biomass Boiler, meters and monitoring system	M&MS: useful and easy to interact with it, all houses should have one. BMB: It stinks and it is ugly and big and throws smoke inside the house, but it does warm up, but to use it is a big fuss, bringing the pellests that last not so much and turning it on, all too complicated.	1. have another heating system. 2. make the sunspace bigger so it is possible to do somthing in there, because it is so narrow that you can only sit and see the view, not much more. 3. the north bedroom is too dark and small, except for a baby perhaps 4. there are too many complicated technologies that I never took the time to learn because I was not interested, but I think it should be easier, everything has too many steps.	**Yes**	
3	Sun Orientation, sunspace	Airtightness, reduce window size	SO: the natural lighting in the house was, most of the time, really comfortable AT: bedroom 2 use to have infiltrations	Ground Air Heat Exchange System, meters and monitoring system	Biomass Boiler, Red Roof Coating	GAHE: It is comfortable, easy to use and really useful BMB: managing the machine wasn't easy at it is supposed to be, it was dangerous (midnight smoke), uncomfortable to use (little space in the plant room), we didn't have a room to store the pellets, the pellets bags were too big and heavy to move them from the storage room (in the neighbours house) to the plant room. It overheat the house. The heat distribution in the house wasn't efficient.	1. Set heat radiators in the bedrooms to the South 2. Change the biomass boiler location and put an automated system shared with the rest of the neighbourhood. 3. Try to control the infiltration of the house.		

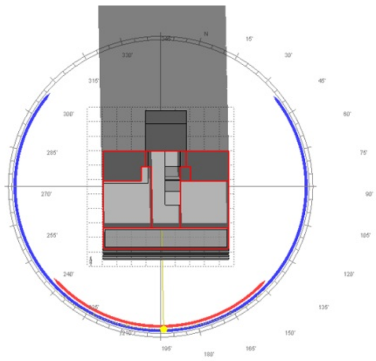
4	Sunspace	Natural Ventilation Mechanism	SS: gives the house a comfortable feeling, plenty of light and the chance to grow plants. However it was a shame that it was always cluttered with test rigs and never been able to enjoy it as a living space. NVS: The natural ventilation mechanisms – the upper vents on the first floor produced uncomfortable draughts. The electronic operating systems made it difficult to control and very noisy.	Meters and Monitoring System	Biomass Boiler	M&MS: because it integrated the latest technology with remote access and showed you clearly the environmental conditions of the interior. My only observation would be that it is not user-friendly and if something didn´t work, you need to call a qualified technician to help you, which is not practical for everyday life! It would also be great if the monitoring system could provide wi-fi connection to the house occupants. BMB: because it is a massive sized system that proved to be very inefficient and expensive to run. The location of the plant room at the entrance of the house gave a feeling of a laboratory rather than a house. I didn't have the chance to try the heating system during winter, but I guess that becomes a priority for the LZC technologies to work well	In regards to the comfort, there are spaces not well designed and hence not well used in the house; for instance the living room is quite small, feels more like a waiting area; the sunspace could be a bit more wide to be able to enjoy it both towards the inside of the house in winter and to the outside of the house in summer; the area outside to the sunspace could become a really nice terrace; the plant room at the entrance gives a 'technical' feeling to the house. The north bedroom has an extremely high ceiling for such a narrow floor area. The exterior design of the house is well deficient, not an avant-garde design for a new generation of eco-homes (specially the north facade). The overall look of the house is like a big shed.	**Yes**	I would implement several of the LZC technologies, like the ground air heat exchanger, the solar collectors, the rainwater harvesting system, and the meter and monitoring. Many of these technologies are suitable for fitting when building a new home, but in the case of retrofit I would still install some of them; for instance the meter and monitoring system, the PCM panels, solar collectors and I would add a small photovoltaic array to supply part of the energy consumption.
5	High Thermal Insulation	High Ceiling		Passive Solar System	Biomass Boiler	BMB: With the biomass in the plant room was not enough space, it was noisy and smelly	Improved sight lines from windows –reduced frame profiles Air to air heat exchanger Bigger living room Not fully glazed on the south or better screening system Reduced ceiling height in bedroom or at least a shading system for upper window. Under floor heating instead of trench No biomass boiler- heat pump instead. Manual thermostat	**Yes**	Passive Solar System

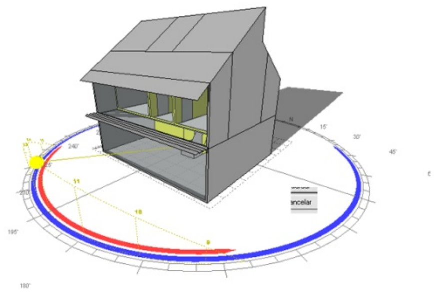
6	Airtightness	Reduce Window Size	AT: the design of airtightness is brilliant as it helps the energy conservation and the effectiveness of natural ventilation. RWS: smaller size makes it very difficult to see what is happening outside.	Meters and Monitoring System	Red Roof Coating	M&MS: Very convenient to monitor and control the energy consumption condition and the lighting, windows and ventilation devices. A brilliant part! RRC: The dust accumulates on top of it, it looks very dirty and rain doesn't wash it away.	1. The plumbing system produces a lot of noise when in use. It would be great if this problem can solved. 2. Dust accumulates on the ground air heat exchanger, which deteriorate the air quality by lifting the dust into the indoor air when the heating is on. So this problem deserves to be looked into.	**YES** Airtightness, natural ventilation, sunspace, monitoring system	
7	Sunspace, Sun Orientation	Airtightness, high thermal insulation	SS & SO: Good light and good sun	Passive Solar System	Biomass Boiler	RWS, HTI & AT: Irrelevant to my experience.	1. Enhancing of the architectural layout and interior design solutions. 2. Architectural Form	**YES** Sunspace, natural ventilation monitoring system, PSS, WC&RH	
8	Sunspace, Sun Orientation	Airtightness, reduce window size	SS & SO: They are excellent strategies for passive solar design, the ss works brilliantly, it is a perfect buffer space in winter time.	Passive Solar System	Biomass Boiler	PSS is really excellent when the sun is there. You don't have to do anything for it to work well, sometimes is noisy, and in sunny days it will be great if the extra heat could be use, since it reaches a temp. over 80ºC. BMB is the worst technology applied to the house, not safe, hard to maintain, ugly, smelly, smoky, it consumes a lot of pellets. When is functioning well, gives nice and pleasant heat to the house and the water.	1. Better layout and space connections. 2. Replace the heating system for another one of different type. 3. The aesthetics of the North facade is ugly 4. Furniture is not appropriate, ex. the wardrobes for bedroom 1 and 2 waste so much space, they should be build in closets. 5. change the white colour on everything for other colours, it's very reflective and uncomfortable in summer.	**YES** Solar system, natural ventilation system	

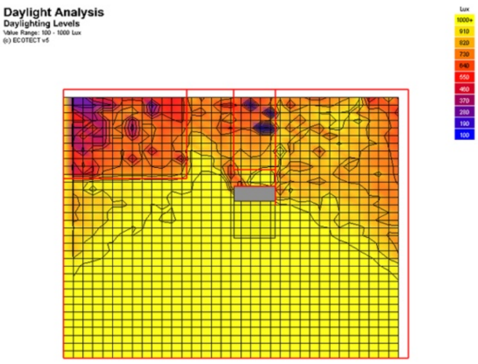
Appendix 14 Ecotect Daylight Analysis

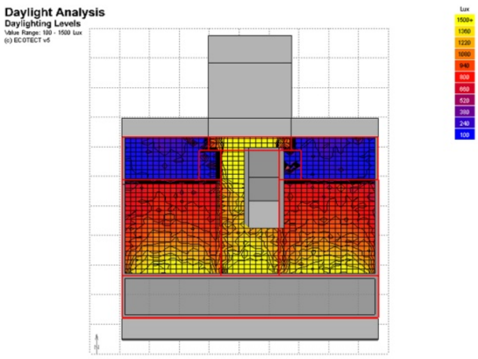
Ecotect Daylight Analysis for the winter solstice (21/12), summer solstice (21/06) and one of the equinoxes (21/09) at noon.

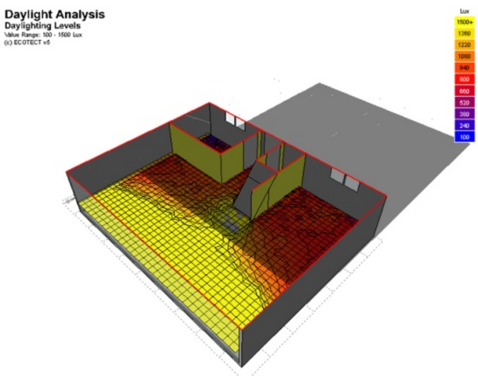




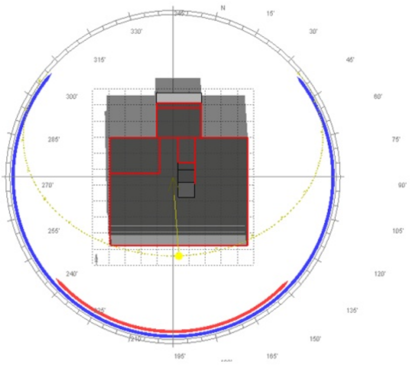


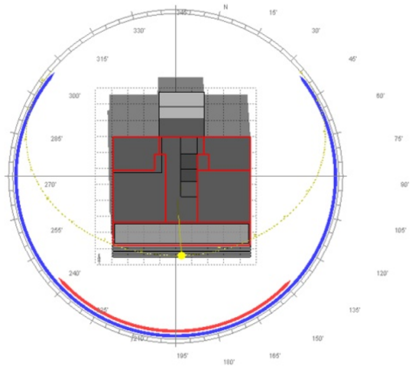


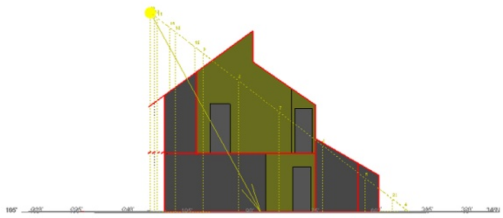


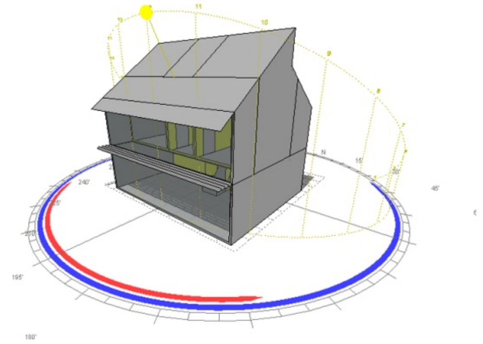


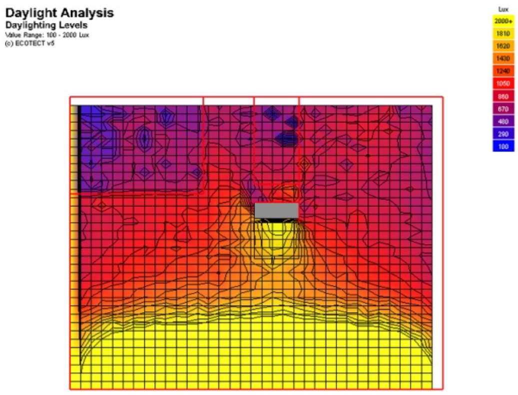
Ecotect daylight analysis of summer solstice, December the 21st at noon

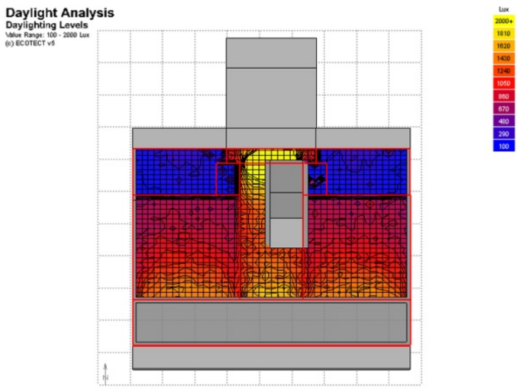


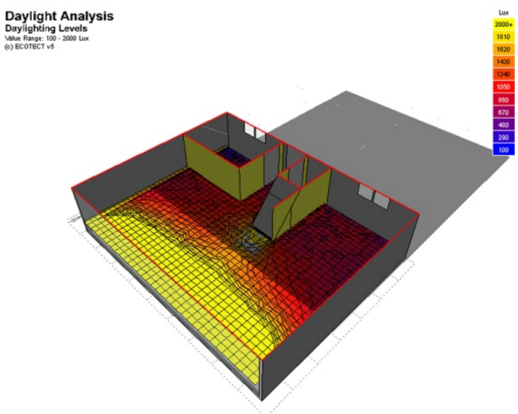




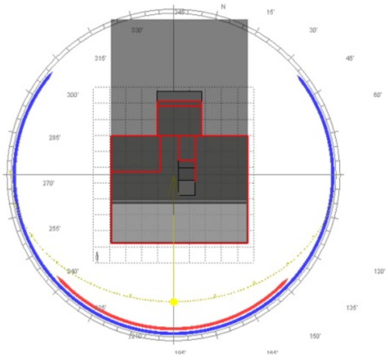


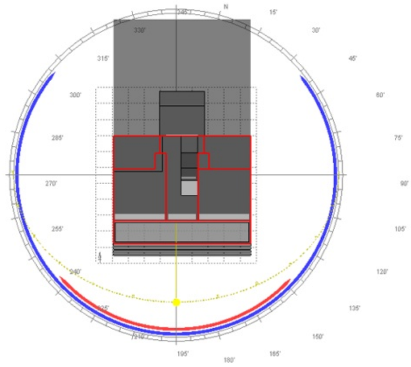


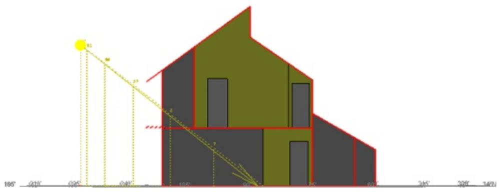


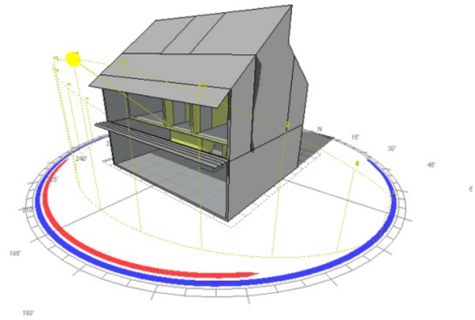


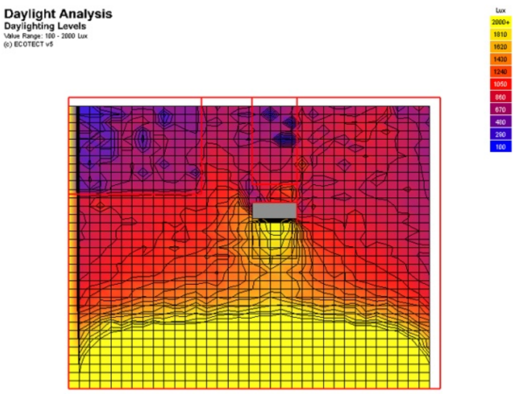
Ecotect daylight analysis of equinox September 21st at noon

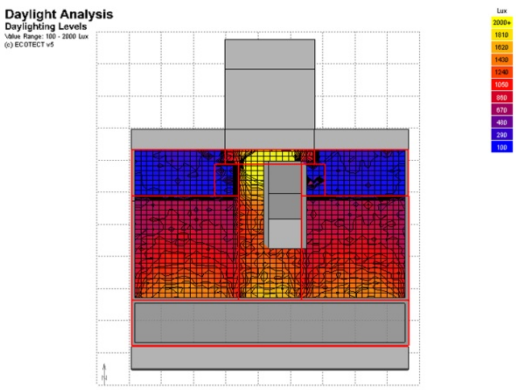


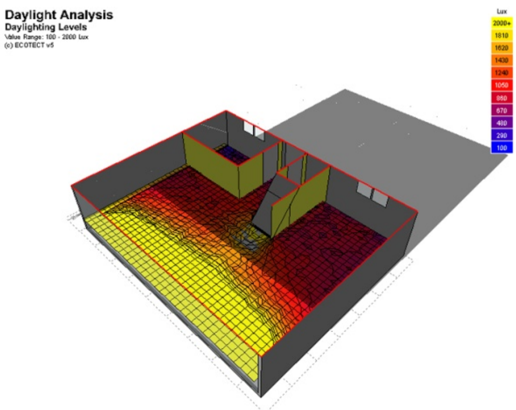








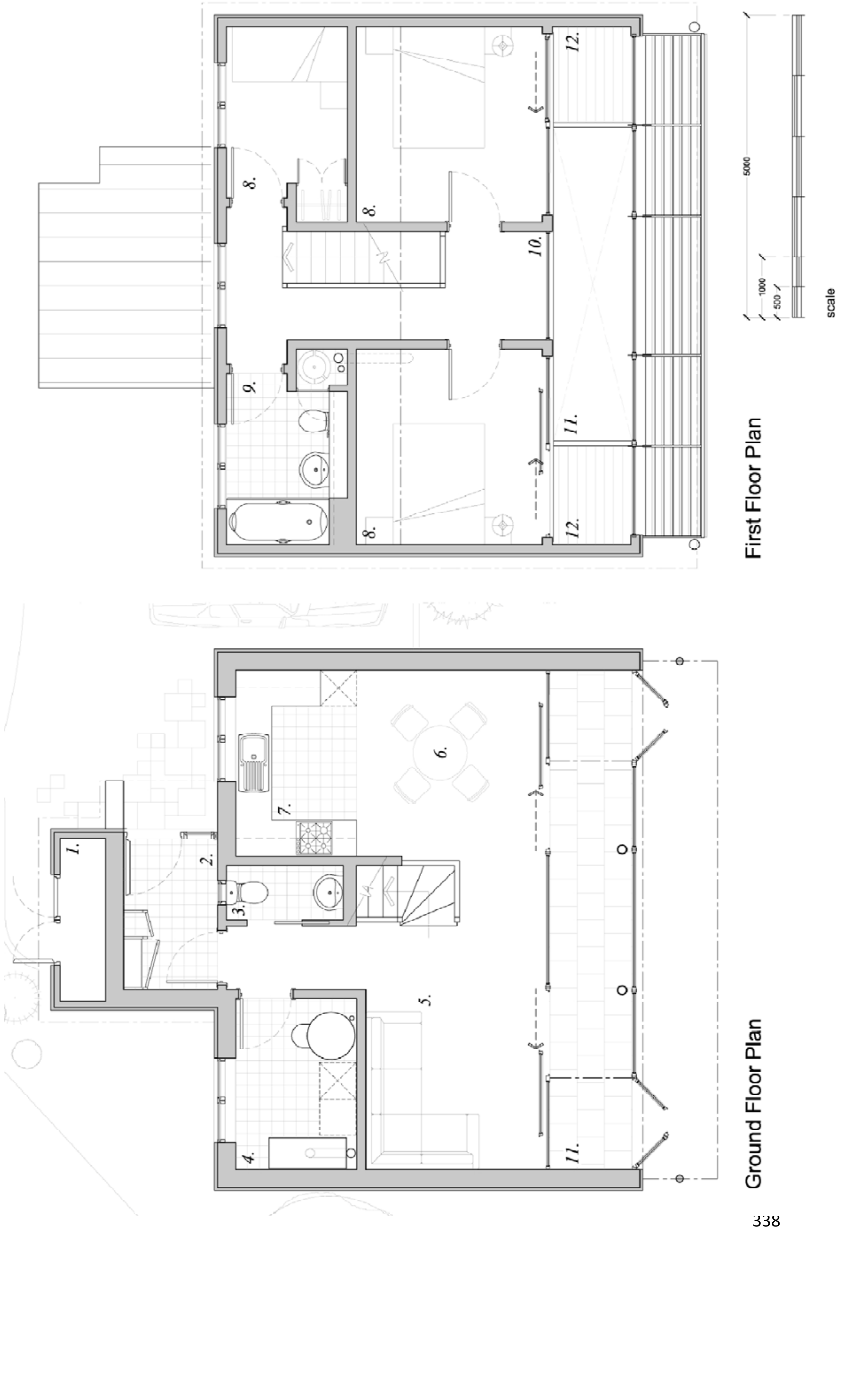




Appendix 15 Drawings and SET description of the BASF House

Set of plans of the BASF House provided by Derek Trowell Architects to the author in 2008:

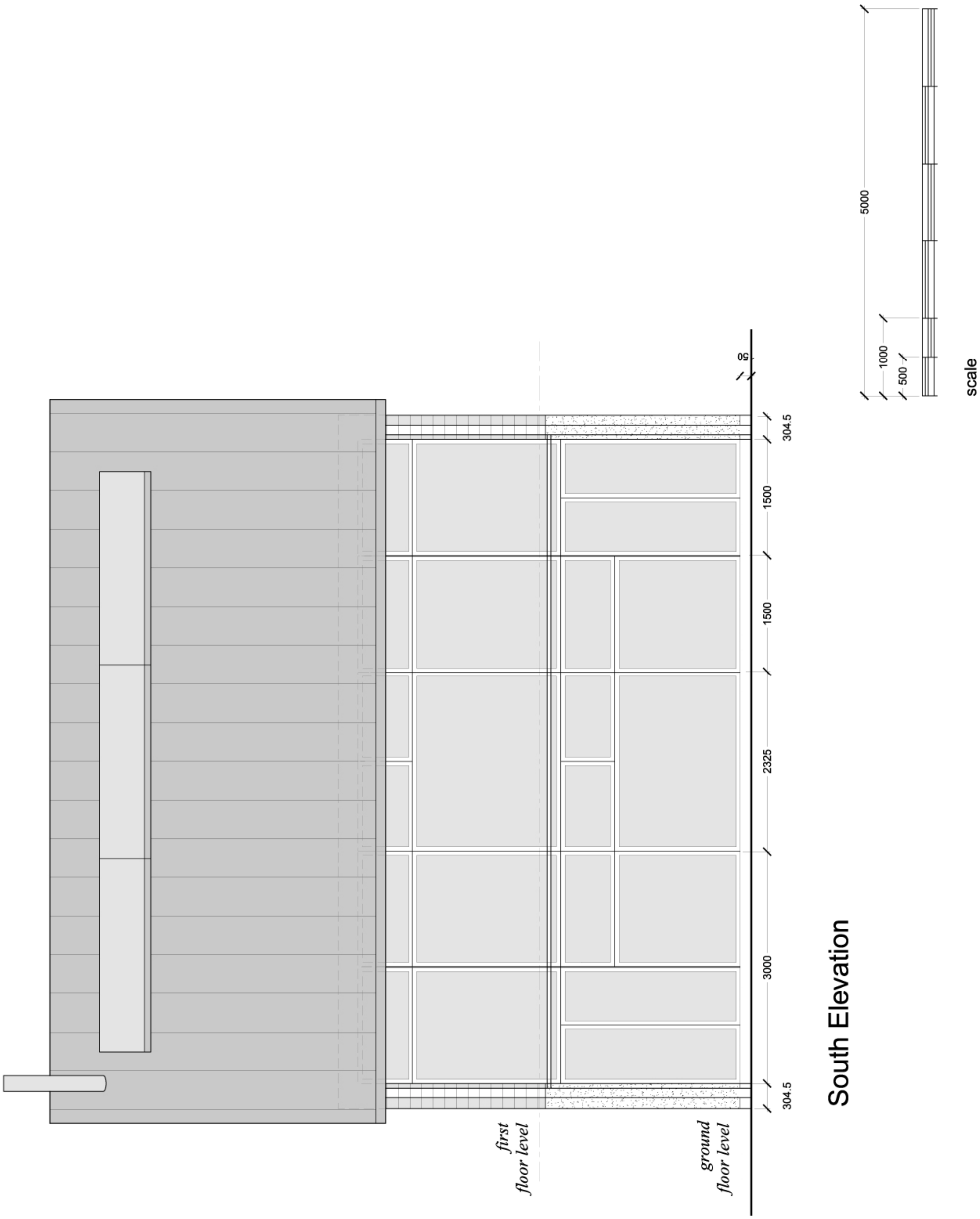
- Ground floor plan
- First floor plan
- North elevation
- South elevation
- East elevation
- Section, structure and walls types
- Ground floor and groundworks plans



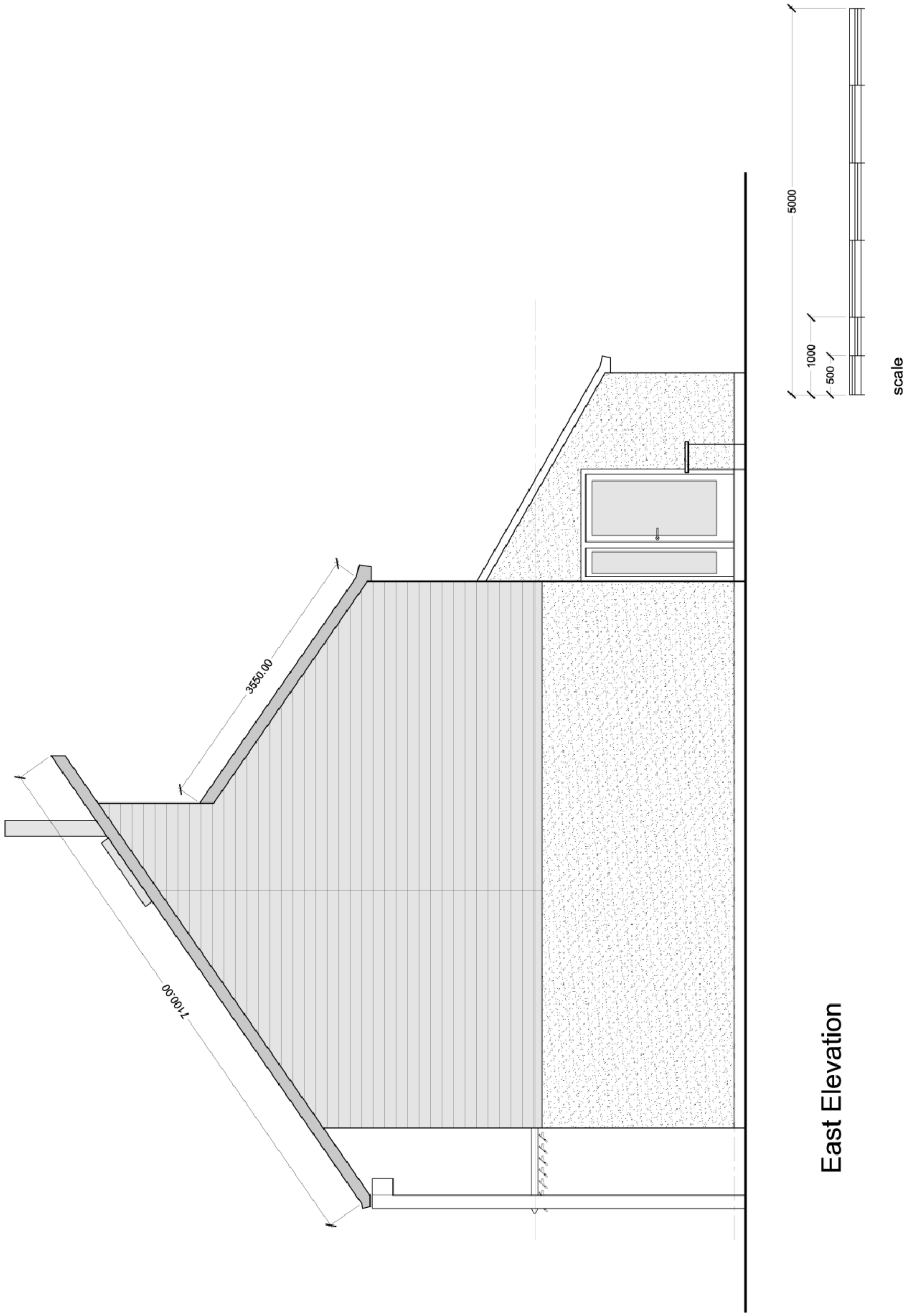
First Floor Plan

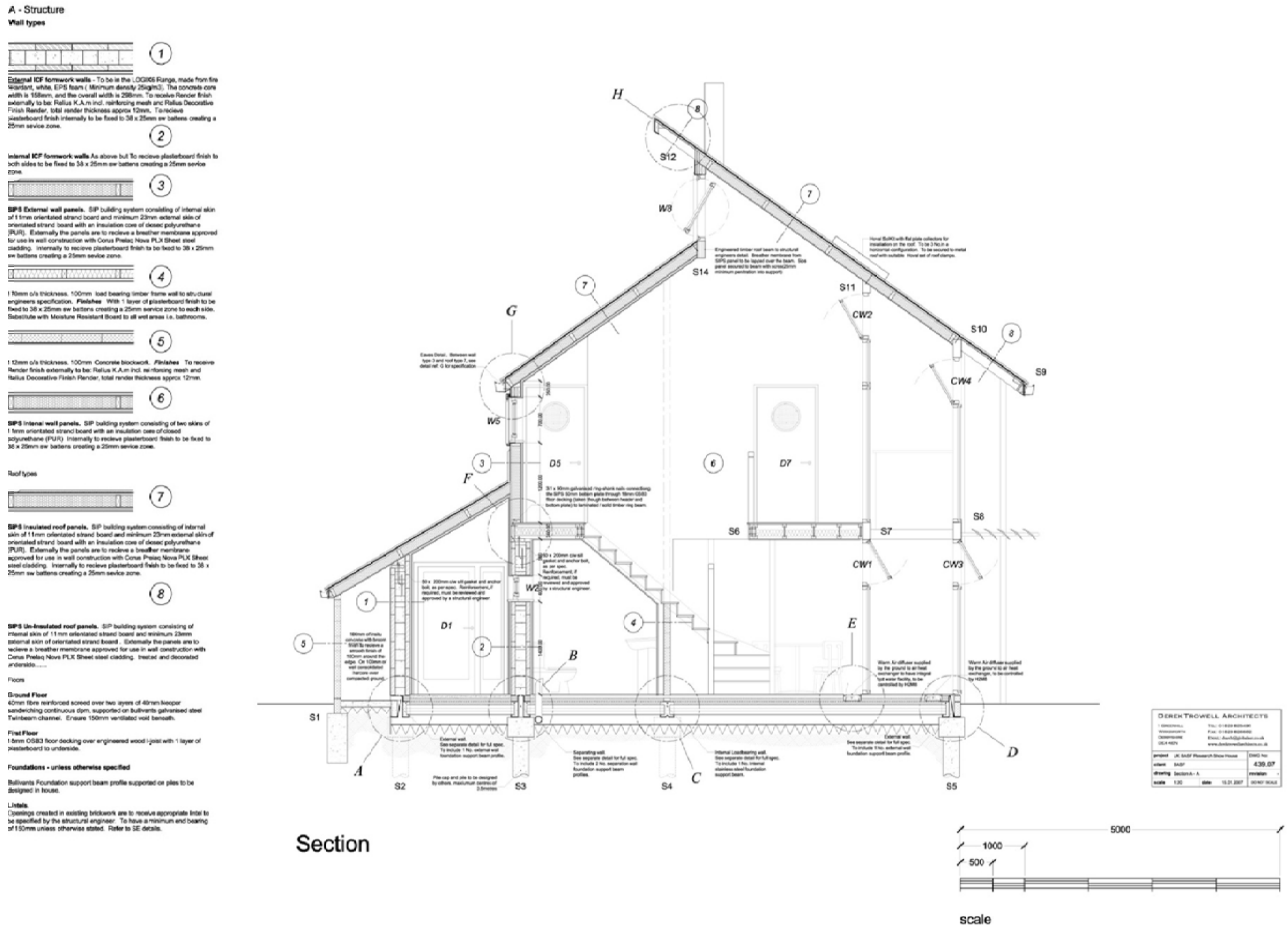
Ground Floor Plan

North Elevation



South Elevation


3550.00
7100.00
5000
1000
500
scale
East Elevation


A - Structure
Wall types
1
External ICF formwork walls - To be in the LOGIX66 Range, made from fire retardant, white, EPS foam (Minimum density 25kg/m3). The concrete core width is 158mm, and the overall width is 298mm. To receive Render finish externally to be: Relius K.A.m incl. reinforcing mesh and Relius Decorative Finish Render, total render thickness approx 12mm. To recieve plasterboard finish internally to be fixed to 38 x 25mm sw battens creating a 25mm service zone.
2
Internal ICF formwork walls As above but To recieve plasterboard finish to both sides to be fixed to 38 x 25mm sw battens creating a 25mm service zone.
3
SIPS External wall panels. SIP building system consisting of internal skin of 11mm orientated strand board and minimum 23mm external skin of orientated strand board with an insulation core of closed polyurethane (PUR). Externally the panels are to recieve a breather membrane approved for use in wall construction with Corus Prelaq Nova PLX Sheet steel cladding. Internally to recieve plasterboard finish to be fixed to 38 x 25mm sw battens creating a 25mm sevice zone.
4
170mm o/s thickness. 100mm load bearing timber frame wall to structural engineers specification. Finishes With 1 layer of plasterboard finish to be fixed to 38 x 25mm sw battens creating a 25mm service zone to each side. Substitute with Moisture Resistant Board to all wet areas i.e. bathrooms.
5
112mm o/s thickness. 100mm Concrete blockwork. Finishes To receive Render finish externally to be: Relius K.A.m incl. reinforcing mesh and Relius Decorative Finish Render, total render thickness approx 12mm.
6
SIPS Intenal wall panels. SIP building system consisting of two skins of 11mm orientated strand board with an insulation core of closed polyurethane (PUR) Internally to recieve plasterboard finish to be fixed to 38 x 25mm sw battens creating a 25mm service zone.
Roof types
7
SIPS Insulated roof panels. SIP building system consisting of internal skin of 11mm orientated strand board and minimum 23mm external skin of orientated strand board with an insulation core of closed polyurethane (PUR). Externally the panels are to recieve a breather membrane approved for use in wall construction with Corus Prelaq Nova PLX Sheet steel cladding. Internally to recieve plasterboard finish to be fixed to 38 x 25mm sw battens creating a 25mm sevice zone.
8
SIPS Un-insulated roof panels. SIP building system consisting of internal skin of 11 mm orientated strand board and minimum 23mm external skin of orientated strand board . Externally the panels are to recieve a breather membrane approved for use in wall construction with Corus Prelaq Nova PLX Sheet steel cladding. treated and decorated underside......
Floors
Ground Floor
40mm fibre reinforced screed over two layers of 40mm Isoper sandwiching continuous dpm, supported on Bullivants galvanised steel Twinbeam channel. Ensure 150mm ventilated void beneath.
First Floor
18mm OSB3 floor decking over engineered wood I-joist with 1 layer of plasterboard to underside.
Foundations - unless otherwise specified
Bullivants Foundation support beam profile supported on piles to be designed in house.
Lintels
Openings created in existing brickwork are to receive appropriate lintel to be specified by the structural engineer. To have a minimum end bearing of 150mm unless otherwise stated. Refer to SE details.
H
S12
W3
S14
G
W5
D5
F
D1
W2
B
E
D7
S6
S7
S8
S11
CW2
CW1
CW3
CW4
S10
S9
S1
S2
S3
S4
S5
A
C
D
Section
DEREK TROWELL ARCHITECTS
439.07
5000
1000
500
scale

Appendix 16 Image of the EPC

Image of the Energy Performance Certificate (EPC) obtained after the Standard Assessment Procedure (SAP) calculation for the BASF House, to comply with the Code for Sustainable Homes (CSH) of the UK Building Regulations from pages 1 to 5.

Energy Performance Certificate

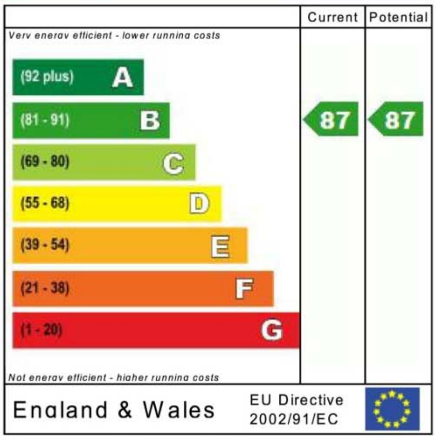
SAP
© Crown copyright 2005

6 Green Close
NOTTINGHAM
NG7 6QB

Dwelling type:	Detached house
Date of assessment:	11 June 2008
Date of certificate:	12 June 2008
Reference number:	8801-4394-9820-1196-0683
Total floor area:	116 m²

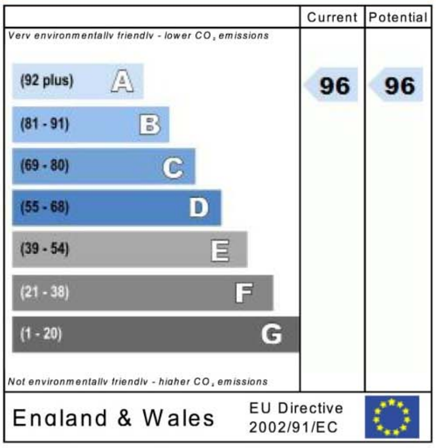
This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

Energy Efficiency Rating



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills are likely to be.

Environmental Impact (CO_2) Rating



The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy use	104 kWh/m² per year	104 kWh/m² per year
Carbon dioxide emissions	0.5 tonnes per year	0.5 tonnes per year
Lighting	£50 per year	£50 per year
Heating	£155 per year	£155 per year
Hot water	£44 per year	£44 per year

Based on standardised assumptions about occupancy, heating patterns and geographical location, the above table provides an indication of how much it will cost to provide lighting, heating and hot water to this home. The fuel costs only take into account the cost of fuel and not any associated service, maintenance or safety inspection. This certificate has been provided for comparative purposes only and enables one home to be compared with another. Always check the date the certificate was issued, because fuel prices can increase over time and energy saving recommendations will evolve.

energy saving recommended
Certification mark

Remember to look for the energy saving recommended logo when buying energy-efficient products. It's a quick and easy way to identify the most energy-efficient products on the market.

For advice on how to take action and to find out about offers available to help make your home more energy efficient, call **0800 512 012** or visit **www.energysavingtrust.org.uk/myhome**

About this document

The Energy Performance Certificate for this dwelling was produced following an energy assessment undertaken by a qualified assessor, accredited by the NHER Accreditation Scheme, to a scheme authorised by the Government. This certificate was produced using the SAP 2005 assessment methodology and has been produced under the Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations 2007 as amended. A copy of the certificate has been lodged on a national register.

Assessor's accreditation number:	NHER003540
Assessor's name:	Mr Don Howard
Company name/trading name:	Energist UK Ltd
Address:	Energist House, Kemble Enterprise Park, Kemble Airfield, Gloucestershire, GL7 6BQ
Phone number:	08458 386 387
Fax number:	
E-mail address:	fionab@energistuk.co.uk

If you have a complaint or wish to confirm that the certificate is genuine

Details of the assessor and the relevant accreditation scheme are as above. You can get contact details of the accreditation scheme from their website at www.nher.co.uk together with details of their procedures for confirming authenticity of a certificate and for making a complaint.

About the building's performance ratings

The ratings on the certificate provide a measure of the building's overall energy efficiency and its environmental impact, calculated in accordance with a national methodology that takes into account factors such as insulation, heating and hot water systems, ventilation and fuels used. The average Energy Efficiency Rating for a dwelling in England and Wales is band E (rating 46).

Not all buildings are used in the same way, so energy ratings use 'standard occupancy' assumptions which may be different from the specific way you use your home. Different methods of calculation are used for homes and for other buildings. Details can be found at www.communities.gov.uk/epbd.

Buildings that are more energy efficient use less energy, save money and help protect the environment. A building with a rating of 100 would cost almost nothing to heat and light and would cause almost no carbon emissions. The potential ratings in the certificate describe how close this building could get to 100 if all the cost effective recommended improvements were implemented.

About the impact of buildings on the environment

One of the biggest contributors to global warming is carbon dioxide. The way we use energy in buildings causes emissions of carbon. The energy we use for heating, lighting and power in homes produces over a quarter of the UK's carbon dioxide emissions and other buildings produce a further one-sixth.

The average household causes about 6 tonnes of carbon dioxide every year. Adopting the recommendations in this report can reduce emissions and protect the environment. You could reduce emissions even more by switching to renewable energy sources. In addition there are many simple everyday measures that will save money, improve comfort and reduce the impact on the environment. Some examples are given at the end of this report.

Visit the Government's website at www.communities.gov.uk/epbd to:

- Find out how to confirm the authenticity of an energy performance certificate
- Find how to make a complaint about a certificate or the assessor who produced it
- Learn more about the national register where this certificate has been lodged
- Learn more about energy efficiency and reducing energy consumption

About this document

The Enerav Performance Certificate for this dwellina was produced followina an enerav assessment undertaken bv a aualified assessor. accredited bv the NHER Accreditation Scheme. to a scheme authorised bv the Government. This certificate was produced usina the SAP 2005 assessment methodoloav and has been produced under the Enerav Performance of Buildinas (Certificates and Inspections) (Enaland and Wales) Reaulations 2007 as amended. A copv of the certificate has been lodaed on a national reaister.

Assessor's accreditation number:	NHER003540
Assessor's name:	Mr Don Howard
Companv name/tradina name:	Eneraist UK Ltd
Address:	Eneraist House. Kemble Enterprise Park. Kemble Airfield. Gloucestershire. GL7 6BQ
Phone number:	08458 386 387
Fax number:	
E-mail address:	fionab@eneraistuk.co.uk

If vou have a complaint or wish to confirm that the certificate is aenuine

Details of the assessor and the relevant accreditation scheme are as above. You can aet contact details of the accreditation scheme from their website at www.nher.co.uk toaether with details of their procedures for confirmina authenticitv of a certificate and for makina a complaint.

About the buildina's performance ratinas

The ratinas on the certificate provide a measure of the buildina's overall enerav efficiencv and its environmental impact. calculated in accordance with a national methodoloav that takes into account factors such as insulation. heatina and hot water svstems. ventilation and fuels used. The averaae Enerav Efficiencv Ratina for a dwellina in Enaland and Wales is band E (ratina 46).

Not all buildinas are used in the same wav. so enerav ratinas use 'standard occupancv' assumptions which mav be different from the specific wav vou use vour home. Different methods of calculation are used for homes and for other buildinas. Details can be found at www.communities.aov.uk/epbd.

Buildinas that are more enerav efficient use less enerav. save monev and help protect the environment. A buildina with a ratina of 100 would cost almost nothina to heat and liaht and would cause almost no carbon emissions. The potential ratinas in the certificate describe how close this buildina could aet to 100 if all the cost effective recommended improvements were implemented.

About the impact of buildinas on the environment

One of the biaaest contributors to alobal warmina is carbon dioxide. The wav we use enerav in buildinas causes emissions of carbon. The enerav we use for heatina. liahtina and power in homes produces over a auarter of the UK's carbon dioxide emissions and other buildinas produce a further one-sixth.

The averaae household causes about 6 tonnes of carbon dioxide everv vear. Adoptina the recommendations in this report can reduce emissions and protect the environment. You could reduce emissions even more bv switchina to renewable enerav sources. In addition there are manv simple evervdav measures that will save monev. improve comfort and reduce the impact on the environment. Some examples are aiven at the end of this report.

Visit the Government's website at www.communities.aov.uk/epbd to:

- Find out how to confirm the authenticitv of an enerav performance certificate
- Find how to make a complaint about a certificate or the assessor who produced it
- Learn more about the national reaister where this certificate has been lodaed
- Learn more about enerav efficiencv and reducina enerav consumption

Recommendations

None.

Further measures to achieve even hiaher standards

The further measures listed below should be considered in addition to those alreadv specified if aimina for the hiahest possible standards for this home. However vou should check the conditions in anv covenants. planning conditions. warranties or sale contracts.

1 Solar photovoltaic panels. 2.5 kWp	£144	A 95	A 103
Enhanced enerav efficiencv ratina		**A 95**	
Enhanced environmental impact (CO_2) ratina			**A 103**

Improvements to the enerav efficiencv and environmental impact ratinas will usuallv be in step with each other. However. thev can sometimes diverae because reduced enerav costs are not alwavs accompanied bv a reduction in carbon dioxide (CO_2) emissions.

About the cost effective measures to improve this home's performance ratinas

Not applicable.

About the further measures to achieve even hiaher standards

Further measures that could deliver even hiaher standards for this home. You should check the conditions in anv covenants. plannina conditions. warranties or sale contracts before undertakina anv of these measures.

1 Solar photovoltaic (PV) panels
A solar PV svstem is one which converts liaht directlv into electricitv via panels placed on the roof with no waste and no emissions. This electricitv is used throuahout the home in the same wav as the electricitv purchased from an enerav supplier. The British Photovoltic Association has up-to-date information on local installers who are qualified electricians and anv arant that mav be available. Plannina restrictions mav applv in certain neiahbourhoods and vou should check this with the local authoritv. Buildina Reaulations applv to this work. so vour local authoritv buildina control department should be informed. unless the installer is appropriatelv qualified and reaistered as such with a competent persons scheme[1]. and can therefore self-certifv the work for Buildina Reaulation compliance.

What can I do todav?

Actions that will save monev and reduce the impact of vour home on the environment include:

- Ensure that vou understand the dwellina and how its enerav svstems are intended to work so as to obtain the maximum benefit in terms of reducina enerav use and CO_2 emissions. The papers vou are aiven bv the builder and the warrantv provider will help vou in this.
- Check that vour heatina svstem thermostat is not set too hiah (in a home. 21°C in the livina room is suaaested) and use the timer to ensure vou onlv heat the buildina when necessarv.
- Make sure vour hot water is not too hot - a cvlinder thermostat need not normallv be hiaher than 60°C.
- Turn off liahts when not needed and do not leave appliances on standbv. Remember not to leave charaers (e.a. for mobile phones) turned on when vou are not usina them.
- Close vour curtains at niaht to reduce heat escapina throuah the windows.
- If vou're not fillina up the washina machine. tumble drver or dishwasher. use the half-load or economv proaramme.

[1] For information on approved competent persons schemes enter "existina competent person schemes" into an internet search enaine or contact vour local Enerav Savina Trust advice centre on 0800 512 012.

Appendix 17 A review on the Upton homes project and the rural ZED, under the scope of this study

The Upton Homes project, a large-scale residential development located in Upton Meadows, Northampton was a real remarkable one in regard to sustainability. It captures much media attention and much expectation for being one of the biggest urban "sustainable" development proposals for the time in the UK. Upton is part of the south-west district of Northampton, and is located also to the south-west of the city of Northampton (figure 80). It has an area of 44 ha approximately and the Upton homes project built over 1,100 new homes on the area that was previously a green field site.

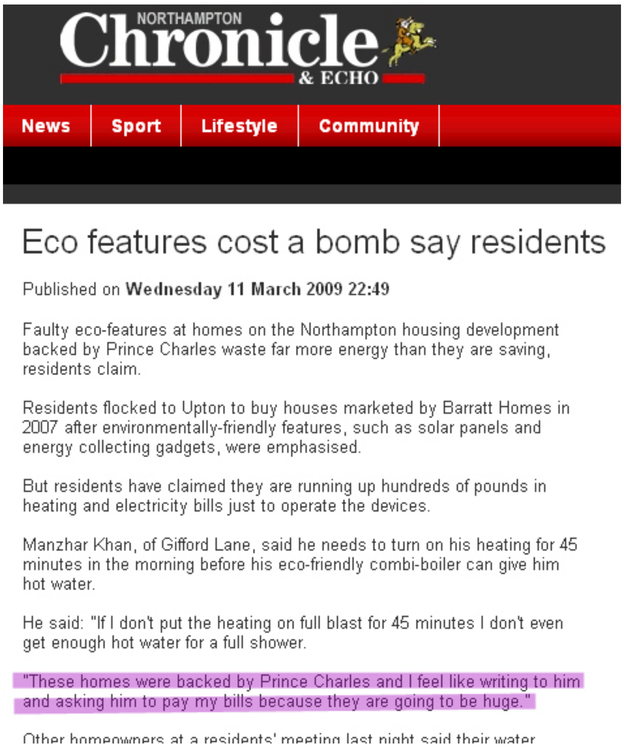
A very remarkable milestone was the creation of the Upton Code, which first edition was published in spring on 2003, followed by a revised version in March 2005. These two versions of the Upton Code were the supplementary planning guidance for the Upton development. They included all the changes and additions that were occurring with the UK codes and Building Regulations, therefore when the Upton homes project started the construction, it was required to comply with CABE 2004 and the BREEAM standards with its three levels of approval (Ecohome, Ecohome Good and Ecohome Excellent), in 2004 the Upton homes project received the status of Ecohome Excellent. Later in 2006 the revised version of the UK code, the Code for Sustainable Homes (CSH) became the new requirements that the project needed to respond to, then the majority of the homes built in 2007 complied with the different levels of the CSH and the current legislation.

Several of the articles published on regard to Upton homes has made echo of the research question of this thesis, which was exactly what the author intended to address on the different parts of the study. The Northampton Chronicle and Echo published in 2002 the environmental reporter Angela Pownall quoted Prince of Wales in regard to the proposal of over 1000 new sustainable homes:

> "a national and flagship example of best planning process with a design that is imaginative, land efficient and sustainable".

Since then a vast number of articles on this development have been published, journalists have gathered positives and negatives comments from the public and specialists, for example on June 2005 an article with a title "Village with Royal approval" describing the coming opening of the first buildings to be revealed to the public and announcing the visionary design techniques and sustainable features of the new homes. In March 11th 2009, the article "Eco features cost a bomb say residents" (figure 103) comments from first buyers were published, highlighting a quote of a homeowner:

> "These homes were backed by Prince Charles and I feel like writing to him and asking him to pay my bills because they are going to be huge" (Resident Manzahar Kahn).



NORTHAMPTON Chronicle & ECHO

News | Sport | Lifestyle | Community

Eco features cost a bomb say residents

Published on **Wednesday 11 March 2009 22:49**

Faulty eco-features at homes on the Northampton housing development backed by Prince Charles waste far more energy than they are saving, residents claim.

Residents flocked to Upton to buy houses marketed by Barratt Homes in 2007 after environmentally-friendly features, such as solar panels and energy collecting gadgets, were emphasised.

But residents have claimed they are running up hundreds of pounds in heating and electricity bills just to operate the devices.

Manzhar Khan, of Gifford Lane, said he needs to turn on his heating for 45 minutes in the morning before his eco-friendly combi-boiler can give him hot water.

He said: "If I don't put the heating on full blast for 45 minutes I don't even get enough hot water for a full shower.

"These homes were backed by Prince Charles and I feel like writing to him and asking him to pay my bills because they are going to be huge."

Other homeowners at a residents' meeting last night said their water

Figure 103 Article from The Northampton Chronicle and Echo. Source: http://www.northamptonchron.co.uk.

The Upton Project, Northampton

The city of Northampton was seen as the area for urban expansion. Strategically dense residential development was feasible given the fact Northampton; the south area within the East Midlands region was identified as one with the highest population and employment rate.

Upton is part of the south-west district of Northampton, and is located also to the south-west of the city of Northampton (figure 80). It has an area of 44 ha approximately and the Upton homes project built over 1,100 new homes on the area that was previously a green field site.

Upton in Northampton was originally farming land that was later acquired by the Northampton Development Corporation. In 1985 the Upton site passed to the Commission for New Towns. In 1997 Upton obtained the planning permission to develop a sustainable urban expansion. Then, in 2003 a new association formed among English Partnerships, Northampton Borough Council (NBC) and The Princes Foundation, the proposal went through new additions and changes, as a result a variation to planning permission was added and the updated permission was granted. Previously to the 2003' planning permission, in 2001 the association hosted a public consultation, 'Enquire by Design', presenting a revised version of a development framework plan. This plan promoted a high quality sustainable urban extension for residential use and services for the community as well as commercial fringe located along the main boundary road to the north of the site, Weedon Road, shown on the masterplan image after next page[17].

A very remarkable milestone was the creation of the Upton Code, which first edition was published in spring on 2003, followed by a revised version in March 2005. These two versions of the Upton Code were the supplementary planning guidance for the Upton development. They included all the changes and additions that were occurring with the UK codes and Building Regulations, therefore when the Upton homes project started the construction, it was required to comply with CABE 2004 and the BREEAM standards with its three levels of approval (Ecohome, Ecohome Good and Ecohome Excellent), in 2004 the Upton homes project received the status of Ecohome Excellent. Later in 2006 the revised version of the UK code, the Code for Sustainable Homes (CSH) became the new requirements that the project needed to respond to, then the majority of the homes built in 2007 complied with the different levels of the CSH and the current legislation.

This Urban Framework Plan for Upton led by EDAW as the consultant firm along with the partnership mentioned above produced a masterplan interpretation (figure 95), which was the origin of the Upton homes. The scheme proposed was very successful and some of the remarkable features were related to the insistence on high standards and strong commitment to create an exemplary sustainable and energy efficient community.

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[17] http://collections.europarchive.org/tna/20100911035042/http://englishpartnerships.co.uk/upton.htm

The expectations from the project were the capability to demonstrate how large-scale developments can incorporate best practice and sustainable principles of urban growth. It was also established that the design strategies contemplate conventional forms of housing to meet the expectations of homebuyers (EST, 2006) [18]. Other very important feature was that the project included a variety of ownerships depending on their socio-economical profiles, and the development should consider about a 22% of social and affordable housing; from the social perspective this feature is a very sensitive one, it prevents social segregation and it makes more inclusive and democratic communities.

The project contemplated different sizes of dwellings from 1 to 5 bedrooms, the heights of the project were also regulated depending on the area; from 2 to 2,5 storeys and 2,5 to 3,5 storeys, with maximum of 3 storeys. The density varied depending on four established character areas within the terrace aspect, going from low to high density; detached, semi detached, town, mews, flats and mix-use homes. A highly sustainable feature for a large–scale the Upton project included was a sustainable urban drainage system (SUDS) that intends to reproduce the same patterns of flow a natural drainage in a given terrain, in this way the system will prevent flood risk and will slow the water drainage. As it can be observed in the picture (figure 104) the SUDS also is a landscape feature to beautify the development with small streams, small lakes and ponds, which add to the biodiversity (EST, 2006).

[18] Creating a sustainable urban extension – a case study of Upton, Northampton. Energy Saving Trust, 2006 edition (need to be included in the bibliography)

Figure 104 Sustainable Urban Drainage System (SUDS) in Upton homes project.

By October of 2007 244 homes were completed, leaving Sites F and G, these sites had an area of 6.019 ha that were the last portion of land to be developed in Upton. For these sites the masterplan indicated that 375 new homes and mixed use commercial area were planned to be built. They were marketed to the several of the UK homebuilder companies. The masterplan stipulated the following square meter distribution:

· 375 homes - 88 of which will be affordable pepper-potted throughout the development, 10 units will be live/work, and 40 units will be first time buyers initiative (FTBI).
· 380 m² convenience store
· 620 m² of small retail units
· Public house
· Approximately 3,200 m² office space
· Cafe/restaurant - 450 m²
· 70 place children's day nursery" [19]

In accordance with the project aspirations, in May 2009 "World Class Cities" published that Upton was one of the few case studies constructed in the UK as an example of a successful application of sustainable urban extension principles, were Research and Development (RD)

[19] http://collections.europarchive.org/tna/20100911035042/http://englishpartnerships.co.uk/upton.htm

approaches brings up a tangible result. On the same year the Upton project received the 2009 Sustainable Development of the Year Award (projects under £2million) granted by the UK Green Building Council.

The Upton project was expected to be built in eight years, it was divided on eight sites or developing areas (figure 17), most of them are completed, however during the study the project was still under construction (winter 2010). As the project continues its development, several housing developers and design firms have taken part of this sustainable urban expansion. For all the sites needed to comply with the energy and environmental requirements and regulations for new residential use. As it has been mentioned, when the project began in 2003 the selected developers had to respond to BREEAM/EcoHomes Excellent, NHER rating 10, with the exception of site A, all the other housing sites (B, D1, D2 and E) were required to include passive solar design, solar water heating and rain water harvesting and had to consider a determined number of units that were going to be demonstration projects including sustainable energy technologies Also as the sites were being developed and built, the demand to implement more systems was higher. After 2007, all the new homes needed to comply with the Code for Sustainable Homes (CSH) voluntarily, except with the elements of the CSH that are included in Part L of the UK Building Regulations; some of them within the Upton project were designed to be Code Level 6.

Demonstration homes in Upton

An example of Code Level 6 certified units and Upton demonstration homes were the one designed by the ZED Factory Ltd. They obtained the certification on December 2008. The project was called RuralZED, consisting of a terrace of six 3-bedroom housing, fast to construct and affordable homes of 100 m² approximately on two storeys of 44 m² each, plus a 14 m² of a south facing sunspace and shading device (Figure 107, number 1 and 2) as part of the passive design feature (Figure 105). Beside the sunspace, other passive design features that RuralZED needed to provide, given the UDC requirements and the own ZED homes specifications for the site D1.

Figure 105 Upton RuralZED demonstration homes before the swift wind turbines were removed.

Specification for the Upton RuralZED demonstration homes

Passive Design Strategies (PDS) and Sustainable Energy Technologies (SET):

· **Sunspace and shading devices** (Figure 107, number 1 and 2)

For the Upton RuralZED homes the sunspace are orientated to south to have the best exposition to natural daylight and maximum solar radiation absorption. They also include an external fixed shading device to prevent overheating and block solar radiation during the hottest days in summertime. The conservatories are facing a main street; however they have a curtain system for occupants to use them as private extra external and storage space when they need it.

· **High level of insulation**

All windows are triple glazed windows. The U values for windows was 1.24 W/m² °C, for walls 300 mm of super insulation gives a U value that varies between 0.12, 0.14 and 0.18 W/m² °C, for the ground floor and the roof 0.12 W/m² °C.

The air permeability value calculated for these homes after the pressurisation test was 3 m³/hr m² at 50 pascals (Pa) and the expected dwelling emission rate of -15.04kg CO2/m2/a.

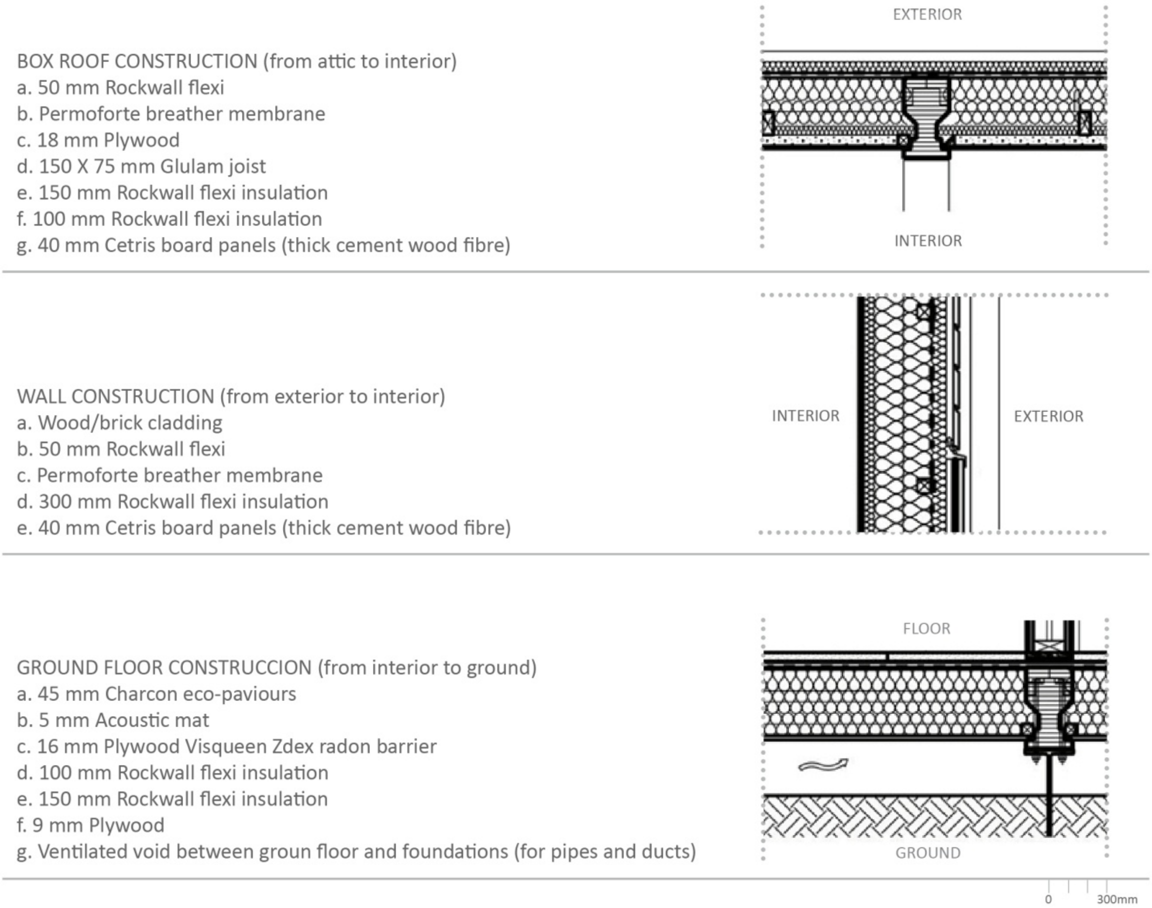


Figure 106 Typical construction details of ceiling, wall, ground floor of the RuralZED homes in Upton.

· **Green Roof** (Figure 107, number 3)

The Sedum Roofing has the purpose of reducing the surface of permeable ground available to absorb rainwater runoff. A green roof like the sedum one is able to retain a very high percentage of rainwater and provide slow and controlled water runoff, in this way it reduces the load on the drainage system and helps the evaporation of accumulated moisture. The green roof also helps the thermal performance of homes, it provides additional insulation to reduce heating loss in wintertime and it helps cooling down in warm seasons by reducing heat absorption.

· **Solar photovoltaic (PV) system** (Figure 107, number 4)

Each of the six homes has a high performance PV modules made of monocrystalline silicon solar cells (1.55 m²) with module efficiency of up to 14.1% from Sharp. The two PV modules of the end of the terrace homes are slightly different in regard to capacity from the ones of the four homes located in between these two. The differences in specification are listed in the following table 32.

Table 32 PV installation specification for the Upton RuralZED homes

Upton RuralZED terrace	**End homes – 2 units**	**Centre homes – 4**
Number of PV panels module	20 panels Sharp NU-	18 panels Sharp NU-
Surface area of array	27 m²	24 m²
Total peak DC power	3.6 kilowatts	3.24 kilowatts
Estimated annual energy	2,880 kWh (of	2,590 kWh (of
Inverters	1 Fronius IG40	1 Fronius IG30
DC Isolator	All 6 modules have 1 ABB 750V DC32A	
kWh Generation meter	All 6 modules have 1 Elster A 100C kWh meter	

* Standard Test Conditions (STC). Source: Chelsfield Solar PV System O&M manual for Upton Village, 2006

The PV system installation in Upton has dual supply (DC and AC) and it is connected to the grid, which implies that the AC outputs from it are connected to the homes' AC distribution system in parallel with the main grid supply. In case the grid is unavailable the PV system stops generating AC power.

· **Heat exchange wind driven ventilation system** (Figure 100, number 5)

To secure high and healthy internal air quality in a super insulated home a good ventilation system is required; considering that many of the typical ventilation system are in charge of about 50% of the heat loss. Most of ZED homes use this type of wind driven ventilation system with heat recovery to draw fresh air into the building, while exhausting the used, stale air out of the home. The heating exchange process then occurs by transferring the heat of the used air to warm up the fresh incoming air without combining them, through an efficient heat recovery unit. This heat exchanger in the wind driven ventilation system recovers between 50% and 70% of the warmth from the outgoing stale air. All the rooms in the home have a pair of ducts to extract and supply the outgoing and incoming air respectively.

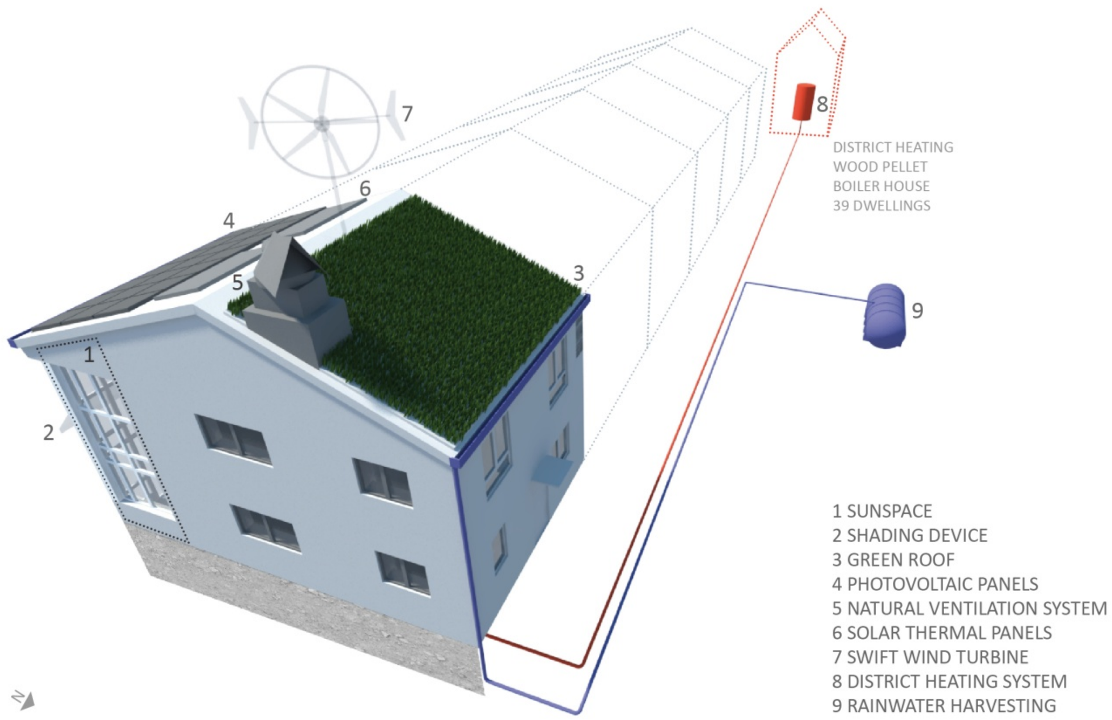


Figure 107 Upton RuralZED demonstration home scheme depicting the passive design strategies and the sustainable energy technologies implemented.

· **Solar thermal panels** (Figure 107, number 6) and

· **District heating wood pellet boiler system** (Figure 107, number 8)

The district heating system was for 39 dwellings of the Upton homes, including the six RuralZED demonstration homes and five of the ten studied homes, is provided by HERZ, the Firematic BioControl Boiler 90-150 kW that works with wood chips and pellets, the heating mains rise into the boiler house and it is distributed to the 39 homes through an underground district heating pipe work, the grid is protected with rigid insulation, which is protected by black HDPE (high density polyethylene pipe) casing. The system controls the complete home energy supply for water and space heating. The system comprises of the wood pellet boiler, a 5000 L buffer tank, a 425 L expansion tank and a pallet store with a wood pellet supply auger. The boiler house should allow capacity for storage of fuel for a whole year, and for the installation of a fuel transport system, which is electronically monitored. The system has a central control system, HERZ BioControl 3000, for operation, maintenance and supervision; it also has a weather compensator to regulate the heating depending on the exterior temperature. Each of the 39 homes then has their individual cylinder cupboard of 350 L capacity with a domestic heating pump DC motor with inverter, from which the heat for domestic hot water and space heating (through radiators) is distributed into the different rooms.

For the system configuration of the hot water storage with solar usage, as the six RuralZED demonstration homes the buffer storage tank utilises the solar energy from the solar collector panels, two HERZ solarkollector panels of 1 m² each per home, to provide supplementary domestic hot water. When the solar radiation is not enough to cover the domestic hot water demand, the heat is then supplied from the buffer storage tank from the district heating. For the space heating the heat is always supplied by the buffer storage tank. The output range of the system is between 45-150 kW.

· **Rainwater collection system** (Figure 107, number 9)

The rainwater harvesting system for the RuralZED terrace homes is a very simple concept; collects rainwater from the roofs, filters it, stores it and uses it for all the non-potable water needs, like flushing the toilet, watering plants, washing clothes for example. It comprises a tank of 7500 L capacity located underground at nine meters approximately from the north façade of the terrace in front of the backyards of the six homes, almost equidistant from the two end homes. It has a ladder access chamber required for maintenance of the tank and ancillaries. It also has another chamber for the leaf filter, ECVLE-VF1 with an adjacent manhole collector for all the rainwater to supply the leaf filter chamber. The rain water from the roofs is draw to the common filter-collector chamber through underground pipes connected to pairs of overflow gullies located adjacent to water butt with 110 mm Ø drainpipes. For every pair of homes there are two overflow collection manholes connected into the rainwater downpipes system to the harvesting tank. Finally to bring the filtered water to homes, the tank is connected to the rainwater harvesting supply pipework chamber passing through the electrical duct to the plant room (boiler house) to connect onto existing electrical ducts to have a constant run into homes.

Originally four of the RuralZED terrace homes included a micro generation **swift wind turbines** (Figure 105-107, number 7); four for the six homes, which were removed before the homes were occupied because of the vibration they produced when running; they are it is still visible on 3D Google Earth page. They were installed following the specifications of a minimum distance from the roofline of 2 feet. The turbine size is 7 feet of the blade ring diameter and the noise was supposed to be less than 35 decibels for all wind speeds. The swift turbines are designed for micro generation of electricity in urban and suburban settings, the turbines are grid connected and the electricity they generate is supplementary and it used first to the electricity from the supplier. The rated power output is 1.5 kW at 14 m/seg. The annual power supply is up to 2,000 kWh and the electric power of 240VAC, 60Hz of output voltage.

Appendix 18 Evaluation of the energy meters for study "smart meters, energy matters"

As it is shown in table 33 on next page the most expensive energy meter was the Wattson, it seems that the cost was related to its design, among the four chosen energy meters this was the only one that uses a colour code system to inform the energy usage, which could be displayed in kilowatts (kW), in CO_2 emissions, an instant projection of the annual cost (£, € and US$), the different colours indicated low, medium or high consumption, it was much bigger than all the others. The Wattson possesses a datalogger, therefore the samples the meter was taking could then be downloaded and analysed, the software gives all the information processed in graphs and spreadsheets and it offer to analyse it centrally by sending the results to the service the company offers, the data information for downloading shows additionally the amount of watts of energy the PV system was generated, however it could be a hassle to do the downloading process; especially if one is not too much into computers. Over all it was a simple device like an anvil as it can be seen on the following image (figure 108).

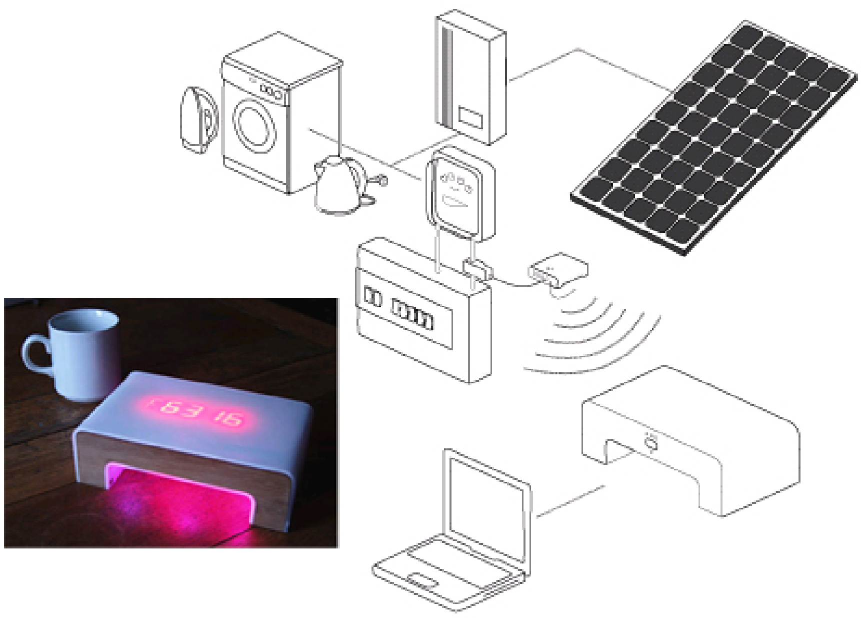
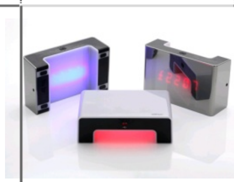


Figure 108 The Wattson energy meter with a scheme showing how it functions.

All the meters have similar features and functioned with the same principles, the clamps were to be connected to the home main electricity meter located outside of all the homes, the instant reading was the power being used at that precise moment in the homes, which could be shown in different ways on the display, depending on what the user wants to read.

However, these readings did not indicate specific appliance consumption, it was a global reading of electricity, therefore it was not possible to disaggregate between the total power use for all appliances, lighting, domestic hot water and space heating and cooling electricity. The fact that most of the homes for the set have boilers, it is assumed the electricity used for heating is really negligible, unless occupants used electrical heaters along with their central heating, which was not known.

Table 33 General descriptions of the real time energy meters: **price, data** and **display**

Features		WATTSON	OWL CM119	ENVI CC128	EFERGY ELITE
Picture					
Price		£ 90.- approx.	£ 30.- approx.	£ 50.- approx.	£ 40.- approx.
	Size of unit	10.5x17x5cm	10.7x11.7x3cm	9.3x12x15.5cm	10.6x7.8x3.2cm
	Digits shown	3	4	3	3
	Unit	kW	W or kW	W or kW	always kW
	Current cost	yes (in mode: annual approximation)	yes	yes	yes
	Current CO2 emission	(it calculates it)	yes	no	yes
	Energy supply	Internal rechargeable	battery or mains	mains	battery or mains
	Digital display	D	LCD	LCD	LCD
	Temperature	no	yes	yes	no
DISPLAY	Time/date	no	yes	yes	yes
	Memory	1 year	1 year and more	7 years	2 years
	Look up consumption	up to 4 weeks is saved, then it needs to be downloaded.	current and last day, week, month, quarterly, year adt	last 1, 7 or 30 days	last 7 days, 7 weeks, 12 months, 2 years
	Connection to PC	yes	no	yes	no
	Currency	£, $, €	£, $, €	£, €	£, $, €
	Location	standing (2 positions)	wall mounted or standing	standing	wall mounted or standing
	Batteries	Internal rechargeable	3 AA	Not considered	4 AA
	Battery life	up tp 6 month	up to 1 year	Not found	Not found

The tables, above and following ones, present an evaluation done previously to install the energy meters in the ten homes families volunteer for the trial of them. Table 33 contains the features related to price, data and display of the four devices, which are very important for occupants because is the way information about power usage is displayed to them, it is the immediate reading of electrical consumption; it seems that clarity and legibility for effective communication should be a desired characteristic, especially for a household with children, however it could be that certain occupants prefer very detailed information and especial gadget to interact or programme functions on the device, therefore the preferences and choices from occupant’s perspectives was surveyed with the questionnaires.

Three of the meters show up to two decimals, except for the Owl that shows three decimals. They all show the cost related to the current power, therefore cost and consumption of electricity are displayed at the same time for three meters but the Wattson; this feature was not to clear in the Wattson, since it shows at the same time the colour and the current consumption in Watt (W) or colour with cost of current consumption of power, but not the three features together, it was necessary to shake the device to change from cost of electricity to power consumption (W), and for the case of cost of electricity it shows an annual projection of the instant power consumption, i.e. if it happens that one reads the screen at the moment of boiling water with an electrical kettle or any high electricity demand of a white line device, the cost of the consumption rises up abruptly, the number look absurdly high until one realises it is a year projection, nonetheless, this aspect once learned it is an interesting feature, because a double information could be obtained out of it, occupants can start recognising which appliance consumes what, so it might make one wonders about replacing appliances that consumes outrageous amount of electricity that will cost user so much, it could make occupants to start comparing electrical demand and then associate that with the specifications of the device, so next buy could be more informed, at last it might develop awareness of how power is used at homes.

Figure 109 The Envi Current Cost energy meter with all its parts, showing all the information it displays.

Two of the meters shows the indoor temperature and three of them shows time, the only one that does not shows this information is the Wattson, however when the data is downloaded it obviously appear in the information, besides the Wattson, the Envi also has PC connection to review history. All of them have memory up to certain period and they have a way to show the history of electricity consumption of the household, but the Wattson does not display it as the others do on their screens. The Owl and the Efergy (Figure 110) have a similar amount of information displayed at a time, while the Envi (Figure 109) has so much information; it even has a bar's graph showing the history of the day consumption, while on the other extreme is the Wattson displaying the data in a very cryptic way that depending the mode one has it on, data needs to be decoded.

Figure 110 The Owl (left) and the Efergy Elite (right) energy meters showing all the information they typically display.

Table 34 portrays a continuation of the descriptions and comparisons among the energy meter's features, for this table covers three aspects related to the setup, clam and transmitter and how these two parts work; it is crucial for setting up the devices. The most complicated in regard to user manual of how to use the devices was the ENVI CC128, also the same meter has a very small, easy to break clamp. All of them have 3-phase where extra sensors could be installed, but for the Owl and the Efergy they were not included; it was necessary to buy them separated. When the meters are operating they indicate it with a blinking light or by colour, the Owl does not have this feature. The frequency of the transmission of the Owl was not found; it is probably within the range of the other three. They all have two additional inputs to add more clamps except for the Envi, and for the Owl this feature was very confusing to use, the inputs were uncovered while normally they are covered, because these inputs differs much from others in regard to what they are for. The transmitter of the Wattson is bulky and heavier compared to the other transmitters.

Table 34 Features and evaluation of the real time energy meters: setup, clamp and transmitter

Features		WATTSON	OWL CM119	ENVI CC128	EFERGY ELITE
Picture					
Price		£ 90.- approx.	£ 30.- approx.	£ 50.- approx.	£ 40.- approx.
SP	User manual	very useful	useful	alright	very useful
	Clamp	easy	medium	easy	easy
	Transmitter	easy	medium	easy	easy
CLAMP	Size	medium	medium	big	small
	Robust	yes	yes	yes	no
	Access to cable	medium	medium	medium	easy
	3-phase	yes	(need 2 extra sensors, each £10)	yes	(need 2 extra sensors, each £10)
	Cable width	3mm	10mm	12mm	12mm
TRANSMITTER	Size	11x8.4x2.6cm	7.8x11.3x4cm	12x7x3cm	Similar to Owl
	Mount on wall	not included	holes need to be drilled	via sticker	not included
	Light during operation	LED = 3 colours display	off	blinking	blinking
	Range indoor	30m	30m	30m	40-70m
	Batteries	4 AA	3 AA	2 D	2 AA
	Battery life	not found	up to 2 years	up to 7 years	not found
	Transmission frequency	3-20 seconds	6-30 seconds	6 seconds	6, 12 or 18 seconds
	Additionas	2	2 (uncoveed)	not inclued	2 (coverd)

Table 35 General aspects of the real time energy meters

Features		WATTSON	OWL CM119	ENVI CC128	EFERGY ELITE
OTHER ASPECTS	Different Tariffs	2	4	1	2
	Cost perkWh	fixed (at 13p/kWh)	manual setting	fixed (at12p/kWh)	manual setting
	Alrm	3 colours indicates electricity usage	Sound + blinking display	No	Red light + Sound; in kW
	Cannels	4	3	10	1
	ccuracy	not found	within 5%	not found	7.5 - 12.5%
	Total Batteries	4 AA batteries	6 AA batteries	2 D batteries	6 AA batteries

Some other evaluated and comparable aspects are described in the above table 35, the aspect in regard to base tariff and currency type is another important feature is meters are going to be flexible in regard to be used in other countries, otherwise they are limited to Europe and the United States solely. More restrictive than the currency is the fixed tariff.

Appendix 19 Upton homes questionnaires

Example of a completed 9-question questionnaire by one of the volunteers of Upton Homes, to evaluate energy meters individually distributed one per week during the study.

Questionnaire for the Smart Meter (SM) 1 - WATTSON

09.02.2009

1. How would you evaluate the Smart Meter your family tested: please tick one of the boxes from 1 = dislike to 5 = like

WATTSON - SM 1	1 (DISLIKE)	2	3	4	5 (LIKE)
Setup	☐	☐	☐	☐	☐
User Manual	☐	☐	☐	☐	☐
Clamp	☐	☐	☐	☐	☐
Safety	☐	☐	☐	☐	☐
Transmitter	☐	☐	☐	☐	☐
Clarity of the Display	☐	☐	☐	☐	☐
Energy Display (kWh)	☐	☐	☐	☐	☐
Cost Display (£)	☐	☐	☐	☐	☐
Design	☐	☐	☐	☐	☐
Colour Signal	☐	☐	☐	☐	☐
Size	☐	☐	☐	☐	☐
Mobility	☐	☐	☐	☐	☐
Historical Reading	☐	☐	☐	☐	☐

PC Connection	☐	☐	☐	☐	☐

2. Where did you locate the Smart Meter? Please tick where appropriated and specified if necessary.

Location	Tick	Specific Location
Kitchen		
Dining Room		
Living Room		
Circulation Area		
Bedroom		
Bathroom		
Study Room		
Other Room		

3. Did you locate the Smart Meter in a visible place for every member of the family to read it?

Yes ☐ No ☐

4. Did you use all the features the Smart Meter has? (Alarm, Historical Reading, etc.)

Yes ☐ No ☐ Don't know ☐

5. How often did you look at your consumption display on the Smart Meter per day?

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☐	☐	☐	☐

6. Did the Smart Meter have an impact on your energy consumption behaviour?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☐	☐	☐	☐

If YES how?

____

____

7. Did you look at your consumption display on the Smart Meter every day?

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☐	☐	☐	☐

8. Did you use the historical readings on the Smart Meter?

Yes ☐ No ☐

9. Did you connect the Smart Meter to your PC?

Yes ☐ No ☐

THANK YOU FOR COMPLETING THIS SURVEY.

5. How often did you look at your consumption display on the Smart Meter per day?

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☑	☐	☐	☐

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☐	☐	☑	☐	☐

If YES how? ____

____

____

7. Did you look at your consumption display on the Smart Meter every day?

ALL THE TIME	OFTEN	OCCASIONALLY	ONCE / TWICE	NEVER
☐	☐	☑	☐	☐

8. Did you use the historical readings on the Smart Meter?

Yes ☑ No ☐

9. Did you connect the Smart Meter to your PC?

Yes ☐ No ☑

THANK YOU FOR COMPLETING THIS SURVEY.

Example of a completed 13-question questionnaire by one of the volunteers of Upton Homes, to analyse the energy meter impact on resident's behaviour in regard to energy consumption, and compare the four different smart meters.

SHINE TRUE: General Smart Meter Questionnaire

SMART METERS – ENERGY MATTERS

"The UK government had already announced that it wanted all UK homes to have smart meters by 2020."

"The Department of Energy and Climate Change Wants to see 47 million meters in 26 million properties by 2020." (Moylan, BBC News, 2/12/2009).

SECTION A: General Smart Meter Evaluation

1. Where you aware of the intention of the UK government to implement Smart Meters, for gas and electricity, in the majority of homes in UK by 2020?

Yes ☐ No ☑

SECTION B: Smart Meter, Energy Consumption and Expectations

2. Do you think the use of a Smart Meter could influence your energy consumption habits?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

3. Do you think the use of a Smart Meter could change your life style?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

4. Do you think the use of a Smart Meter could change your awareness of the way you use energy?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☑	☐	☐	☐	☐

5. Do you think the use of a Smart Meter could help you to save money?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

6. Do you think the use of a Smart Meter could help you identify how the electricity is being used in your home?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☑	☐	☐	☐	☐

7. Do you think the use of a Smart Meter could help you identify which appliance consumes more energy?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☑	☐	☐	☐	☐

8. Do you think the use of a Smart Meter could help to obtain more accurate billings?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☐	☐	☑	☐

9. Do you think the use of a Smart Meter could help you identify the changes of energy usage throughout seasons?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

SECTION D: Comparison of the different Smart Meters

10. Did you find that the Smart Meter can help to decrease your energy consumption?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

11. Would you like to keep a Smart Meter in your household?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☑	☐	☐	☐	☐

12. Compare the features of the 4 Smart Meters

	Favourite Feature	Least Favourite Feature	Feature you would like to add
SM 1 – WATTSON	VISIBILITY – BIG DISPLAY DIDN'T REQUIRE EFFORT TO SEE ENERGY USE.	—	NONE
SM 2 – OWL CM119	—	IT DIDN'T WORK	—
SM3 – ENVI CC128	LOTS OF ONSCREEN INFO. GOOD [illegible].	NOT VERY VISIBLE SO DON'T MAKE AN IMPACT.	[illegible]
SM 4 – Efergy Elite	—	IT DIDN'T WORK	—

13. How important to you is to have a Smart Meter in your home?

HIGHLY AGREE	AGREE	INDIFFERENT	DISAGREE	HIGHLY DISAGREE
☐	☑	☐	☐	☐

THANK YOU FOR COMPLETING THIS SURVEY

Appendix 20 Verbatim interview transcriptions

Transcription of the verbatim interviews of occupants of Upton Homes in Northampton.

ENERGY METERS – ENERGY MATTERS

"The UK government had already announced that it wanted all UK homes to have smart meters by 2020."

"The Department of Energy and Climate Change Wants to see 47 million meters in 26 million properties by 2020." (Moylan, BBC News, 2/12/2009).

Interview Questions (Answers to be recorded)

(number 1 and 2 are very similar, they could be answer as one or combined)

Q1. (Q2) Do you think the use of a Smart Meter could influence your energy consumption habits? How? What was your experience with them?

Q2. (Q4) Do you think the use of a Smart Meter could change your awareness of the way you use energy? How? Did you learn something new from this experience?

Q3. (Q13) How important to you is to have a Smart Meter in your home? Why? Would you buy one? Any of the one you tested?

Q4. What were the limitations you have experienced with the energy meters?

Q5. Tell us about your experience during this testing period?

USER 1 (this user didn't use the Wattson energy meter) (10' 36'')

Q1. You just need your washing done, so you put it on at any time, so having a small meter in your house is not going to make a slightest bit of difference.

If it was so clearly detailed that you could exactly see how much it cost you for one dishwasher or washing machine at night and one during the day and there was a huge difference, then yes, you would, with money… that would be the thing, saving money is important, not necessarily saving the energy but saving money .

Q2. Yes, definitely… dogs back home…

What if it was something you could easily see and understand then it would make a difference, but if it's too complicated , I wouldn't be bother with it, I just couldn't be bother but if I could instantly see something, yes, no, up, yes then I would it make a difference.

Information about the Wattson is like that, easy to use, it uses colours.

Hmmm that would have been perfect… colours would be perfect, and you don't, where in my case you don't need to put a pair of glasses on to see a colour, where for this (Envi Meter) I do have to put on glasses

Q3. I, really , don't think… for me at the moment it's not important to have one in my home, unless it was so simple, you plug in and go with it, but it's not something that me personally, I'm not into the energy consumption mode yet. I think they need trying to do something, push more literature, make us aware of it rather just sitting a device. For the moment I wouldn't buy one, so literature, information needs to pass out to us. Ok we need to do it by 2020, it said.

The companies that provide energy need to provide the energy meters.

They have to give it or leave it with you, they have to buy and leave in your property, and install it.

So the energy companies are going to want to be able to provide the simplest, easiest, quickest machine, because otherwise they are going to get a lot of inquiries from people saying: "this isn't working, what do I do?, and blah blah blah blah. And, they will need a special team to deal with the problems. They will need that, because as it stands at the moment it's not going to work.

Q4. Limitations with energy meters

Incomprehensibility and just not working in one of the case, which is a shame, but, if it's too complicated, the instructions in one of them I couldn't find any indications of how to change, for instance, the date or the time and that's a simple, straight forward thing for everybody to have. And I couldn't read, find it at all and I did look at quite clearly and it was small instruction booklet, so I thought bound to be in here, nothing. It's all complicated stuff, it wasn't simple stuff. No user friendly.

Q5. the government initiative?

Well, I think, probably the good thing I got about is that there is this initiative the government has or is trying to put into place by 2012, price of this, I have no idea about it, ok, that might stand for the fact that I have not been living in the UK for a while. But, haven't heard anything, haven't read anything, haven't listened to anything so, from that point of view that's been good, but it's fiddly, some of them are fiddly and the fiddlyness it's something that… it just, if you have patience for it, sometimes I do, it's just annoying.

Someone else use it?

No, no it just me, my husband is away… and he is the one who volunteer for this and he left…

USER 2 (10' 36'')

Q1. hmm… what do I think of them individually? like

As a personal thing I probably wouldn't change my habits because I'm quite… I turn things off anyway. But I do think that someone else who might have it, who isn't as stubborn as me, if you like, would probably think "Oh, I'm using a lot of electric there I might turn that off." But because I, myself, do turn things off anyway, I probably couldn't turn any more stuff off and save any more energy than I already was. Having a meter would still be a good thing.

These types of meter you can also plug into appliances. Nina

Q2. For me, awareness wise, I know that I like to try and save energy as much as possible, but that's a personal thing. On a general scale, I do think that it would make someone else aware of the energy they are using and make someone else think, "Hmm, maybe I should turn that off." Again, having a smart meter helps in my awareness of what I am using and what I shouldn't be using if I'm using too much. If I wasn't as aware, I think the smart meter would have changed my habits for the better.

Q3. I think it is quite important because it does always make you aware of what you are using and what is on and there might be times where you don't realize you have left something on and you look at the smart meter and its reading quite high and you might think, "That's odd." And it might make you think "I'll go and look to see what I may have left on." And it might show that you've left something on, in the bathroom, maybe a hairdryer or something like that.

So you turn off every single socket?

I do. The only thing I leave on is the fridge and the telephone, only because it's a cordless telephone so it needs the power all the time, and the fridge obviously needs it but even the oven I turn off. My mum says I'm stupid, she says "You don't need to turn the oven off because it doesn't use hardly anything," but I just sort of thing, "What is the point in using that energy if you are only using it for an hour a day. There is no point in having energy constantly going to it, whether it's saving money or not. To me, it's using energy that I don't need, so I turn it off.

Maybe another way to use the smart meter is to take it to your mum's house and tell her "this is how much you are spending monthly on those things that you don't need."

Q4. Speaking in terms of the Wattson one, the limitations were, it didn't tell you very much. Although it was very bright and it told you very clearly what you wanted to know, it literally only told you yearly power usage and yearly price, I think it was yearly.

But you can figure out with downloading.

Yeah. So the limitations for that are, if you can download it, then fine. But if you are someone that doesn't have a PC, for instance, than apart from it telling you how much you're using than its --. The other ones did tell you a lot more which can be a good thing. But one of them, for some reason I didn't like it, but I can't tell you why because it was the same as sort of the other two. It was just, I don't know.

Chemistry?

Mainly. I did like that one, the one you could move around easily and there was a stand. I think that was the one that you had to have plugged in, I didn't like that because the one that I got after that you could stick anywhere, it was quite small and you could just put it – I actually put it up there, and it still worked well, not needing to be plugged in. The third one, the only thing I didn't like about it was the fact that you needed to have it constantly plugged in, and as soon as you unplugged it, it turned off.

Hmm it didn't bother that much.

Easy to move and dependency of power are features User 2 pointed out as good.

In fact I can use that, I walk it just for the fact that I might want to move at some point I got to keep in the right socket. To do experiment

Q5. general experience of this testing period

It's been a bit of an eye opener, for instance, the oven, when the oven was on, I just assumed that the moment you turn the oven on, it was using power, I didn't realise that it preheats it to a temperature and when it gets to that temperature it stops using power. I didn't realise it, it took me the use the meter to find that out. Same with the fridge as well, obviously the fridge turns off at some point, I just assumed as it was constantly on, it was always on.

A rated appliances.

Yes, the house in general I think, is been given an A rating for energy efficiency, I think, but I don't want to leave with you…wrongly. It's been fun

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USER 3 (17' 49'')

Q1. It gives you much bigger awareness of what you're using, especially the, the one that coloured, the Wattson, because it went red it attracts you straight to order, so you knew when it was blue you knew it was running well and the energy was down, on the red you knew, one of the kit switch sign on it was costing you a fortune, so that one, definitely, it just make you so aware of what you're using and where you can make the cut back, so.

When you saw it red on…

Yes, yes, because… we recently had problems with the heating in the house, the gas boiler, because we had that I brought my son an electric heater for his room, and we knew exactly when he had it that on, 'cause it went from running cost from 400W to 2100W, so I knew exactly when he had that switched it on, so that soon went off.

What was the problem that you had with the gas boiler?

Insufficient system to the house, it's not being fitted correctly.

Did they fix it for you?

Well, it's been on-going for 6 months, they fixed the other day, and we still have a few on-going problems, but I better ring them tomorrow to get them back out. Basically the boiler wasn't strong enough to heat the upstairs, the top floor, so that is the problem. It´s fine when the solar panels are going on but…

With the solar you warm up the water?

Yes, it is a brilliant system, it is, but, right now it is we got the Grandville, the Gretville, whatever it is called…? Gledhill... it's a very good system, is a top of the range system, but it's too complicated, it's just you know, you look at it and it's like, one it looks like a tardiest, it so many displays on it, just you know, it's too complicated.

The interface between the user and the technology sometimes can be difficult; do you get manuals or explanations?

Well, yes a man said that will get us a manual, that was 8 months ago, and then my son suddenly found one behind the actual system itself, hidden, it actually fallen down the ax. We now have a manual , the manual is does explain things, but the problem we are founding with the system of this house, it's what the manual says, the people who… who fitted it are saying "no", so we got in the eight months we've had the problem with the system we had four different plumbers, and each plumber has said a different thing to do and this is where all are contradicting with each other, and this is where and it just gets you so annoyed. Because the people who make this so panels or anything else, it doesn't seem like they are letting the other people in the industry let them know exactly what is going on. So you get someone, a plumber coming off the street, who is meant to be solar aware, but he goes up there, but because this thing is huge, he is not up to date on it. So we are having on and on problems, you are meant to have this down and then have that down, and this is meant to be switched on this gage, you know, and it's constant. So this is a good system in a sense because the last guy who came who used to work for, Medvilles or whoever they are, he said basically this system you leave it alone. It sorts itself out. It will tell the boiler when it needs heat, you don't need to touch it. But my argument with them was why put dials on it when you can do your own settings. If you not meant to touch it, why put the dials on it? Just leave it. You know. This is the problem, it tells you on the thing how you can set it to this time, set it to that time, or have it on that time, come off at that time, have it winter settings, summer settings, yet the guy who works for the company is saying don't touch it.

He said it should never ever be touched. It will, basically it will sort out what it needs and tell the border when it needs. So in the winter time the border will be heat a lot more, and in the summer time that will take over and tell the border 'don't need you mate I'm fine'. So, is a good system but it just needs… and unfortunately it just feels like we are Guinea pigs. And I suppose it does in anything with meters, and with you in Nottingham, it just feels like you are a Guinea pig, but it should be ready. It should be trialed and tested. You know we've bought a house. I've paid a lot of money for this house for a system that doesn't work. They should be paying me, for my time to sort the system out. If they want these systems trialed and tested they should give it to people and say: try it. The government should day, look, we have 10 million pounds, give 10 million worth of solar panels to different walks of life people and let them see. Give it a 5 years system and then we will be able to say, yes… this is it!

Yes this is the best one, and is the most energetic one…

Because eventually someone has to say this doesn't work, is a brilliant system just too complicated.

Yeah, exactly the same you are saying, I've been already living almost two years in an energy home, it's an experimental one though.

No… it's just… You know you get a basic idea of how, I mean I'm not a plumber, but you get a basic idea of how the system works, but when you mix the two, the solar system you understand, the boiler system you understand, but when you mix the two, it becomes completely different. Because we are constantly seeing, on the wall thermostat, you see the flame symbol. And then the boiler is not on, and we are thinking 'hold on a minute', it's signing it wants heat, but the boiler is not. But that's because it's taking the heat from the solar system. But because we weren't told any of that, we were constantly ringing up saying 'look!' I've got a flame symbol on the thermostat; the boiler is not switching on. Then they are sending out their plumber, I've taken a day of work for the plumber to come out, and he is saying 'oh no that's not meant to be like this', and then you say, oh??? 'well I don't know, I'll change the thermostat', so it's like 'woh', you are just all over the place!

Yeah, yeah, when you were saying that four people came to see, I have a biomass boiler. Also four persons came to see the biomass boiler and I remember one that said 'I've never seen something like this in my life' so he just walked off.

The first three ones we had one tried to trouble off that there was nothing wrong with the system. So I just said 'okay so I just bought seventy quid for an electric heater in an ecohouse, so there got to be something wrong with the heater...It's not the boiler.

The second one… they fair used it, and they tried and they tried to beat the rads (radiators), and they said this was wrong and I said that was wrong, but in the end they gave up. The third one gave up after about three visits. Luckily Nigel, the last one, who used to work for the solar panel people, he came in and within twenty minutes he said 'I know what they've done'. And basically all they did is where you got the big tank up… in the top room where it collects all the water. Every system has a bypass system; it basically has a pipe that comes out the tank, goes round the floor bottom and goes back in. And when the system gets too hot, it shoves it round there to cool it down, to keep it at a constant temperature. This system shouldn't have it and they fitted it. So all it was doing was heating the rad stand here and heating the rad in the middle floor. But when it go up the top it was saying 'I don't want to do this' and it was just shoving the water around the system so it never heated the top floor. So he has taken it out now and blocked that off. But the problem we've got now is that it sounds like the boiler is straining, it's under too much pressure…

And it got wired and (strange sound), and you feel 'oh my goodness, it's going to explode in a minute'. So we have to have him back out, but he did say, Nigel did say that the guy that did all this 'let us know what happens now, 'cause we are learning'. So we now found out that problem… so you know… 'we are learning'…

But you didn't pay a new house to learn all this

Why, I've lost about ten days worth of work, self employed so I don't get paid and there is no apologies… And extra energy…

At one stage, it was running so badly, it was running 24/7 because all the water that this boiler was heating up was going round the bypass system. So it was heating up no rads at all, and that just cost me a fortune, and you don't get an apologies or anything else. That's what really annoys you.

You know, you should get together, because all the houses we've been looking, all of them have certain problems…

Yes.. and this where the government should say 'okay you build those eco-sites, yes.. you have to attract people. But… it's like… I've got a good mark to write to the local newspaper. Because the local newspaper are up in arms saying 'What a fantastic site this is, it's brilliant, prince Charles opened it, and it's all his idea, and it's this and that and this and the people on it…' they are not saving a fortune, they are not, because everything is not working right. The windows are deft. They have fitted softwood windows. The reason they've fitted softwood windows it's because you grow trees quicker. It doesn't mean that you have to kill an 80 or 100 year old tree, which I can fairly understand. The problem they'll rot.

So there is people here in houses that are two years old and the windows have rotten. And they have to be wooden. We cannot supply, put in the PVC because we are not allowed to, which would only cost say ten thousand pounds, we have to go for wooden ones which cost you twenty-five thousand pounds.

There is all this lack of thought or lack of trial and test maybe?

Yeah… So what they should do is build a place like this and say 'you buy it say… 50% lower than the asking price, you leave in it for 5 years and give us all the information we can. And in the end of the five years you can pay the extra 50% if you want or you can get out and sell it, take it from there'.

Cause that's what I would do. I would have love to… This was originally 225 thousand they said to me you can have it for 113, you know at 50%... Yeah! And leave in it for 5 years, give it a try for 5 years, and at the end of 5 years you can either buy it back at original price or sell it and give your 50% back. I would have said yeah, fine…

I think it also has to do with the code. The code wants to do things very fast… the rushing to it… All of a sudden the world is getting warm; we are all going to die if we don't change our ways, but in a weird we've been polluting for the last 60 years really badly. So what we do in the next 5 to 10 years is not really going to make a lot of difference. Everyone is… is like with eco-lives. They have supplied us with eco-lives, but they've supplied us free from eco-lives. You can't get them anywhere! You have to go on the internet to order them from one manufacturer because they are not made.

Who is the lucky man I wonder… One manufacturer… he is making a fortune out of ‘em ‘cause you can’t get them. Is not like you can go (…) and get some.

Let me ask you the other question… for me it’s great I can listen to your experience… Then I can have evidence of what it’s really happening in real life home, not in an experimental case. And I guess you should be aware of all this problems…

Do they care to know?

The thing is, they don’t live in the real world… They live in a little cocoon of people telling them what we want…

So… for me it’s been a beautiful research from that perspective…

It’s good for us because in a way we can see what the hell is going on with the house… and what’s happening.

Let me… The other question is… If it’s important for you to have a device like this one and if you would buy one or not for the moment, what do you think abou?

I would buy one. I like the Watson. I don’t know the price on the others… 90 quid?

92 I guess…

It’s very good, I like the red light, everything on it and the style… Anything I would say against the Watson is that it’s too big. It wants to be half that size. If they made it half that size, they don’t half the price, but half that size it would be a lot better. Because… not so much as a man thing, but as a woman, you know… My wife comes in and says ‘that bloody thing is an asshole’ you know… Because it shines up in the wall… I like it, but it needs to be a bit more petite. From the woman side of it…

Yeah… That is a good point what you just said. Another question is, can you tell me some limitations about this experience or things that we could improve. This is a research project so looking from that perspective…

I think the whole trial went really well. I particularly enjoyed it in a sense that trying different things. Um… I don’t think there is any improvement or anything else. I think you managed… I can honestly say it was a good research.

So now analyzing the results, also because the government wanted to put these devices, compulsory starting 2020, but is compulsory for the energy companies, so they will provide them, they are supposed to provide them for every user. And we have questions in regard to that too, because it’s not just to put a measure and then apply it and then not finding out what people think. So we are trying to be a little bit ahead and see if we can contribute in a positive way.

I know if it is a government is gonna do, it’ll go completely wrong anyway… definitely wrong

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USER 4 (6’ 49’’)

Q1. Obviously when you see that it is high I knew that there was a lot on so if the kids had left the lights on near the stairs I would make sure that it was less nights on, when it was not needed and how many times you put the kettle on, even though you just boiled it and you are realizing how much it is going up, And the washing machine especially. Then you ask, do you really need to use it, or leave it on?

Q2. Well I don't leave the bathroom light on at nighttime anymore, because before I'd go to bed I make sure it was dropped as low as I could get it. The only thing I left on at night in the kitchen was the refrigerator, and that was it. And the kid's TVs once they finish watching a film, I would make sure they are turned off at the switch on the wall. Whereas normally I'd just leave them running.

Q3. I'd buy one, yes, I'm going to miss that. I like to know how much I'm using, like many; I reckon you said before you would buy the Watson.

Yes, the Watson one, yes.

Q4. I'd buy the Watson because it was easy to install, clear on what you're using and what uses more because obviously as soon as you put the kettle on it goes sky high, so you realize what uses more electricity. Also I like the color change feature on that one as well, because if it was to change, though it never did-it did stay on blue so I was quite happy about that.

You can also measure by appliances. (Nina)

I was wondering if there is a cheap way of boiling water.

Q5 ….initially when I first started using it, it was a lot higher, during the course of the day, but now during the bedtime making sure – it's not going to be on zero- I think it was 23 …..(@5:30).

A small amount of power is being used even on standby. It's costing me a small fortune

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USER 5 (7' 58'')

Q 1. Yes I do. I would certainly be more conscious of leaving the lights on. Obviously the everyday things that you use, you can't help but, turning the cooker on for cooking or whatever. But we have a limited ……like instead of using the dishwasher for a few minutes we will go back to washing them up (by hand). Also I have changed some of the light switches, like in here and in the front room. I had one light switch which turns both lights on and now I have changed them over so now they are independents switches …… one switch is adequate depending on what you do. We've already got energy efficient light bulb, so there is a significant change there. And just being aware of leaving the light on.

What about the stand by things?

We always used to leave the microwave switched on but now we just pull the plug out. I've already get a clock there and a clock there and one there; you don't need ten clocks telling you what the time is? Some of the appliances you may use once a day or once every couple of days, if we don't use them we switch them of by the wall, unplug them.

Q 2. Well , I wouldn't be boiling my water in the microwave. But to be fair, we are always pretty good anyways. If we are making tea we only pour enough for a couple cups of tea –

what is needed? If you didn't, seeing your meter go up three or four thousand pounds for that period of which the kettle is on could result in (indistinguishable @3:35)

It's an inductions hub?

It does both, the front (grote pans) are induction and the back two are conventional (hot plate)

Oh is very nice. It's safer because it's the one kids can't touch one of the experiments, I did (@4:00)

Q 3. A smart meter is good to have in your home to check your energy consumption but what I was annoyed whit most of them, although they gave you a current usage, it was for that split second of time. None of them gave you a breakdown of you can download it.

That's if you get past you wife on the computer, your daughter on the computer and everybody else on the computer.

It displayed a lot of information and some of the information was very good, it showed what was going up and down. But the basic thing that I would think would appeal to most people is knowing how much last week you spent, or how much this month or last month. And none of them, from what I see, did that. And to me that is the basic bit of information everyone would like to know, like "last month I used £100 and this week I reduced to £90" or "oh my god, we spent £130 this month". That would get more people thinking about what they are using than kilowatts or whatever it says up, down.

The Efergy has some of that, the actual display on that I found quite good but it was a lot of information too.

Yes, but where the graphs were it was like "what does that means?"

USER 7 (4' 20'' – the first 2 answers went missing)

Q3. And for me I would rather to see just the physical data, how much if I save 1 kW by switching off something or changing the electricity plug and I did actually save the 40% by switching to… those smart plugs when you switch off the tv, switch off the computer and everything is shut down, from it was 30 to 17.

Everybody in the family got involved in?

Just me, just me.

Q4. I said one feature, but then I forgot what was the feature, it was something?

Basically for you was most important to look at the kW-h?

Yes.

I like in this one there was a light in, one thing in this one is missing because it is quite small, it's nice that it's small because it doesn't take a lot room and it is wireless. You can take it around the home and the batteries keep… last for a long time. It just the only data to the computer but, that would be much better probably. When you got there an electricity meter just in one place plugged in, you're not always there but if you can carry it around the home you know, you keep it with you know that you've left something behind, especially when you got a big house and a family, someone could forgot to switch off the washing machine or something and it just consumes electricity. (Transportability)

What type of heating system do you have in the house?

It's a wood boiler

A biomass boiler?

Yes

and it has been working well?

Hmmmm today it's a… we have some problems… can you stop it for a second, if you can pause it for a second? (pause, baby is crying)

… so you were saying you have a biomass boiler and that you said you were having some problems

Oh yeah. Because, it's a, it's a … we got the boiler and it's like a tank in here, it's just an electric boiler, it's the back-up system but then we got the big exchange at the end of the houses here and it just supplies for all the houses here. They got some problems in the main supply and it just, it was just fitted maybe one year ago by someone else, some other self-contractor and they didn't finish it properly and that's the reason. Then, someone else took over the company and they stick too many hands and now, it very difficult to get to the person who did it and everyone don't want to do the service but they are trying to fix it, it's just so problematic because it's a new thing but they saying they says it very simple because they understand the system that is working here but not over there, and sometimes we don't get the water from the main unit, but we got a back system here (immersion control system), it's not that we are without...

Do you know how many sqm this house is?

No idea. 2 floors. Downstairs is quite small, it's a 5m long, the bathroom is 4 and the…

Probably around 100m2, isn't it?

Yes, something like that, or 80…

USER 9 (10m 10s)

Q1. I think the smart meters we're had, have had an impact on our consumption habits because it provides something that actually visible whereas before-we all know that leaving stuff on standby will use electricity but because you don't actually see a figure in front of you, telling you immediately how much you are saving pr using, it isn't real so you just carry on anyway. particularly the Watson because it's so visible and it's there all the time and you don't have to make any special effort to see it – you can walking to the kitchen, everyone can see it – the kids can see it, I can see it- and when its glowing anything other than blue. It makes you think. It helps you identify the appliances that use the most electricity, the kettle, the oven, the toaster- things that we are not going to stop using but the most important thing is switching off the things on standby. We started switching them off at night because it's just a waste of money.

Q2. The Watson, because it was a big screen and it had the colours, the very simple screen, and also not having to make any special effort to see it. I could be the other side of the room and know what the figure was, and it is a conversation piece because it is so bright and the design is very good whereas the others were just little boxes which just sat there- we just didn't even look at them and didn't really care about them but that's a conversation peace.

Q3. I would prefer to have a Watson than not have it, the others I would not go out of my way to buy and having tested them I wouldn't miss them if they went and I was left with nothing, we still use all the same appliances we did anyway. It wouldn't make any difference. It was a good educational piece, how we know not leave the things on standby and the differences that really make (4:18).

It has been a valuable experience, but if it was taken away I wouldn't immediately go buy one, but if I saw one for the right price, specially the Watson, I'd go pick it up.

Q4. The other one, excluding the Watson, were there was just too much data, and it really didn't interested me. They made an attempt to show the price. Obviously two of them didn't work in the first place. Limitation with the Watson, I think is the range of the sender, could be better …I actually prefer having just a big headline, in a massive writing and big bold colors for when it is just sitting on the side. For the other, it was so much on there (the screen) and there was so much writing, it was small and just never got looked at, it was information overload. If I just wanted my information on the Watson, I could just access it.

Q5. The testing period has been helpful because we're got awareness of what appliances have a energy demand. It's really important to understand the importance of standby. And it's also good because we can see our habitats well, our general energy use when we are not there. It's point less just burning energy when we are not there and cause it's costing us. It has been valuable and it's made us aware so we have changed the light bulbs in here to energy saving ones. But also it's good to know that we leave a light on for the kids, and makes hardly any difference because it's an energy saving one and that gave us peace of mind on that one, so we are not just throwing money away… (@9:13) if you leave in the morning and you see it on read you think, "Hang on a minute, what's on? Also I went around the house and turned everything on to see if I could beat my high score, just for an education- "oh my word, we could probably get £ 10,000 worth of electricity".

Actually that's a good idea (Nina)

Then went round and switched everything off and went "oh right, if we turn stuff off that we normally leave on we can get it down to £ 69 a year". It has been fun as well as trying to save us money.

Appendix 21 Statistical analysis of Wattson meter data

Pearson correlation, Cluster analysis and peak hour analysis of the data logged with the Wattson energy meter.

Table 36 Pearson correlation for the seven users of Upton homes

CORRELATIONS								
		USER 2	USER 3	USER 4	USER 5	USER 6	USER 9	USER 10
USER 2	Pearson correlation	1	-.127	.074	-.549	.262	.170	.074
	Sig. (bilateral)		.695	.648	.065	.410	.321	.809
	N	40	12	40	12	12	36	13
USER 3	Pearson correlation	-.127	1	.226	-.166	-.291	.235	.327
	Sig. (bilateral)	.695		.480	.606	.359	.487	.527
	N	12	12	12	12	12	11	6
USER 4	Pearson correlation	.074	.226	1	**.387**	.132	.198	.323
	Sig. (bilateral)	.648	.480		.172	.653	.247	.282
	N	40	12	42	14	14	36	13
USER 5	Pearson correlation	-.549	-.166	**.387**	1	.124	-.625*	-.252
	Sig. (bilateral)	.065	.606	.172		.673	.040	.630
	N	12	12	14	14	14	11	6
USER 6	Pearson correlation	**.262**	-.291	.132	.124	1	-.349	**.398**
	Sig. (bilateral)	.410	.359	.653	.673		.293	.434
	N	12	12	14	14	14	11	6
USER 9	Pearson correlation	.170	.235	.198	**-.625***	-.349	1	.433
	Sig. (bilateral)	.321	.487	.247	.040	.293		.160
	N	36	11	36	11	11	36	12
USER 10	Pearson correlation	.074		.323	-.252	**.398**	**.433**	1
	Sig. (bilateral)	.809	.527	.282	.630	.434	.160	
	N	13	6	13	6	6	12	13
**. The correlation significance level is 0,05 (bilateral).*								

All the the correlations showed to be significant; therefore a null hypothesis in regard to correlation between variables was accepted. Unfortunately, this result did not contribute in this fact, due to the low level of current lineal association between variables, the highest value of correlation was 39% between *user 10* and *user 6,* while the rest were barely over 35%, even more some of them had a negative value, as it is the case of *user 9* and *user 5*. Then,

Clusters Analysis

The following dendrogram (figure 113) shows a first cluster of spot formed by *user 9, user 10* and *user 2* which presented the closest proximity between the set, this association also happened when the means were analysed with the descriptive statistic approach. Then, a second cluster of spots formed by *user 4* and *user 6*, both classified as extreme users before. Nevertheless, it is still possible to visualise the proximity of *user 9, user 10, user 2* and *user 4*, on top of *user 6*, *user 5* and *user 3*, which household profile includes adults and children among their occupants.

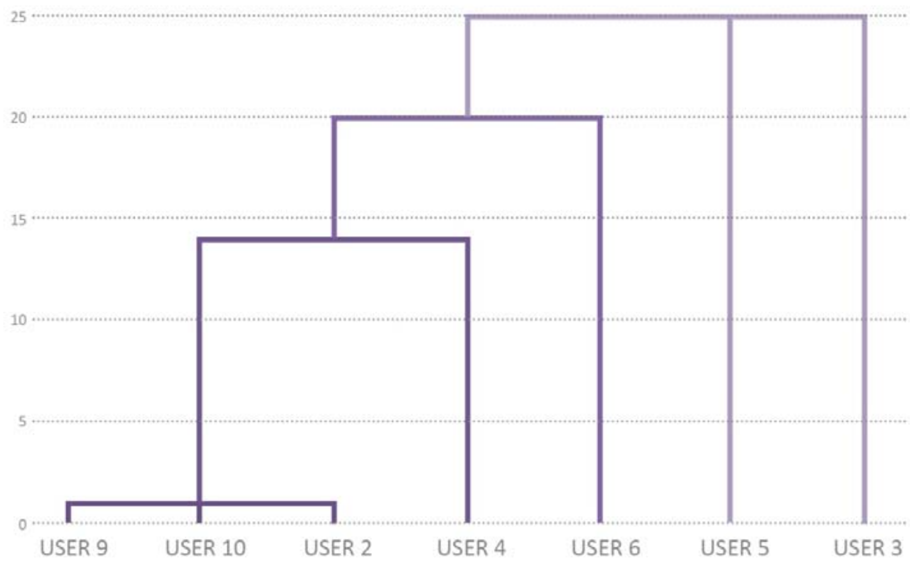

Figure 111 Single link dendrogram with rescaled distance cluster combination.

Now, if the distance is changed to an Euclidean metric, the new dendrogram (figure 114) depicts a high level of association among all the users, except *user 6,* which as it has been reiterated, presents the highest energy consumption of the whole set.

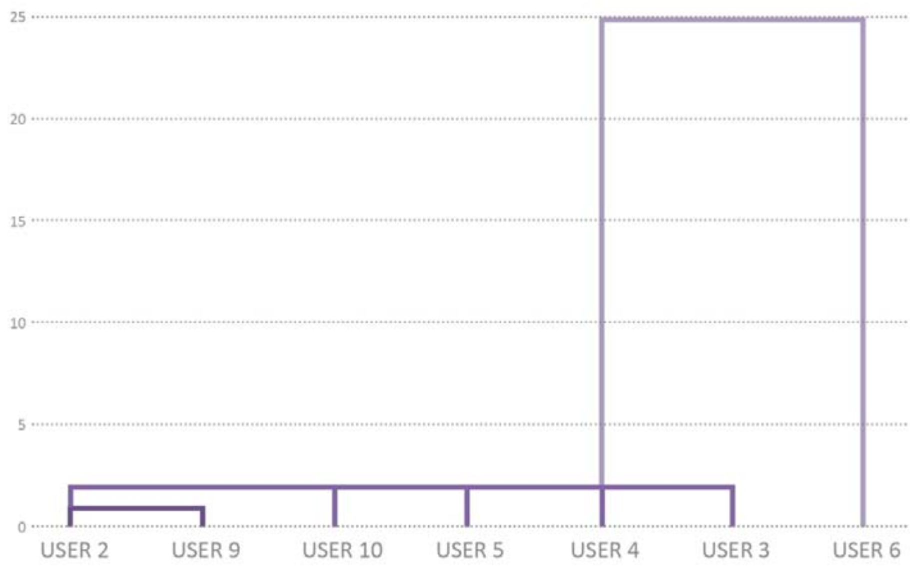

Figure 112 Single link dendrogram with Euclidean metric distance cluster combination.

Finally, it was possible to determine that the daily mean for the energy consumption value for the studied homes, keeps a referential level of 500W, except for the household with a baby as one of the occupants, *user 6.*

Peak Hour Analysis

Having determined the regular power consumption per household in wintertime by the seven users of Upton homes, in this section the objective is to identify the times of a weekday when the rate of power consumption has its peaks, it was expected that it will happen at morning time when the household begins a working day, then around the hours when the occupants return back home and have dinner. These two sets of hours were contrasted with a set of hours in the middle of the night, between 2 am to 4 am, when the household was supposed to be sleeping and the exterior temperature reached the minimum values in a typical day. To be able to analyse the behaviour for spots of hours also helped to confirm conclusions and add new information to the thesis.

7:30 am weekday

When sorting the data to identify peak hours during a working day, the period around 7:30 am was selected. By looking to a simple graphic inspection (figure 115) it showed up that the user with higher power consumption tendency was *user 10*; a home two adults. The other users, except for *user 2* with a stuck value, depicted a very homogeneous behaviour. Before going into the next step, it is important to point out the great difference on the readings between the seven homes under study.

	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile 25	Third Quartile 75
USER 2	454	686	54	148	22042	421	532
USER 3	**1038**	**2503**	**317**	**722**	**522001**	**525**	**1776**
USER 4	194	854	61	128	16307	114	245
USER 5	138	250	93	33	1084	113	155
USER 6	**584**	1971	122	683	466657	139	1105
USER 9	456	**3793**	**217**	581	337901	284	400
USER 10	216	244	197	16	263	201	230

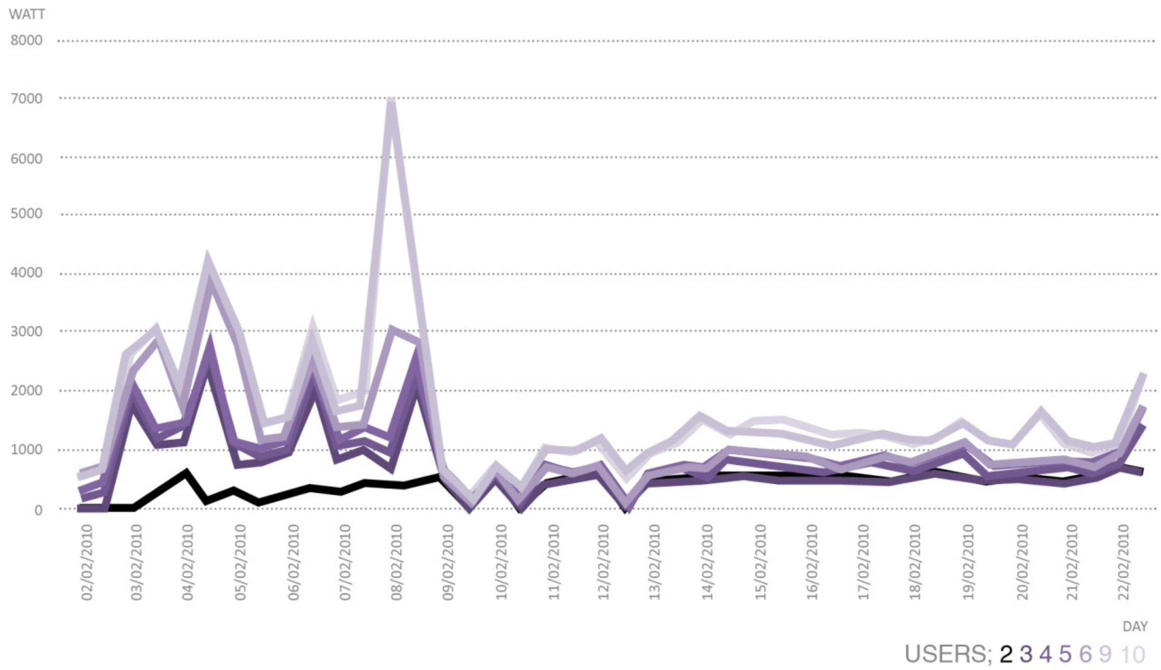

Figure 113 Graph of the energy consumption comparison at 7:30 am by the seven users of Upton homes.

Table 37 Descriptive statistics of the energy average values at 7:30 am for the seven households of Upton homes

	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile 25	Third Quartile 75
USER 2	454	686	54	148	22042	421	532
USER 3	**1038**	2503	317	722	522001	525	1776
USER 4	**194**	854	61	128	16307	114	245
USER 5	138	250	93	33	1084	113	155
USER 6	584	1971	122	683	466657	139	1105
USER 9	456	3793	217	581	337901	284	400
USER 10	216	244	197	16	263	201	230

It is possible to observed on table 24 that *user 3*, with 2 adults and 2 children, was in average the household that has the higher energy consumption, but it is also the home that has the higher volatility, 722W, with a difference as high as 1100W on its consumption rates. It also shows that *user 4* maintained its tendency, being the household with lower energy consumption, comparable to *user 5*, these two homes have two children and 1 adult, and 2 children with 2 adults for the latest. It is interesting to accentuate that *user 2*, with one occupant only of a 44 m2 flat approximately, shows similar energy consumption to *user 9* (2 adults and 2 children, in 113 m2 of a detached home) and *user 6* (2 adults, 1 toddler and 1 baby in 105 m2 approximately of a terrace home).

The above analysis is completed with the following dendrogram (figure 116) to analyse the proximity among variables with Euclidean metric.

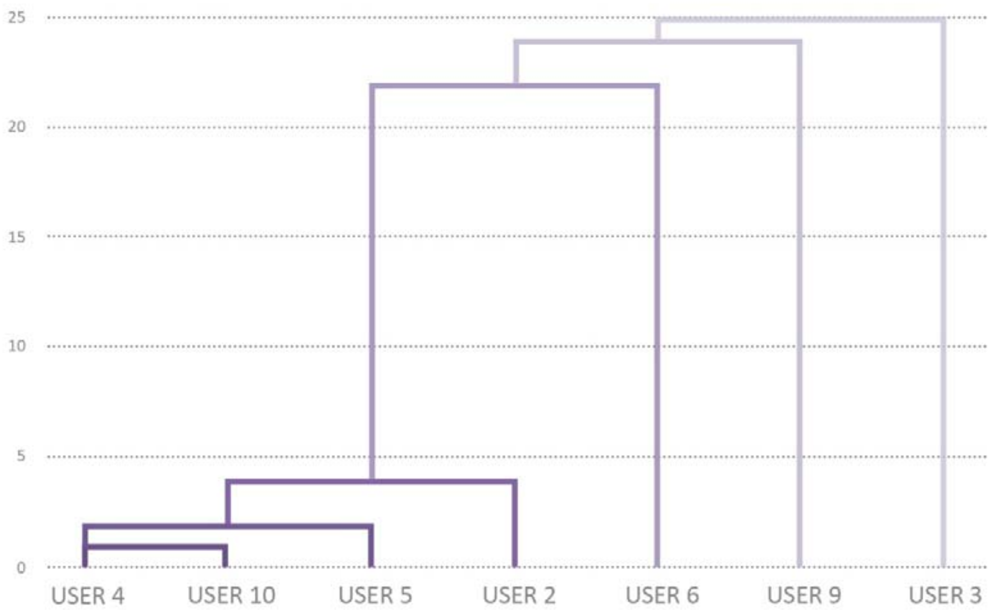

Figure 114 Single link dendrogram with Euclidean metric distance cluster combination for 7:30am.

The above dendrogram (figure 116) shows a first cluster of spot formed by *user 4, user 10, user 5* and *user 2* which homes all have energy consumption below 500W as it was shown too on the previous table 24. Then, a second cluster of spots formed by *user 6, user 9* and *user 3* shows higher energy consumption for this specific time of the day.

However, it was difficult to visualise levels of the proximity among users with such a different data in relationship to the number of occupants each home has. Therefore, just by analysing one specific time of the day, it is not possible to reach any robust conclusion in regard to energy consumption behaviour of the seven homes in Upton, therefore the next step was to pick two other specific times during weekdays.

6 pm, 9 pm and 4 am on a weekday

To continue with the 'peak hour power consumption' three more time slots were analysed: 6 pm was assumed as the time when most of the families are back home and it is a typical dinnertime schedule, especially for a household with children. 9 pm, by sorting different periods of the day, one of the schedules where peaks in rate occurred in most homes was at this time, night-time after supper, assuming the entire household was back home. When realising an exploratory analysis of the data, it was decided to leave *user 10* out of the set due the nature of the recorded values; they were disparate, many were missing taking value 0, many values were under 20 W and few over 200 W. 4 am was assumed as time of 'quiet hours', it appeared interesting to compare this rate with the peak hour rate. Assuming the level of the household activities was reduced therefore the electricity demand was expected to be lower and steady.

The following table 25 includes the four chosen schedules to visualise all of the results at once, the columns that are included are the two first ones for each schedule.

Table 38 Descriptive statistics of the energy average values at four times on weekday (Mo-Fri) for the seven households of Upton homes

Power Usage - W	**Daily average value**		**7:30 am**		**6:00 pm**		**9:00 pm**		**4:00 am**	
Rate	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
USER 2	493	753	454	686	637	1379	790	2597	373	**2706**
USER 3	635	861	**1038**	2503	**921**	2399	333	532	**935**	**2742**
USER 4	304	498	**194**	854	528	2381	533	**6069**	214	567
USER 5	399	507	138	250	**348**	1079	485	2227	399	2567
USER 6	**1155**	**1445**	584	1971	**909**	4174	**985**	**5531**	670	2418
USER 9	464	691	456	**3793**	**969**	**5010**	669	2364	270	362
USER 10	427	607	216	244	541	1781	null	null	226	272
Average	554		440		693		632		441	
	Without USER 10		477		Without USER 2		692			

On table 25 the energy consumption mean value for 6 pm is 693W, where *user 3, user 6* and *user 9* have a much higher value, more than 200W each. *User 3* is occupied by 2 adults and 2 teenagers and *user 9* is occupied by 2 adults and 2 children, it is possible to assume then that these homes have higher energy consumption than the homes inhabited just by adults in regard to the mean values. However, *user 5* with an occupation of 2 adults and 2 children, it is found much lower power consumption, in fact this household is the one that had the lowest consumption at this particular time of the day, although at 9 pm this user increased the consumption in 130 W. Also, it is remarkable that *user 2* with only one occupant has higher energy consumption than homes inhabited by families with adults and children.

18:00 h	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile25	Third Quartile75
USER 2	637	1379	**399**	212	44824	477	800
USER 3	**921**	**2399**	193	**809**	**655288**	**344**	**1383**
USER 4	528	2381	42	523	273112	188	713
USER 5	**348**	1079	88	253	64188	150	432
USER 6	**909**	**4174**	132	1233	1519078	162	1218
USER 9	**969**	**5010**	**196**	1152	1327863	317	1148
USER 10	541	1781	26	611	373287	211	572

At 6 pm it was found higher power consumption in relationship with the daily mean value; however this type of peak does not occur exclusively at dinnertime, it also occurred at 9 pm, a similar pattern in regard to power consumption was also found, except for *user 2*, who drop the power rate abruptly compared to all the other hours and to its maximum.

21:00 h	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile25	Third Quartile75
USER 2	**790**	**2597**	61	545	296916	469	912
USER 3	333	532	**193**	98	9599	267	394
USER 4	533	**6069**	96	952	905814	203	392
USER 5	485	2227	88	482	232316	156	490
USER 6	**985**	**5531**	125	1558	2426035	154	759
USER 9	669	2364	198	480	230706	407	749

The mean value for 9 pm was 632W for power consumption, which represents a bigger value than the monthly mean value of 575W and over the value for 7:30 of 477W; without including *user 10.* The mean was very similar to 6pm if *user 2* is not considered; given the big differences

in those values compare to the rest. It is important to emphasize that the means become much more homogeneous, however keeping the trend, where the tendency of *user 6* is to have the highest power consumption household, being followed by *user 2.*

4:00 hr	Mean	Maximum	Minimum	Typical Deviation	Variance	First Quartile25	Third Quartile75
USER 2	**373**	**2706**	**67**	**469**	**219690**	**105**	**496**
USER 3	**935**	**2742**	**366**	**783**	**613420**	**475**	**988**
USER 4	214	567	71	124	15447	112	311
USER 5	399	2567	88	594	352655	95	346
USER 6	670	2418	131	798	636042	174	848
USER 9	270	362	105	48	2310	244	301
USER 10	226	272	201	25	609	206	242

For 4 am, the values on power consumption by the set was very regular compared to peak hours and mean values, however the mean value was almost equal to the 7:30 am value. It was somehow assumed that the energy consumption would be lower and subjected to activity/functioning of the households. With these results it is possible to associate the consumption rates to basal energy consumption. It is also shown that *user 3* is the household with the higher energy consumption at early morning hours, which is occupied by 2 adults and 2 teenagers. However, the results for this schedule were not easy to correlate to number of occupants.

Although some minimum and maximum values of power consumptions of the different users shown extreme values compared to the mean value, it can be asserted through analysing the quartile values that great part of the data was close to it. It is interesting to observe *user 3* that stands out with a power consumption value quite low for its monthly mean and also quite low compared to the 7:30 am schedule.

The following two dendograms shows the typical graphs generated by SPSS (Spanish version)