EVALUATING A COST EFFECTIVE CARBON ABATEMENT STRATEGY FOR HIGHER EDUCATION IN WALES

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Certificate of Research

This is to certify that, except where specific reference is made, the work described in this thesis is the result of the investigation undertaken by the candidate. Neither this thesis, nor any part of it has been presented or is currently submitted for any other degree other than the degree of Master of Philosophy at the University of Glamorgan.

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Abstract

The environmental and financial drivers for reducing energy consumption and associated CO_2 emissions are well established and widely accepted. The UK and Welsh Governments have demonstrated their commitment by setting CO_2 reduction targets across the public sector including Higher Education.

The literature shows that detailed research has been carried out by SQW Consulting on behalf of the Higher Education Funding Council for England to inform strategic planning but that no such body of under-pinning knowledge is available for the Welsh HE sector. The aim of this study is to identify a cost-effective carbon abatement strategy for the HE sector in Wales with the intention of informing future strategic planning.

Using sector specific datasets individual and collective emissions baselines are established for Higher Education Institutions and the Welsh HE Sector respectively. These results are used to benchmark the relative energy efficiency of the Welsh HE Estate, identify good practice and to define a single case study. Cardiff Metropolitan University is highlighted and further noted for their acclaimed use of automatic monitoring and targeting as a means of achieving sustainable behaviour change.

In this thesis HEFCE's assessment of the cost effectiveness of abatement measures and abatement potential is validated from the critical evaluation of the case study.This shows that whilst applying their predictions on a pro-rata basis to the HE sector in Wales was a justifiable approach to identify the individual measures within a cost-effective carbon abatement strategy, the cost of delivering sustainable behaviour change is understated.

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Glossary

AHU	Air Handling Unit
aM & T	Automatic Monitoring and Targeting
BEMS	Building Energy Management System
CCC	Committee on Climate Change
CIBSE	Chartered Institution of Building Services Engineers
CHP	Combined Heat and Power
CMU	Cardiff Metropolitan University
CRC	Carbon Reduction Commitment (Energy Efficiency Scheme)
CSM	Cardiff School of Management
CV	Calorific Value
EMS	Estates Management Statistics
EPBD	Energy Performance in Buildings Directive
DEC	Display Energy Certificates
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment Food and Rural Affairs
FIT	Feed in Tariff
FTE	Full Time Equivalent
GIA	Gross Internal Area
GHG	Green House Gas
HE	Higher Education
HEEPI	Higher Education Environmental Performance Improvement
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
HESA	Higher Education Statistics Agency
HEI	Higher Education Institution
HEIDI	Higher Education Information Database for Institutions
ICT	Information and Communications Technology
KPI	Key Performance Indicator
LMS	Lighting Managment System

LNG	Liguified Natural Gas
MACC	Marginal Abatement Cost Curve
MCS	Micro-generation Certification Scheme
NIAC	National Indoor Athletic Centre
ORCalc	Operational Ratings Calculation Software
RHI	Renewable Heat Incentive
RUMM	Remote Utility Monitoring and Management
RWCMD	Royal Welsh College of Music and Drama
SIP	Strategy and Implementation Plan
WRI	World Resources Institute
UNFCCC	United Nations Framework Convention on Climate Change
UUK	Universities UK
UWCM	University of Wales College of Medicine
VAV	Variable Air Volume

1.0 Introduction

International concerns over the threat of climate change to sustainable development lead to the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The United Nations (1992) sets out a framework for action to minimise emissions of gases including carbon dioxide, methane and nitrous oxide believed to be a major contributor to climate change.

In 1997, The Kyoto Protocol described by the United Nations (no date a) as "an international agreement linked to the United Nations Framework Convention on Climate Change" commited developed countries and countries with economies in transition to achieve quantified emissions reduction targets. This agreement was subsequently translated into UK statute in the form of the *(Great Britain. Climate Change Act 2008)*.

In response to this and the UK Government's commitment to the Kyoto Protocol, the Welsh Assembly Government (2010, p.34) set targets for the public sector in Wales to reduce greenhouse gas emissions including CO_2 by 3% per annum from 2011 against a baseline averaged between 2005-10.

Similarly in England, targets were set by the Higher Education Funding Council for England (2010a, p. 12) who proposed that the sector "commit to meet the government targets for carbon emission reductions in scopes 1 and 2 of 34 per cent by 2020 and 80 per cent by 2050 against a 1990 baseline".

Despite differences in individual targets and baselines, both countries are similarly ambitious. However, if targets are to be met, it is imperative that they are taken seriously by the sector, as achieving meaningful reductions in CO_2 emissions is a long term process that requires strategic planning and significant investment. The need for acceptance was reinforced when Adam (2008) reported that David King, former chief scientific adviser to the government believed that it is critical that official targets are "seen to be achievable". Furthermore, targets are likely to be met only if the appropriate level of activity is quantified and the availability of resources are fully considered. Sir Alan Langlands, Chief Executive of the Higher Education Funding Council for England (2010b, p.1), when referring to "the commitment of the sector to reducing its carbon emissions..." warned that "We should not underestimate the size of the challenge, nor its cost."

Reinforcing the need for strategic planning and to prepare for significant investment, the Higher Education Funding Council for England (HEFCE) commissioned various research initiatives to inform carbon reduction strategies for higher education in England. Understandably, HEFCE's research was restricted to Higher Education Institutions (HEIs) in England and to date, there has been an absence of similar work in relation to the Higher Education (HE) sector in Wales.

Therefore this study is intended to similarly provide a body of knowledge to support future strategic planning for the HE sector in Wales. It also seeks to determine whether targets are achievable for the period to 2020, as this is the timescale noted by the Higher Education Funding Council for England (2010c, p. 4) as applicable to interim government targets.

2.0 Aim of the Study

The aim of the study is to examine carbon management strategies and investigate the opportunities that exist for reducing CO_2 emissions within the HE sector in Wales, defined as the higher education instituitions (HEIs) receiving funding from the Higher Education Funding Council for Wales (HEFCW).

In particular, the study will encompass scope 1 emissions (direct emissions from sources owned or controlled by the organisation) and scope 2 emissions (emissions from the generation of purchased electricity consumed by the organisation).

A research methodology will be developed to critically evaluate the level of investment required to cost-effectively comply with long term CO_2 emission reduction targets with the intention of informing future strategic planning for the HE sector in Wales for the period to 2020.

Specifically the research will:

- Investigate recent work carried out on behalf of the Higher Education Funding Council for England by SQW Consulting.
- Establish scope 1 and scope 2 CO_2 emissions baselines for individual HEIs and hence the HE sector within Wales.
- Evaluate existing emissions growth trends against published targets to quantify required emissions reductions.
- Benchmark the existing Welsh HE estate as the basis for quantifying potential improvement and to Identify an exceptional case study.
- Use a case study approach to validate research outcomes.
- Determine the most appropriate abatement strategies to achieve the required level of CO_2 emission reductions and whether CO_2 emission reduction targets are economically achievable in the Welsh HE sector.

3.0 The Plan of Study

The plan of study provides an overview of this thesis and a brief description of the content of individual chapters.

Chapter 1 Introduction

The introduction stresses the importance of CO_2 emissions reduction targets within the national and international context and the need for strategic planning and significant investment if the HE sector is to meet this challenge. Research conducted by HEFCE to inform strategic planning in the English HE sector is acknowledged and the need for similar sector specific knowledge in Wales identified.

Chapter 2 Aim of the Study

The aim of the study is to examine carbon management strategies and investigate the opportunities that exist for reducing CO_2 emissions within the Welsh HE sector. This chapter further defines the more specific aims of the project in support of informing future strategic planning for the HE sector in Wales.

Chapter 3 The Plan of Study

This chapter provides a brief overview of the content of this thesis.

Chapter 4 Research Methods

The methods designed to investigate the research question are detailed within this chapter. They include a literature review, quantitative analysis of sector wide data and an action-research project used as a single case study.

Chapter 5 Literature Review

The literature review was conducted to provide the context in which the study is set including recent sectoral, political and legislative developments and to inform the quantitative analysis by selecting appropriate data sources and analysis techniques.

Chapter 6 Sector Analysis

The Higher Education Statistics Agency database was used as the primary source of sector specific data for analysis. This chapter details the analysis of growth trends, calculation of baseline emissions, benchmarking of the Welsh HE Estate and the determination of absolute CO_2 reductions to 2020.

Chapter 7 Case Study

The sector analysis detailed within chapter six was also used to identify Cardiff Metropolitan University as a single exceptional case study based primarily on achieving the greatest reductions in CO_2 emissions. This Institution was further distinguished when measured against peers and national benchmarks. This chapter considers their approach as the basis for critically evaluating the research findings of HEFCE and to directly inform the research aims of this study.

Chapter 8 Results and Discussion

Within this chapter the research outcomes are discussed. The differences in baseline emissions, targets and hence absolute CO_2 reductions using HEFCW's methodology are compared with the methodologies applicable to English HEIs.
The cost and effectiveness of individual abatement measures identified by HEFCE's research are critically evaluated against the findings of the case study and the results used to calculate the cost of achieving sector emissions reduction targets in Wales.

Chapter 9 Conclusion and Recommendations

The conclusion summarises the research outcomes of this study and details seven key recommendations including areas for further research.

4.0 Research Methods

4.1 Introduction

This study focusses on carbon management within the higher education sector in Wales. This specific area of the public sector has been selected to facilitate a detailed study and has been further defined to differentiate between the regulatory regimes in England and Wales.

It was acknowleded that whilst research has been conducted in this area on behalf of HEFCE, this had been restricted to the HEIs in England and it was evident that to date, no such detailed analysis had been completed in relation to the Welsh HEIs. The differing CO_2 emissions reduction targets set by the respective funding bodies further distinguishes Wales from England. Therefore this study makes an original and independent contribution to the body of knowledge existent in this field.

Whilst this applied research has been directed at a specific area of the public sector within Wales, the author believes the approach and much of the knowledge to be transferable to other areas of the public sector across the UK.

It was therefore necessary to develop research methods to critically evaluate the level of investment in the sector to effectively meet long-term scope 1 and 2 CO_2 emissions reduction targets through cost effective abatement measures. The research method formulated includes a literature review, quantitative analysis of sector specific data and the evaluation of a single case study.

4.2 Literature Review

A literature review was conducted to provide the context in which the study is set including recent sectoral, political and legislative developments and to inform the research methodology. The review was also developed to inform the quantitative analysis by selecting appropriate data sources and analysis techniques.

It was first necessary to establish the scope and magnitude of CO_2 emission reduction targets that apply to HE in Wales in the period to 2020, to identify relevant baselines against which performance was to be measured and contextualise this against long-term UK targets.

A particular focus for the review has been the recent research conducted by SQW Consulting on behalf of HEFCE which was used as a source of knowledge for differentiating between the HE sectors in England and Wales and the approach by their respective funding bodies.

The literature review was also used to identify the availability and suitability of datasets to facilitate detailed quantatitive analysis. Consideration was also given as to how CO_2 emissions should be measured and reported with particular reference to evaluating normalised performance indicators.

Prior to evaluating the required level of investment and in order to assess whether targets are realistic, it was necessary to appraise the energy efficiency of the HE Estate in Wales. To complete this analysis it was first necessary to identify appropriate benchmarking techniques for use to differentiate between the current position and the 2020 requirements.

4.3 Quantitative Analysis

The literature review identified the data held within the Higher Education Statistics Agency database as the most complete dataset available and this has been used as the primary source of sector specific data for analysis.

Energy consumption data has been used as the basis for establishing a baseline of CO_2 emissions for individual Institutions and the HE sector in Wales to identify trends over a 5-year period (2005-2006 to 2009-2010). As CO_2 emissions data is commonly derived from energy consumption data by the application of conversion factors, inconsistencies can arise from using factors which vary over time therefore the manner in which the data is processed has also been considered to provide uniformity.

A comparison of identified energy consumption (and CO_2 emissions) trends against sector targets has been used as the basis for quantifying the magnitude of absolute CO_2 reductions that will be necessary in future.

However, as the literature review identified significant growth in the sector over recent years, in terms of both income and student numbers and to assist in gaining a more accurate assessment of energy efficiency, emissions data has also been normalised for growth against a variety of factors including total income, gross internal area of the estate and combined staff and student numbers. The results have been examined to both quantify the performance of individual Institutions and as the basis for discussion on the suitability of individual metrics as performance indicators. The validity of normalising performance against weather data has also been considered.

Energy consumption data for individual Institutions has also been used to benchmark within the peer group and against UK wide industry standard benchmarks eg. CIBSE TM46:2008 which are also used as the basis of the calculation of Display Energy Certificates. As highlighted in the literature review the relevance of these benchmarks has recently been reviewed on behalf of CIBSE by Bruhns, Jones and Cohen (2011, p. 9) who confirmed that in general they remained valid but noted "a marked trend across many sectors..." (including University Campus) "for higher electricity consumption and lower heating consumption..." but noting "some category medians end up close to the CO_2 benchmark".

This benchmarking exercise has been used both to establish the relative energy intensity of the Welsh HE estate and to assist in quantifying the potential for improvement. It has also been useful in identifying potential examples of best practice.

Having determined whether targets were achievable based on absolute CO_2 emissions reductions from a given baseline to 2020, it was then necessary to consider and apply known methods of assessing the cost-effectiveness of abatement measures.

The absolute reductions in scope 1 and scope 2 emissions that are required from the Welsh HE Estate have been quantified as previously discussed by comparison with existing trends. The required investment to achieve this level of reduction has been estimated using established methods such as marginal abatement cost curves and has been underpinned where possible by the use of field data from a live case study.

It is intended that the results of the quantitative analyis will assist the HE sector in Wales to identify the likely expenditure necessary to meet ongoing CO_2 reduction targets and to highlight the most cost effective abatement measures.

4.4 Case Study

A single case study approach was adopted based on an information orientated selection made to identify a suitable subject. However, the author was mindful that as Ousey (2007) summarises "critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generalisability of findings. Others feel that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool".

However, Flyvbjerg (2011, p. 302) observed that whilst "At the same time that case studies are widely used and have produced canonical texts, it may be observed that the case study as a methodology is generally held in low regard…". Flyvberg (2006, p. 220) also stated that whereas "it is correct that the case study is a detailed examination of a single example," … "it is not true that a case study cannot provide reliable information about the broader class."

The literature review and subsequent quantitative analysis was used to highlight a single exceptional case study subject from within the Welsh HE sector. In particular, Cardiff Metropolitan University (formerly the University of Wales

Institute Cardiff) where a 12% reduction in CO_2 emissions was found to be the highest recorded within the HE sector in Wales during the period covered by this study. As the subject of a (Carbon Trust, 2011) case study, their strategies had been well documented and were backed up with good historical energy consumption data. Of particular interest was their approach and the differentiation that could been made between the cost effectiveness of interventions.

As the author is also the Energy Manager at Cardiff Metropolitan University, the case study became an action-research project and whilst this is beneficial in providing depth and detailed local knowledge, this also required self vigilance to maintain objectivity. However, the Higher Education Funding Council for England (2010a, p. 21) have recognised the value of such an approach in their Carbon reduction target and strategy for higher education in England by stating that "One option we are considering is providing small levels of funding for a number of Institutions to undertake action-research projects on their own practice in carbon management."

5.0 Literature Review

The literature review provides the context in which this study is set including recent political and legislative developments affecting the HE sector in Wales.

To aid further analysis, the literature review also sought to identify appropriate:

- Data sources
- Methods of measurement
- Means of establishing baselines
- Normalising factors
- Benchmarking tools
- Cost-effective interventions

5.1 Targets

The United Nations (no date a) through the Kyoto Protocol 1997 set binding targets on developed countries to limit or reduce emissions of greenhouse gases including carbon dioxide (CO_2). The United Nations (no date b) further note that the then 15 member states of the European Union were issued a collective target which was later re-distributed amongst themselves.

This agreement was subsequently translated into UK statute *(Great Britain: Climate Change Act 2008)*.The requirements of this legislation were summarised by the Department for Energy and Climate Change (2012) as placing "a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050, to be achieved through action in the UK and abroad and a reduction in emissions of at least 34% by 2020. Both targets are set against a 1990 baseline."

The Wales Assembly Government (2009, p. 33) noted that: "The Climate Change Act places the UK target to reduce greenhouse gases by at least 80% by 2050 into statute. It also establishes a system of 5 year carbon budgets for the UK."

and announced that “We will reduce our greenhouse gas emissions by 3% a year by 2011 in those areas where we have devolved competence.”

The Wales Assembly Government (2010) set out further details of their targets for the public sector in Wales including Higher Education Institutions (HEI’s). The expectation is for the sector to reduce CO_2 emissions by 3% p.a. from 2011 (financial year 2011-2012) which equates to a 27% reduction by 2019-2020. These reductions are to be measured against a baseline of the average emissions during the years 2005-2010.

In England, the Higher Education Funding Council for England (2009, p.3) in a joint HEFCE, Universities UK and Guild HE consultation document acknowledged that:

> The Climate Change Act 2008 aims to improve carbon management and help the transition towards a low-carbon economy in the UK. It sets the world’s first legally binding reduction targets for greenhouse gas emissions of at least 80 per cent by 2050 and at least 34 per cent by 2020, against a 1990 baseline.

In response the Higher Education Funding Council for England (2009, p.10) proposed that the sector:

> Commits to achieving a reduction in scope 1 and 2 emissions of 80 per cent by 2050 and at least 34 per cent by 2020, against a 1990 baseline.

In a September 2010 amendment to their “Carbon reduction target and strategy for higher education in England”, the Higher Education Funding Council for England (2010a, p.2) reported that:

> Against a 2005 baseline, this is equivalent to a reduction of 43 per cent by 2020 and 83 per cent by 2050;originally these figures were 48 per cent and 84 per cent respectively.

However, in their earlier consultation document the Education Funding Council for England (2009, p.10) had originally suggested that the sector:

> Aspires to achieve a carbon reduction target from scope 1 and 2 emissions of 50 per cent by 2020 and 100 per cent by 2050, against 1990 levels.

All targets are intended to be absolute as defined by the Higher Education Funding Council fo England (2010a, p. 12) "...as actual carbon emission reductions against the levels in a fixed past year." They explain the reason for absolute targets is because "The UK national targets under different policies and legislation are absolute and set against a 1990 baseline year. The rationale for this approach is based on the fact that the capacity of the Earth to manage carbon emissions is itself finite.

The Higher Education Funding Council for England (2010a, p.4) strategy includes for "a sector-level target for carbon reductions that is in line with UK targets" and "a requirement for Institutions to set their own targets for 2020 for scope 1 and scope 2 emissions against a 2005 baseline."

However, the Higher Education Funding Council for England (2012) later conceded that "Institutional targets are not required to be the same as the sector target because it is recognised that each Institution will be able to make a different contribution to the target...." according to factors including but not limited to academic activity, space utilisation and the age profile of the Estate and went on to identify "The collective impact of institutional targets as a 38 per cent reduction between 2005 and 2020. This is slightly lower than the sector-level target, but demonstrates the commitment of the sector to reducing emissions."

UK Requirements	Baseline Year	Target Year	Reduction %
Kyoto Protocol 1997 (1st period 2008-2012)	1990	2012	8
Kyoto (EU "Burden Sharing" Agreement)	1990	2012	12.5
Climate Change Agreement 2008 (original)	1990	2020	26
Climate Change Agreement 2008 (revised)	1990	2020	34
HEFCE (2009, p.10)	1990	2020	34
HEFCE (2010a, p.2)	2005	2020	43
HEFCE (2012), HEI's collective targets,	2005	2020	38
HEFCE (2009, P.10) aspirational targets	1990	2020	50
Climate Change Agreement 2008 (original)	1990	2050	60
Climate Change Agreement 2008 (revised)	1990	2050	80
HEFCE (2009, p.10)	1990	2050	80
HEFCE (2010a, p.2)	2005	2050	83
HEFCE (2009, P.10) aspirational targets	1990	2050	100
Wales Assembly Government (2009, p.33)	2005-10	2020	27
includes HEFCW	(average)	annual	3

Table 5.1 Summary of chapter 5.1, UK and HE sector CO_2 emissions reduction targets.

5.2 CO_2 Emission Categories

The following categories are as defined by the Greenhouse Gas Protocol developed by the World Resource Institute (2004) and adopted by the Department for Environment, Food and Rural Affairs (2009) and can be summarised in relation to the HE sector as below:

- **scope 1: direct emissions** – these include direct emissions from the combustion of fossil fuels within the estate, such as natural gas, heating oil, coal and other fuels, as well as in assets owned by the institution, such as motor vehicles (petrol, diesel and other transport fuels). Recent research conducted on behalf of the Higher Education Funding Council for England (2010c, p.6) estimated that vehicles typically account for 0.71% of an HEI's total scope 1 emissions.
- **scope 2: electricity emissions** – these include indirect emissions associated with purchased electricity consumed by the institution.
- **scope 3: other indirect emissions** which are a consequence of the activities of an organisation but occur from sources not owned or controlled by the company. Within the HE sector this could include water, waste, business travel and commuting. Whilst there is currently no sectoral requirement to report scope 3 emissions, The Higher Education Funding Council for England (2010a, p.27) have stated that "Institutions are encouraged to measure a baseline for scope 3 emissions and in the longer term we will expect these to be included."

5.3 Sectoral Data Sources

CO_2 emissions are commonly derived from applying CO_2 conversion factors to underlying energy consumption data. Therefore a readily accessible and accurate historical record of energy consumption data is essential for evaluating sector wide CO_2 emissions.

Whilst reporting of "verified" energy data is now a requirement under the *(Great Britain. The CRC Energy Efficiency Scheme Order 2010)*, there is little or no historical data available. Furthermore, not all UK HEIs are captured by the CRCEES due to the 6,000 kW·h half-hourly electricity annual consumption qualifying threshold outlined by the Department of Energy and Climate Change (2012). In addition, as reporting periods do not align with those historically used in the sector i.e. financial years (1 August to 31 July), direct comparisons with other sector datasets would not be possible.

Fortunately, since 1996 UK Higher Education Institutions have voluntarily reported energy and other data on an annual basis as part of a dataset known as the Estate Management Statistics (EMS). These statistics were initially collated by the Association of Directors of Estates (2012). Responsibility was later transferred to the Higher Education Statistics Agency (HESA) through a web-based management information service known as the Higher Education Information Database for Institutions or HEIDI available at http://www.heidi.ac.uk/.

In addition to the EMS, HEIDI provides access to a wide range of quantitative datasets compliled by HESA covering students, staff, finance, teaching and research. HEIDI includes functionality to facilitate normalisation and benchmarking analysis.

In their report to HEFCE, SQWenergy, SQWconsulting (2009, p.6) noted that "The EMS cover all 150 current Higher Education Institutions (HEIs) in the UK." SQWenergy, SQWconsulting (2009, p.38) also indicated that "The Estates Management Statistics (EMS) were generally felt to be a useful tool in comparing Institutions with one another." But added that:

> However, there is still substantial leeway for interpretation and there may be a need to review the input guidance of the EMS to ensure that results looking forward are genuinely comparable (e.g. guidance on how to treat purchase of green electricity). A detailed guidance to Institutions on which parameters to monitor and report will not only improve the setor-level understanding of carbon emissions but also facilitate individual HEIs in developing their own targets and delivery plans.

The dataset was subsequently adopted by the Higher Education Funding Council for England (2012) for the purposes of monitoring carbon management who have stated that “Performance against the sector level target will be published annually using data collected through the Estates Management Statistics”.

As the various datasets within HEIDI have been approved by HEFCE for performance measurement in England and represent the most comprehensive sector specfic statistics, they have been adopted as the primary source of energy and other data for quantitative analysis within this study, in particular the following data sub-sets as defined by the Higher Education Statistics Agency (2011) were considered:

- D38A C1 Energy consumption for the whole estate (including residences) with the following sub-categories in kW·h:
    - Oil
    - Gas
    - Electricity
    - Coal
- D4 Total FTE students
- D5 Total FTE staff
- D1 Total HEI income.

For the raw data used from these datasets see appendix A.

For the period considered by this study (2005-2006 to 2009-2010) energy consumption data within the EMS for the welsh HEIs is complete with the exception of:

- Glyndwr University, who have consistently failed to report any energy data for this period but have reported other data within the EMS. Based on GIA data contained within the EMS, it was noted that Glyndwr University accounts for approximately 3.5% of the GIA of the welsh HE estate, therefore it was decided that the missing data was unlikely to significantly affect the validity of any analysis.

- Cardiff University, who did not return energy consumption data for 2006-2007, 2007-2008 and 2008-2009. However, the missing data was obtained by the author directly from Cardiff University's Estates Department (see appendix B) and as this would have been the original source of the data within the EMS, it has been retrospectively incorporated into the dataset accessed through HEIDI for the purposes of this study.

5.4 Measurement of CO_2 Emissions

As previously noted, CO_2 emissions are commonly derived from applying CO_2 conversion factors to underlying energy consumption data. Relevant conversion factors along with further guidance is available and periodically updated from Department for Environment, Food and Rural Affairs (2011, pp. 9-13). It can be seen from these guidelines that CO_2 conversion factors are not a constant, particularly for grid electricity where actual emissions are dependant upon the generation source and therefore vary over time.

Year	kg CO_2 per kW·h
1990	0.74524
1991	0.73191
1992	0.71092
1993	0.68108
1994	0.66135
1995	0.62342
1996	0.58867
1997	0.55521
1998	0.53948
1999	0.51877
2000	0.50925
2001	0.50605
2002	0.50840
2003	0.51339
2004	0.52435
2005	0.52612
2006	0.52958
2007	0.53429
2008	0.53156
2009	0.52114

Table 5.2 CO_2 conversion factors for electricity from Great Britain. Department for Environment, Food and Rural Affairs (2011, p.12).

As can be seen from table 5.2 these factors can vary significantly over the long-term which could lead to inconsistencies when making historical comparisons particularly when considering performance against a 1990 baseline.

Fuel	$kgCO_2$ per unit			
Unit:	kW·h	Therm	Litre	Tonne
Natural gas	0.18523	5.4286		
Burning oil	0.24683		2.5421	3,164.9
Coal (industrial)	0.32227			2336.5
Petrol	0.24176		2.3220	3162.6
Diesel	0.25301		2.6720	3201.1

Table 5.3 CO_2 conversion factors for direct fossil fuel combustion from Higher Education Funding Council for England (2010c, para. B-1).

In contrast only minor historical changes were observed in the CO_2 conversion factor for natural gas which could potentially be attributed to an increasing reliance on imported natural gas and in particular Liquified Natural Gas (LNG) which has a CO_2 impact associated with its' transportation.

The Higher Education Statistics Agency (2011) suggests using conversion fuel factors taken from the Defra for calculating CO_2 emissions unless a more appropriate conversion rate is available to an HEI. Therefore, in the interest of consistency all sectoral CO_2 emissions quoted within this study are based on direct calculation from the underlying energy consumption data within the EMS unless otherwise stated.

As the prime objective of setting CO_2 reduction targets is to improve the performance of Institutions individually and collectively, it is important that the effect of variations in CO_2 conversion factors is accounted for within reporting mechanisms. This study has considered two potential methods:

- **Option 1:** Reporting and targeting improvements against the underlying energy consumption. Whilst this method would provide the necessary consistent time-based comparisons it would not account for the relative CO_2 intensity of individual fuels.

- **Option 2:** Applying a constant CO_2 conversion factor to both the baseline and reporting years. Whilst factors from either the reporting or baseline years could be used, retrospectively applying and adjusting the baseline to take account of current CO_2 intensity is believed by the author to offer the most accurate assessment of actual CO_2 savings.

Advice from Department for Environment, Food and Rural Affairs (2011, p. 63) is to retrospectively apply current CO_2 conversion factors where changes are due to the publishing of more accurate emission factors, as described in option 2.

5.5 Baselines

All baselines referred to in this study are measured on an academic or HE financial year, e.g. a 2005 baseline measures emissions from 1 August 2005 to 31 July 2006.

The grant letter to HEFCE from the Secretary of State for Innovation, Universities and Skills of 21 January 2009 (Great Britain. Department for Innovation, Universities and Skills, 2009) contained the following requirements relating to climate change:

> Last year, I set out our ambition that capital funding for institutions should be linked to performance in reducing emissions. Following your advice to me, I am now confirming that such links should be in place for 2011-12. In May 2008 I asked you to finalise during 2008-09 a strategy for sustainable development in HE, with a realistic target for carbon reductions that would reduce carbon emissions by 60 per cent against 1990 levels by 2050 and at least 26 per cent by 2020. This former target should now be upgraded to 80 per cent, in line with Parliament's decisions in passing the Climate Change Act 2008.

In parallel with this, the 2009 update to the strategic plan for 2006-2011, the Higher Education Funding Council for England (2009b, p.48) outlined a revised key performance target (KPT) relating to sustainable development. Formed following discussion with the then Department of Innovation, Universities and Skills, the new KPT14 is:

> To develop during 2009-10 in consultation with stakeholders a realistic strategy and target for carbon reductions which are sufficient to ensure satisfactory progress towards the government targets of reducing carbon emissions by 80 per cent against 1990 levels by 2050 and at least 34 per cent by 2020.

As national targets have arisen from UK obligations under the Kyoto Protocol they are set against a 1990 baseline. However, as previously noted comprehensive data collected by the Higher Education Statistics Agency was not available prior to 1996.

The Higher Education Funding Council (2010c, p. ii) stated that SQW were asked "...to provide individual HEI carbon baselines for two years:

- **1990** (which relates to the 1990-91 academic year) as the year against which most national and sectoral targets are set
- **2005** (which relates to the 2005-06 academic year) as a more recent year for which higher quality data is available."

In their "Carbon reduction target and strategy for higher education in England", the Higher Education Funding Council for England (2010a) reported "Against a 2005 baseline, this is equivalent to a reduction of 43 per cent by 2020 and 83 per cent by 2050;...".

This compares with the Wales Assembly Government (2010) public sector target of 3% per annum from 2011 (2011-2012) or 27% by 2020 (2019-2020) against a baseline of an average of emissions during the years 2005-2010 (2005-2006 to 2009-2010).

Therefore in order to differentiate between the requirements placed upon the English and Welsh HE sector it was necessary to consider the following baselines for Welsh HEIs:

- An average of emissions during 2005-2010 as required by the Welsh Government.
- A 2005 baseline as adopted by HEFCE.
- A 1990 baseline as referred to by HEFCE and against which UK obligations are measured.

5.6 Normalising Data

5.6.1 Factors Affecting Consumption

Historical energy consumption patterns are affected by many factors other than the effectiveness of energy conservation (or carbon management) strategies. Influencing factors are likely to be many and varied and can include changes to the scale and nature of a business, operating methods and even weather variations.

The Higher Education Funding Council for England (2012) acknowledged that "Institutional targets are not required to be the same as the sector target because it is recognised that each institution will be able to make a different contribution to the target, and that carbon emissions will vary according to several factors". They continued by quoting examples of Institutional differences such as:

- the mix of subjects
- the ratio of teaching to research
- institutions that made significant reductions prior to 2005
- institutions that currently occupy energy-inefficient buildings or are relocating to energy-efficient buildings will have greater opportunities
- opportunities for onsite renewable energy vary between institutions
- some institutions have more potential than others to rationalise space use
- particular challenges from reducing carbon emissions in historic buildings
- assumptions behind the targets (for example on the de-carbonisation of grid electricity) which may vary.

The UK Government and the higher education funding bodies in England and Wales require an absolute reduction in CO_2 emissions as outlined in section 5.1 of this document. This contrasted with advice from Higher Education Environmental Performance Improvement (2012) whose original website once cited within its "Energy – Best Practice" page (see appendix E), an example of best practice being when "The organisation has identified and actively uses an appropriate measure of specific energy consumption (SEC) e.g. GJ per m^2 or unit product. Account is taken of changes in business size or activity levels."

If the purpose of CO_2 reduction targets is to quantify the effectiveness of energy conservation (or carbon management) strategies, HEEPI were suggesting consumption data should be normalised to gain a more accurate assessment of performance.

In order to identify methods of normalising energy data, the author has considered factors that could significantly affect energy consumption within the following categories:

- Growth
- Institutional Factors
- The weather

5.6.2 Growth

The core business of HE can be defined in the broadest terms as teaching and research.

Growth can be easily expressed in both financial terms and student numbers, as with any business, growth in an HEI would tend to be reflected in customer numbers and turnover. In the case of an HEI increased staff/student numbers would in turn influence the necessity for additional information technology or specialist research equipment, the size of the estate and/or increased occupancy hours. All of these factors are likely to affect energy consumption and the use of an absolute CO_2 reduction metric without normalising for growth, would disadvantage succesful Institutions that have grown or are continuing to grow their businesses.

As energy consumption can be seen to be directly related to occupancy levels a specific metric taking account of total staff and student numbers may seem appropriate.

Similarly growth in income may be a useful indicator particularly in Institutions with a large contribution from research. However, whilst initially appearing to be a simple and straightforward growth metric, caution should be exercised with regard to inflationary pressures and changes in funding mechanisms.

The physical size of the estate expressed in gross internal area (GIA) could reasonably be expected to have a close correlation with energy consumption and therefore be an obvious metric against which to normalise. However, improving space utilisation which is a valid CO_2 reduction measure would detrimentally influence results measured by this metric.

Whilst recommending that reduction targets for scope 1 and scope 2 carbon emissions in the Higher Education sector in England should be absolute against a base figure (i.e. not relative to sector growth), SQWenergy, SQWconsulting (2009, p. 29) further noted that "Relative carbon emission metrics and respective targets, such as carbon dioxide per student or staff, GIA, or revenue are, a useful, complementary approach as they can encourage greater discipline at the Institution level and also allow for more direct comparisons between Institutions."

The use of specific energy consumption metrics to aid "comparisons between Institutions" or benchmarking is further discussed in section 5.7.

This approach is endorsed by People and Planet (2012a, p. 37) who have included a growth normalising metric based on total staff/student FTEs in addition to scoring absolute reductions. These metrics are used as part of their scoring criteria for the People and Planet (2012b) "Green League" which ranks UK HEIs based on their sustainability credentials.

5.6.3 Institutional Differences

Whilst there are clearly differences between Institutions which as previously indicated in section 5.6.1 may include the:

- mix of subjects *e.g. science v business*
- ratio of teaching to research
- relative energy efficiency of the Estate
- opportunities for onsite renewable energy
- potential to rationalise space use
- particular challenges posed by historic buildings

Additionally, other factors such as the mix of buildings within the Estate e.g. amount of residential v. academic space can all affect the relative energy consumption of individual Institutions and can be valid explanations of the differences in sector benchmarking results. But as any changes to these factors at an individual Institution level would logically be gradual they are less important for HEIs measuring against their own historical performance than they become for making peer comparisons.

5.6.4 Weather

The Chartered Institution of Building Services Engineers (2004, p.1-3) estimated that in the year 2000, 41% of UK CO_2 emissions from energy use in non-domestic buildings arose from heating and 5% from cooling and ventilation.

The actual amount of energy required to condition buildings will be dependent on several factors including environmental conditions e.g. external temperature. Research by Day, A. (1999, p. 3-4) observed that "buildings are highly complex systems with multiple heat flow paths, each of which can be influenced by a number of different factors". He summised that "these dynamic relationships will mean that heat flows will be constantly varying due to fluctuations in environmental conditions, the behaviour of the occupants and controls and the response of the heating system". Whilst it is difficult to quantify the latter two factors it is possible to access data relating to the outdoor environment i.e. the weather.

The Carbon Trust (2012) suggests that "degree days provide a powerful but simple way of analysing weather related energy consumption". This statement may explain why they are such a commonly utilised method for normalising energy consumption used to heat (or cool) buildings.

The Chartered Institution of Building Services Engineers (2006, p. ii) explain that "Essentially degree-days are a summation of the differences between the outdoor temperature and some reference (or base) temperature over a specified time period." The Chartered Institution of Building Services Engineers (2006, p. 4) add that "In the UK, degree-days are published monthly for 18 regions to a traditional base temperature of 15.5 °C". The Carbon Trust (2012, p.4) quotes that "the base temperature is defined as the outside temperature above which the heating system in a building would not be required to operate".

Degree days are also published and similarly applied to calculations relating to energy used to cool buildings. The Chartered Institution of Building Services Engineers (2006, p. 10) explains that "Cooling degree-days are calculated from temperatures *above* a base temperature; the equations to calculate them simply subtract the base from the outdoor temperature using similar principles as for the heating case".

Degree days are commonly used in energy management for simple ratio-based weather normalisation and to determine non-weather related energy consumption using a technique known as linear regression analysis.

However, despite the widespread use of degree days there are a number of inherent inaccuracies in the methodology which could give misleading results highlighted by Bizee Energy Lens (2012) in an online article paraphrased below:

- **Base temperature**: As the actual outside temperature above which a building does not require heating is dependant on many factors including internal heat gains, internal temperature setpoint and the thermal characteristics of the building, it is unlikely that a base temperature of 15.5^0C (or 18.5^0C) would be the correct value for all buildings.

- **Non-weather related baseload:** It will be necessary to estimate the proportion of the energy consumption to be weather normalised unless weather and non-weather related consumption is separately metered. The technique usually used to do this is known as linear regression analysis and the accuracy of the approximation is highly dependent on whether the base temperature is appropriate for the particular building.

- **Intermittent Heating:** As degree days are collected over a 24-hour period the highest incidence occurs overnight when heating systems would normally be off. The closeness of the correlation between energy consumption and heating degree days can be further affected by heating systems operating in "frost condition". Calendar related issues such as the incidence of bank holidays and weekends in a given month can also distort correlations.

- **Meter Reading:** Further inaccuracies will be created unless the timing of meter readings coincide with the period for which degree day data is collated.

- **Degree Day Region:** Degree days are commonly reported for 18 regions in the UK and and Welsh HEI's would be based in either:

    - Region 5 – Severn Valley
    - Region 16 – Wales

  Accuracy will also be affected by whether the region is "site representative".

- **Applying Degree Days:** Normalisation of fossil fuel consumption is common practice but as HEI's are increasingly using electricity for heating with air and ground source heat pumps becoming more popular normalisation of electricity consumption may also need to be considered.

Tables 5.4 and 5.5 compare 20-year average values and annual data for the two "degree-day regions" within which the welsh HEIs are located i.e. Region 5, Severn Valley and Region 16, Wales against a 2005-2006 baseline.

Whilst data is usually published by the Carbon Trust on a monthly basis and arranged into calendar years the following table has been arranged into academic years to facilitate further analysis within this study.

Severn Valley	20yr Av.	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
August	17	29	20	29	15	16
September	47	39	27	64	65	77
October	126	66	67	128	146	139
November	213	269	197	227	226	217
December	310	330	245	307	369	396
January	302	334	248	242	357	434
February	269	325	242	281	301	323
March	239	300	242	258	235	277
April	178	188	120	219	170	177
May	103	95	105	86	117	132
June	40	32	33	45	47	31
July	18	9	29	24	20	17
Annual Total	1,862	2,016	1,575	1,910	2,068	2,236
%+/- Difference against 2005-2006	-7.6		-21.9	-5.3	2.6	10.9

Table 5.4 Degree day data for Severn Valley region comparison with 2005-2006 baseline from Carbon Trust (2011).

Wales	20yr Av.	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
August	35	33	32	40	29	35
September	62	53	25	60	75	68
October	137	85	83	117	156	108
November	216	232	202	197	223	198
December	301	286	251	289	313	340
January	309	324	250	256	343	387
February	281	303	248	258	296	336
March	266	308	260	274	263	300
April	214	221	152	232	194	216
May	143	143	129	92	143	173
June	76	56	51	86	72	73
July	39	18	51	40	37	28
Annual Total	2,079	2,062	1,734	1,941	2,144	2,262
%+/- Difference against 2005-2006	0.8		-15.9	-5.9	4.0	9.7

Table 5.5 Degree day data for Wales region comparison with 2005-2006 baseline from Carbon Trust (2011).

Variations against the baseline year were observed to range from 10.9% "colder" to 21.9% "warmer" which illustrates the extent to space heating loads vary year to year and illustrates the difficulty in assessing performance without accounting for the weather.

In spite of such fluctuations. the methodology adopted for measurement within the sector is to use absolute data without any weather normalisation. The Higher Education Funding Council for England (2010c, p.3) stated that "Weather correction has not been applied to any figures as an absolute approach is required under CIF2". CIF2 refers to their capital investment framework which is linked to an HEIs carbon reduction peformance.

5.7 Benchmarking

CIBSE TM 46 published by the Chartered Institution of Building Services Engineers (2008) contains a comprehensive set of energy benchmarks for buildings and populates the database within the ORCalc software used to generate Display Energy Certificates.

The Chartered Institution of Building Services Engineers (2008) CIBSE note in the foreword to this document that "Performance management is all about tracking performance and identifying opportunities for improvement. This relates not only to past performance but also how current performance compares with other buildings, especially those of similar type."

The benchmark values applicable to the HE Estate are identified by the Chartered Institution of Building Services Engineers (2008, p.5) as "Category 18, University Campus" and are intended to represent a "Typical campus mix for further and higher education universities and colleges".

Recent research by Bruhns, H., Jones, P., Cohen, R. (2011) carried out to validate the benchmark values concluded with regard to the "University Campus" that: "Overall ratings in the category are reasonable although the heating benchmark is thought to be too generous (240 $kW{\cdot}h/m^2$ cf offices 120 $kW{\cdot}h/m^2$) but this is compensated by the slightly leaner electricity benchmark (80 $kW{\cdot}h/m^2$ cf offices 95 $kW{\cdot}h/m^2$)." Possible explanations may include longer operating hours for Universities as compared with offices.

Actual energy and illustrative CO_2 benchmark values are quoted as follows:

Energy Benchmarks		Illustrative CO_2 benchmarks calculated from the energy benchmarks		
Electricity typical benchmark (kW·h/m^2)	Fossil-thermal typical benchmark (kW·h/m^2)	Illustrative electricity typical benchmark ($kgCO_2/m^2$)	Illustrative fossil-thermal typical benchmark ($kgCO_2/m^2$)	Illustrative total typical benchmark ($kgCO_2/m^2$)
80	**240**	**44.0**	**45.6**	**89.6**

Table 5.6 CIBSE TM46:2008 benchmark values for category 18 university campus.

The Chartered Institution of Building Services Engineers (2008, p.12) lists the CO_2 conversion factors it has applied to obtain the illustrative CO_2 emission benchmarks as 0.550 $kgCO_2$/kW·h for electricity and 0.190 $kgCO_2$/kW·h for fossil-thermal.

The Chartered Institution of Building Services Engineers (2008) note in the foreword to TM46 document notes that "Display Energy Certificates (DECs) are intended to provide information to operators of larger public buildings about how well they are actually being run, based on metered energy consumption data."

Guidance on the introduction of Dispay Energy Certificates is provided by the (Great Britain. Department for Communities and Local Government 2008, p.5). Their guide:

> ...provides an introduction to the Regulations for display energy certificates for large public buildings. Display Energy Certificates ('DECs') promote the improvement of the energy performance of buildings and form

> part of the final implementation in England and Wales of the European Directive 2002/91/EC on the Energy Performance of Buildings.

In this guidance document the (Great Britain. Department for Communities and Local Government 2008, p.7) state that:

> ...A DEC and advisory report are required for buildings with a total useful floor area (see Glossary of terms for a definition) over 1,000m^2 that are occupied in whole or part by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by those persons.

Not all buildings have a DEC due to the area threshold and low compliance rates identified by Bruhns, H., Jones, P., Cohen, R. (2011, p. 3) who reported that:

> There are two categories of non-compliance. First and most importantly, there are those buildings which do not have a DEC but should have. These are not detectable from examination of the database which covered 33,419 different buildings (as indicated by UPRN). A regulatory impact assessment in March 2007 had estimated at least 42,300 buildings would be caught by the DEC Regulations which implies over 20% have not complied. Secondly, as was shown by the analysis, there was a widespread non-compliance manifested by only about half the properties having a renewal DEC.

Therefore comparisons between HEIs on this basis would not be representative of the welsh HE estate in its entirety.

More detailed benchmarks for a range of building types are provided by the Chartered Institution of Building Services Engineers (2004, p. 20.1).

Building type	Energy consumption benchmarks for existing buildings kW·h/m^2 per year			
	Good Practice		Typical Practice	
Education (further and higher)	Fossil Fuels	Electricity	Fossil Fuels	Electricity
Catering, bar/restaurant	**182**	**137**	257	149
Catering, fast food	**438**	**200**	618	218
Lecture room, arts	**100**	**67**	120	76
Lecture room, science	**110**	**113**	132	129
Library, air-conditioned	**173**	**292**	245	404
Library, naturally ventilated	**115**	**46**	161	64
Residential, halls of residence	**240**	**85**	290	100
Residential, self catering/flats	**200**	**45**	240	54
Science laboratory	**110**	**155**	132	175

Table 5.7 CIBSE Guide F (Second Edition) 2004: Benchmark Values for Education (further and higher) buildings.

The above data illustrates the diverse range of buildings that form a University Campus and the significant variance in energy consumption per m^2. Therefore comparisons of individual campuses with CIBSE University Campus benchmarks may be as much an indicator of the mix of buildings as it is of energy efficiency.

Similarly other HE building specific benchmarking tools are available such as "CE-Benchbuild an excel tool developed for the HE sector" as described by the Sustainable Procurement Centre of Excellence (2012).

Based on an explanation of the tool from the Sustainable Procurement Centre of Excellence (2012) buildings are placed in one of the following eight categories:

1. Office (single use).
2. Sports & Recreation (single use).
3. Libraries (single use).
4. Residential (single use).

5. Mixed HE, Academic (typical HE academic building).
6. Teaching (Tailored): buildings with lecture theatres, seminar rooms, offices and other spaces related to teaching.
7. Support (Tailored): buildings with catering, meeting rooms, offices and other support.
8. Laboratories and other buildings (Tailored).

However, the guide goes on to explain that the tool requires far more detail for analysis than is available through the EMS, including energy consumption and energy cost data along with building details such as GIA, occupancy, thermal mass, exposure etc. For the purposes of reviewing the whole of the Welsh HE Estate it is unlikely that this level of detail would be available without conducting detailed site surveys.

A report by the National Audit Office Wales (2005, p. 6) entitled "Energy and Water Management in the Higher Education Sector in Wales", noted that:

> Energy and water efficiency vary widely across the higher education sector in Wales, with several Institutions exceeding national benchmarks. Although direct comparisons between Institutions must allow for the different uses to which the estates may be put, the overall performance suggests there is scope for improved energy and water efficiency, a view supported by our own local energy survey findings and by opinions of estates managers across the sector. Furthermore, current arrangements for energy and water management commonly fall short of good practice.

The benchmarks identified within the literature review will be used to benchmark the HE Estate in Wales and determine whether the findings of this 2005 report remain valid.

5.8 Best Practice Case Studies

Whilst there are many examples of best practice case studies across the HE sector in the UK, the research method selected for this study is to select a single case study from quantitative analysis of HEIs in Wales.

However, it was noted by SQWenergy, SQWconsulting (2009, p.35) that "Whilst technical solutions are currently being widely adopted across the sector, there are few sector-wide projects looking specifically at behavioural change, although studies suggest that between 5-10% carbon reductions are realistically possible through behaviour change alone."

5.9 Cost Effectiveness of Interventions

The Higher Education Funding Council for England (2010a, p. 4) emphasised that:

> Setting targets is essential to identify the size of the challenge, co-ordinate efforts nationally and internationally, and demonstrate commitment to meaningful change. However, targets alone do not achieve results. They need to be supported by a strategy so that the methods by which the targets are to be achieved can be agreed and the necessary actions and investment put in place.

In his foreword to The Higher Education Funding Council for England (2010a, p. 1) and in reference to the commitment of the sector to reducing its carbon emissions Sir Alan Langlands, Chief Executive of HEFCE warned that "We should not underestimate the size of the challenge, nor its cost."

SQWenergy, SQWconsulting (2009, p.16) in their 2009 report to HEFCE observed that "....in theory, all (100%) of the carbon emissions can be saved – this is ultimately a question of cost...." In practice, the likelihood is that the HE sector will be unable to provide sufficient funds to eliminate all carbon emissions and would logically seek to prioritise implementation of the most cost effective abatement measures.

The Higher Education Funding Council for England (2010a, p12) suggest that:

> The carbon hierarchy (Figure 4) provides a systematic and structured approach to managing and reducing emissions in a socially responsible and cost-effective way. Actions at the top of the hierarchy are more transformative and lasting in terms of reducing emissions. A carbon hierarchy is being used by the Department for Children, Schools and Families' Zero Carbon Task Force to help move towards the Government's ambition of delivering zero-carbon school buildings from 2016.

The carbon hierarchy is shown in figure 5.1 below.

REDUCE energy/fuel demand	Avoid unnecessary use	**MONITOR** • Learn from existing projects and practice • Apply control measures • Evaluate impacts
	Passive features (for example insulation, daylight, solar gain/shading, thermal mass)	
	Encourage energy-conscious behaviours	
EFFICIENCY of equipment and energy/fuel sources	Use energy-efficient equipment	
	Provide simple and effective controls	
	Recover useful heat	
	Use clean fossil fuel technology	
DECARBONISE energy/fuel supplies	On-site or near-site renewable energy sources, including community schemes	
BEFRIEND	Seek partnerships to increase your capacity to do the above	
NEUTRALISE energy/fuel supplies	Consider responsible carbon offsetting schemes	
	Procure green electricity supplies	

Figure 5.1 The Carbon Hierarchy The Carbon Hierarchy as cited in Higher Education Funding Council for England (2010a, p. 13).

It should be noted that whilst the "carbon hierarchy" includes "responsible carbon offsetting" within the "NEUTRALISE" category, the Higher Education Funding Council for England (2010a, p. 24) clearly states that "Carbon offsetting may not be used to meet an institution's carbon reduction target for scopes 1 and 2". But do add that "carbon offsetting may form part of an institutions carbon management plan for mitigating the effects of essential activities that create emissions under scope 3."

Therefore interventions to reduce scopes 1 and 2 CO_2 emissions will need to focus on consuming less energy and sourcing a greater proportion from low or zero carbon sources.

Whilst the carbon hierarchy is useful in providing a systematic and structured approach, for strategic planning purposes a method of assessing the relative cost effectiveness of potential abatement measures is also necessary.

The Higher Education Funding Council for England (2010a, p.15) reports that the six most viable interventions in terms of scale of impact and cost-effectiveness for the sector as:

- lights and electric appliances (including information and communication technologies (ICT))
- building energy and space management
- building fabric upgrade
- efficient energy supply (combined heat and power (CHP)/tri-generation, district heating)
- renewable energy
- behavioural change and new ways of working.

As this report was not explicit in defining these categories it was also useful to consider how potential abatement measures are categorised by the Carbon Trust who are more specific as can be seen from figure 5.2.

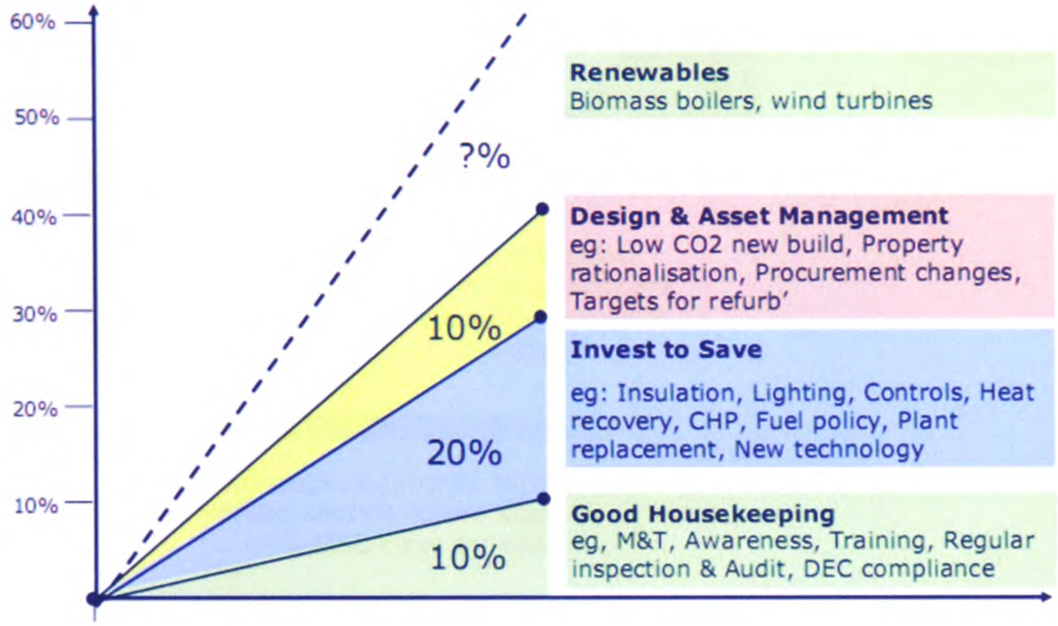


Figure 5.2 Carbon Trust categorisation of potential abatement measures cited by Evans, L. (2012).

HEFCE identified the six most cost-effective interventions to reduce carbon emissions based on the use of Marginal Abatement Cost Curves (MACCs) which the Higher Education Funding Council for England (2010b, p. 44) describe as an "...assessment and decision-making tool regarding carbon-reduction interventions...".

Figure 5.3 below provides a simple explanation of how to interpret a MACC.

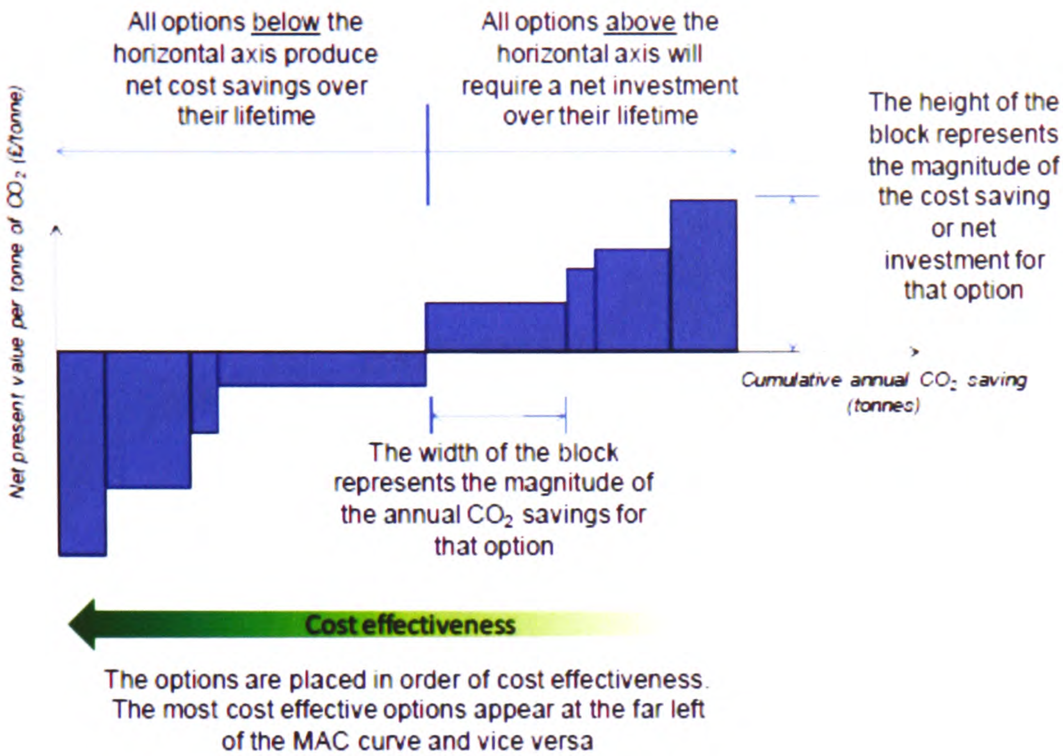


Figure 5.3 An explanation of how to interpret a MAC Curve from National Health Service, Sustainable Development Unit (2010, p.12).

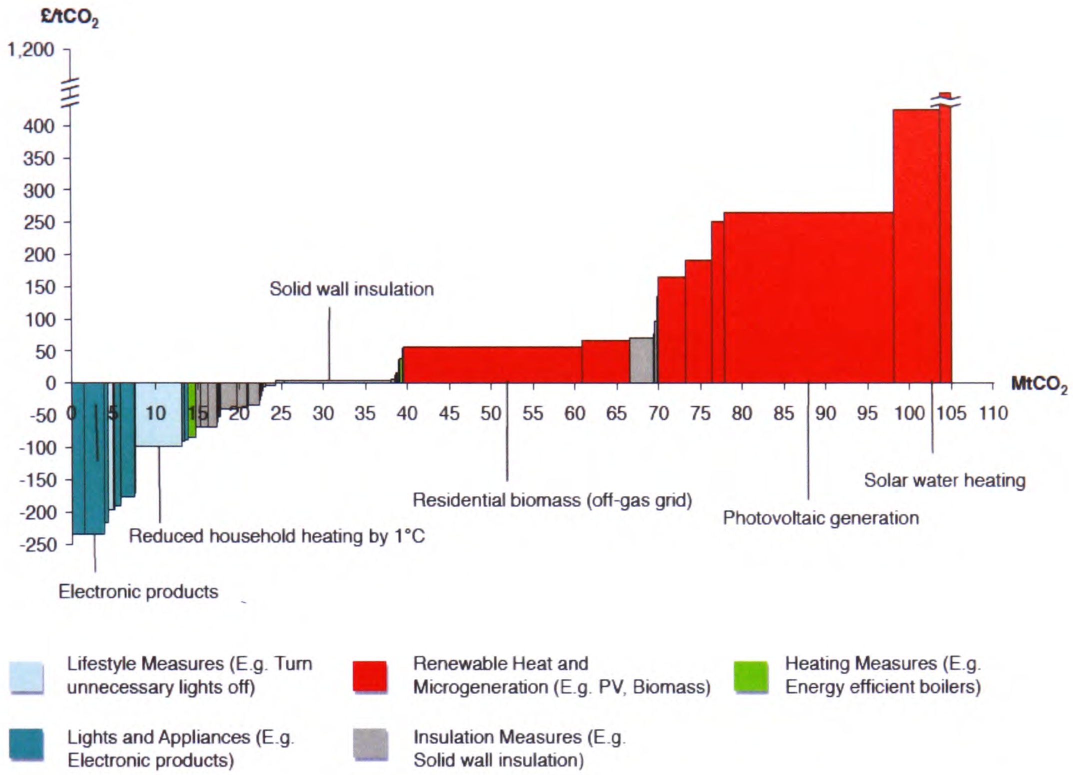
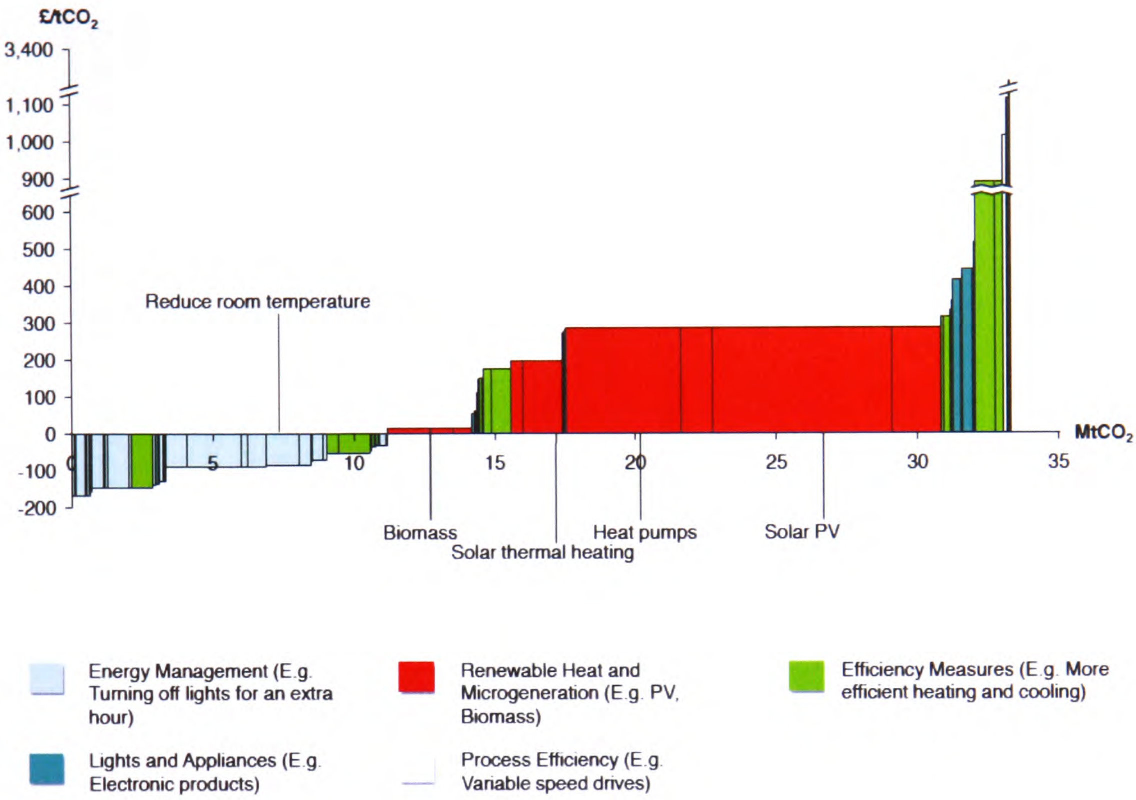


Figure 5.4 Marginal abatement cost curve in 2020 for residential buildings at the UK level, 2008 , as cited in SQWenergy, SQWconsulting (2009, p. 18) from Committee on Climate Change (2008, p.221).



Source: Committee on Climate Change, 2008

Figure 5.5 Marginal abatement cost curve in 2020 for non-residential buildings at the UK level, 2008, as cited in SQWenergy, SQWconsulting (2009, p. 19) from Committee on Climate Change (2008, p.226).

SQWenergy, SQWconsulting (2009, p. 18-19) referenced the particular MACCs shown above in figures 5.4 and 5.5. The information they provided was later summarised by Higher Education Funding Council for England (2010a, p. 16) HEFCE to form a table entitled "Costs and benefits of the six most viable intervention to reduce carbon emissions in HE" which is shown below in table 5.8.

	Cost-effectiveness (lifecycle)* (£/tCO_2)	Estimated abatement potential for the sector ($MtCO_2$)	Investment (£million)	Net benefits by 2020 (£million)
Behavioural change and new ways of working	-300 to -400	0.2	Minimal: interventions often only require human resources or integration into existing budgets and initiatives, such as staff/student induction, training and internal marketing activities.	50-70
Lights and electric appliances (including ICT)	-100 to -200	0.02 to 0.35	0.3 to 5.0	3 to 50
Building energy and space management	average of -150	1	30 to 50	150
Building fabric upgrade	-50 to -100	0.28	Hundreds of millions	15
Efficient energy supply (CHP/tri-generation, district heating)	Average can be taken as neutral (£0/tCO2). Most standard on-site CHP options are cost-effective, but depending on the circumstances (for example location, demand density) these, as well as district heating, could be non-cost-effective	0.05	Tens of millions	Marginal, yet positive

	Cost-effectiveness (lifecycle)* (£/tCO_2)	**Estimated abatement potential for the sector ($MtCO_2$)**	**Investment (£million)**	**Net benefits by 2020 (£million)**
Renewable energy	200 to 300. There is a sub-set of technologies that are more cost-effective, such as biomass boilers, solar water heating and ground-source heat pumps.	0.3 to 0.6	100 to 130	These should be increasingly cost-effective closer to 2020 due to falling capital costs.

Table 5.8 HEFCE's assessment of costs and benefits of the six most viable interventions to reduce carbon emissions in HE, from Higher Education Funding Council for England (2010a, p. 16).

* These figures are based on Marginal Abatement Cost Curves. These are an assessment and decision-making tool regarding carbon-reduction interventions. The absolute cost-effectiveness is the cost (£) of saving a tonne of carbon (tCO_2) calculated on a lifecycle basis, capturing all costs and revenues and factoring in inflation and amortisation. A negative figure indicates that the intervention will generate net cost savings/revenues over its life.

The relative cost effectiveness of these measures is summarised below.

Intervention	Cost-effectiveness (lifecycle)* (£/tCO_2)
Behavioural change and new ways of working	-300 to -400
Lights and electric appliances (including ICT)	-100 to -200
Building energy and space management	average of -150
Building fabric upgrade	-50 to -100
Efficient energy supply (CHP/tri-generation, district heating)	Average can be taken as neutral (£0/tCO2). Most standard on-site CHP options are cost-effective, but depending on the circumstances (for example location, demand density) these, as well as district heating, could be non-cost-effective
Renewable energy	200 to 300. There is a sub-set of technologies that are more cost-effective, such as biomass boilers, solar water heating and ground-source heat pumps.

Table 5.9 HEFCE's assessment of the cost effectiveness of the six most viable interventions to reduce carbon emissions in HE, from Higher Education Funding Council for England (2010a, p. 16).

Based on table 5.9 it can be seen from the categorised interventions, renewable energy is the only intervention that has a positive cost-effectiveness (lifecycle) (£/tCO_2) value. Meaning that the intervention will not result generate in or generate sufficient savings over its lifetime to cover associated costs.

5.10 Funding Improvements

Winsum, A., James, P. (no date) reported that “Experience shows that some of these improvements can be achieved through no-cost measures such as raising awareness and changes in behaviour. However, the majority of reduction opportunities will involve some capital expenditure”.

5.10.1 Barriers to Investment in Energy Efficency

Winsum, A., James, P. (no date) further remarked that “unfortunately, there are several reasons why investments in energy efficiency in higher education can be difficult to make including:

An understandable management focus on key organisational objectives such as attracting students or research findings, resulting in energy conservation having a low priority

A lack of capital resulting in ‘essential’ investments rather than apparently optional ones such as energy efficiency, or only on investments with very short paybacks

Funding mechanisms, which sometimes means that capital costs are borne from project budgets but energy costs are not (or only for the project’s duration, even though they will carry on for longer).”

These barriers will need to be circumvented if the HE sector is to meet long-term CO_2 emissions reduction targets. Reductions in energy consumption reduce revenue costs which could be used to provide a source of funding for projects with short-term paybacks or to facilitate repayments for loan funding.

5.10.2 External Funding

External funding could be a useful solution to the barriers that exist to capital investment in energy efficiency highlighted above.

A major source of external funding for HEIs currently available is from Salix Finance (2012a) who describe themselves as "an independent, not-for-profit company funded by DECC and the Welsh and Scottish Governments…".

Salix Finance (2012a) report as of October 2012 they have "… funded over 9,000 projects with 662 public sector bodies, valued at £194m, saving the public sector £56m annually and £750m over project lifetimes."

Salix Finance (2012b) explain that in Wales:

> Projects must comply with the following criteria:
>
> - the project must pay for itself in energy savings within a maximum 8 year period
> - the cost of CO_2 must be less than £200 per tonne over the lifetime of the project
> - the project must be "additional" (see below)
>
> There is a minimum value for any single project of £500 and a total minimum application and loan value of £5,000. There is no maximum level for an application.

5.10.3 Renewable Energy Incentives

Whilst renewable energy has been shown to be the least cost effective of the potential interventions, UK Governments have introduced schemes offering financial incentives to increase the uptake of such technologies (Great Britain. Department of Energy and Climate Change, 2012b).

The schemes currently applicable to HE are:

- Feed in Tariff (FIT)
- Renewable Heat Incentive (RHI)

The UK Government (Great Britain. Department of Energy and Climate Change, 2012c) indicate that the "Small-scale low-carbon electricity technologies eligible for FITs are:

- wind
- solar photovoltaics (PV)
- hydro
- anaerobic digestion
- domestic scale microCHP (with a capacity of 2kW or less)"

They further describe "the three financial benefits from FITs:

- Generation tariff – the electricity supplier of your choice will pay you for each unit (kilowatt) of electricity you generate
- Export tariff – if you generate electricity that you do not use yourself, you can export it back to the grid. You will be paid for exporting electricity as an additional payment (on top of the generation tariff)
- Energy bill savings – you will not have to import as much electricity from your supplier because a proportion of what you use you will have generated yourself, you will see this impact on your electricity bill."

As a consequence of these payments a number of third parties including energy suppliers have been offering to install systems without any capital expenditure on the part of the Client, these arrangements are sometimes referred to as "rent-a-roof" schemes.

Key aspects of the RHI are described by the (Great Britain. Department of Energy and Climate Change, 2012d) as:

- "Support for a range of technologies and fuel uses including solid and gaseous biomass, solar thermal, ground and water source heat-pumps, on-site biogas, deep geothermal, energy from waste and injection of biomethane into the grid.

- Support for all non-domestic sectors including: industrial and the commercial sector; the public sector; not-for-profit organisations and communities in England, Scotland and Wales.
- RHI payments to be claimed by, and paid to, the owner of the heat installation or the producer of biomethane.
- Payments will be made quarterly over a 20 year period.
- For small and medium-sized plants (up to and including 45kWth), both installers and equipment to be certified under the Microgeneration Certification Scheme (MCS) or equivalent standard, helping to ensure quality assurance and consumer protection.
- Tariff levels have been calculated to bridge the financial gap between the cost of conventional and renewable heat systems, with additional compensation for certain technologies for an element of the non-financial cost.
- Heat output to be metered and the support calculated from the amount of eligible heat, multiplied by the tariff level.
- Biomass installations of 1 MWth capacity and above will be required to report quarterly on the sustainability of their biomass feedstock for combustion and where they are used to produce biogas."

With both incentive schemes actual tariffs are particular to individual technologies and are under continual review.

These incentives are designed to improve the cost-effectiveness of renewable energy interventions and it is essential that they are considered as part of any financial assessments of proposed renewable energy schemes.

5.10.4 Future Funding Options

An innovative financing mechanism is planned to be introduced in October 2012 and a summary given by (Great Britain. Department of Energy and Climate Change, 2012e) states that:

> The Energy Act 2011 includes provisions for the 'Green Deal', which intends to reduce carbon emissions cost-effectively by transforming the energy efficiency of British properties...

The scheme will be open to non-domestic properties and will allow a range of interventions to be financed whilst providing reassurances that repayments will be covered by savings on energy bills. At the time of writing the finer details of the scheme have not yet been finalised.

6.0 Sector Analysis

Some of the the aims of the study that were outlined within chapter 2 can be summarised as follows:

- Establish scope 1 and scope 2 CO_2 emissions baselines for individual HEIs and hence the HE sector within Wales using absolute and specific metrics.
- Evaluate existing emissions trends against published targets.
- Benchmark the existing Welsh HE estate as the basis for quantifying potential improvement.
- Define and analyse an exceptional case study.
- Identify the most appropriate abatement strategies to achieve the required level of CO_2 emission reductions.
- Determine whether CO_2 emission reduction targets are economically achievable.

Whilst many of these aims are addressed within this chapter they are critically evaluated and discussed more fully within chapter 8.

6.1 Targets and Baselines

The Literature Review identified differing targets and baselines applicable to the English and Welsh HE sectors (refer to table 5.1). Measured to 2020 these were:

- A 38% (collective) reduction target against a 2005 baseline in England. A 1990 baseline was also calculated by HEFCE primarily to enable direct comparison against UK wide targets to inform sectoral target setting against the 2005 baseline.
- A 27% reduction target against a 2005-2010 (averaged) baseline in Wales.

To distinguish between the requirements placed upon English and Welsh HEI's it was necessary to generate similar performance baselines for individual Institutions to establish an overall Welsh HE sector baseline.

6.1.1 Baseline Calculation Methodology

To ensure consistency with analysis of the English HE sector, the approach adopted by Higher Education Funding Council for England (2010c, p. 4) was followed. "Energy consumption data for each institution was converted into carbon dioxide emissions by applying the latest standard Gross Calorific Value (CV) conversion factors from DEFRA 2010."

These can be summarised as:

Fuel	**$kgCO_2$ per unit**			
Unit:	kW·h	Therm	Litre	Tonne
Natural gas	0.18523	5.4286		
Burning oil	0.24683		2.5421	3,164.9
Coal (industrial)	0.32227			2336.5
Petrol	0.24176		2.3220	3162.6
Diesel	0.25301		2.6720	3201.1
Electricity	0.53909*			

Table 6.1 Conversion Factors used by SQW Consulting in recent research for Higher Education Funding Council for England (2010c, p. B-1).

* "For the calculation of electricity emissions for the 2005 baseline (2005/06 academic year), an average of the carbon conversion factors for 2005 and 2006 was used."

Whilst acknowledging that these conversion factors had been updated in 2011, the 2010 factors were retained for calculating Welsh baselines to permit an approach consistent with the Higher Education Funding Council for England (2010c, p. B-1).

Scope 1 emissions were calculated from the sum of fossil fuel consumption data with the addition of a 0.71% allowance for vehicle fleet emissions, again to be consistent with the approach adopted by the Higher Education Funding Council for England (2010c, p. 6).

Scope 2 emissions have been calculated directly from electricity consumption data.

Energy consumption data for 2005-06, 2006-07, 2007-08, 2008-2009 and 2009-2010 was obtained from within the EMS (see appendix A). As previously stated, the dataset within the EMS was complete for Welsh HEI's during the years 2005-2010 with the following exceptions:

- Energy consumption figures for Cardiff University were missing for 2006-2007, 2007-2008 and 2008-2009. For the purpose of this study they were obtained directly from Cardiff University (refer to appendix B for raw data). As Individual HEIs are the original source of data within the EMS they were accepted as having equal validity to the remainder of the dataset.
- For Glyndwr University there was an absence of energy consumption data for all five years under consideration however all other data required was available for this Institution. As the GIA of Glyndwr accounted for c. 3.5% of the total Welsh HE estate, it was decided that estimating data was an approach unlikely to significantly distort overal results or conclusions. Gas and electricity consumption data was derived from multiplying the sectoral median relative consumption (kW·h/m^2) by the GIA of Glyndwr University for each of the five years. A summary of the estimation calculation is shown in appendix C.

6.1.2 Baseline Year 2005

HEFCE's baseline is a straightforward total of emissions during 2005 based on this being the earliest year for which robust data was available for the sector.

The Welsh HE sector CO_2 baseline for 2005 was calculated as 0.106 $MtCO_2$ (see table 6.2) using the methodology described within 6.1.1.

Using a single year as a baseline would not necessarily be representative as it will be susceptible to weather fluctuations this is illustrated by referring to degree day data (see tables 5.4 and 5.5) for this particular year which shows degree days for the period covered by this study and the 20 year average:

- c.1% below the 20- year average for Wales
- c.8% above the 20-year average for Severn Valley

Further details including individual baselines for each of the Welsh HEIs are shown in table 6.2.

6.1.3 Baseline 2005-2010 Average

The Wales Assembly Government (2010, p.35) stated that:

> To measure the target, we will compare the relevant emissions in each year from 2011 onwards to a baseline. This baseline will be an average of the relevant emissions between 2006 and 2010.
>
> Beginning with 3% in 2011, the target is to reduce greenhouse gas emissions by an additional 3% of the baseline in each subsequent year. The baseline has been selected to ensure that it is as up to date as possible, and representative of our emissions levels at the start of the target period.

For the purposes of this study the same CO_2 conversion factors as used to calculate the 2005 baseline were applied to each of the five years. Total emissions for each of the five years were then averaged to determine the Welsh Government's baseline for the HE sector in Wales.

The Welsh HE sector CO_2 baseline for 2005 was calculated as 0.111 $MtCO_2$ (see table 6.2) using the methodology described within 6.1.1 and above.

Further details including individual baselines for each of the Welsh HEIs are shown in table 6.2.

6.1.4 Baseline Year 1990

As previously stated, HEFCE also calculated a 1990 baseline to enable comparison against UK targets. As datasets for 1990 were incomplete this baseline was derived from 2005 data for the purposes of informing target setting, The Higher Education Funding Council for England (2010b, p. 15) noted in their guidance that:

> ... institutions may wish to reference their targets against a 1990 carbon baseline for comparative purposes. It is recognised that estimates will vary in their accuracy. For institutions where relevant 1990 data are available from the 'Hull' statistics, more accurate estimates can be produced.

Two methods were tested by the Higher Education Funding Council for England (2010c, p. 5) with the following method applied

> .. using the group of 42 HEIs for which energy data were available for 1990 and adjacent years, but also taking their 2005 data to establish a carbon emissions trend per student FTE. The total emissions for the sample group were divided by the total number of students for both 1990 and 2005 and the percentage difference was established. The result showed that emissions per student in 1990 were on average 64% higher than in 2005 (the median percentage difference). Therefore, for the remaining HEIs, their known 2005 total emissions were divided by the number of students in 2005 and then increased by 64% to arrive at the

$kgCO_2$/student estimate for 1990. This figure was then multiplied by the number of students in 1990 to come up with the total emissions for the HEI in 1990.

The level of variation within the group of 42 HEIs for whom 1990 energy data are available is considerable. After excluding the outliers, results ranged from -56% to +159%. Most institutions in the sample, however, had higher emissions in 1990 and many were around the median of 64%. This is a plausible outcome as growth in student numbers has outpaced growth in energy consumption during this period.

The main **advantage** of this approach is its HEI-specific results. It uses the HEI's own and rather accurate 2005 carbon baseline and back-casts per FTE student emissions in 1990 applying a sector average trend. It acknowledges the fact that HEIs have different energy and carbon intensity (per student) on the basis of their estates portfolios and layout, as well as academic focus (mix of teaching and research). Given a similar mean change observed in the sample group (57%) and that many of the institutions had changes around the median of 64%, the modelled carbon estimate for all other HEIs for 1990 does not introduce a significant (and therefore unacceptable) level of error. The results are illustrative and provide consistency between institutions, but do, however, need to be used with caution as the level of accuracy is moderate to low. Given the changes to the sector and individual institutions since 1990, direct comparisons may also be misleading.

The **limitation** of this approach is that institutions that have been particularly effective at improving their carbon efficiency prior to 2005, for example through more efficient use of space, will show a lower initial carbon baseline in 1990, making absolute carbon reduction against 1990 more challenging."

As HEFCE urged caution due to the "moderate to low accuracy" of results using this method 1990 baselines for individual Welsh HEIs were not calculated as part of this study.

However, it was noted by the Higher Education Funding Council for England (2010a, p. 2) that "The sector targets for carbon emissions in scopes 1 and 2 are 34 per cent by 2020".....(against a 1990 baseline) and "Against a 2005 baseline, this is equivalent to a reduction of 43 per cent by 2020." Therefore for the purpose of comparisons of sectoral performance against UK targets this study has applied a 43% reduction to the 2005 baseline.

However, despite this and as identified within the literature review, the outcome of encouraging HEIs to set their own individual targets was HEFCE accepting a collective reduction target of 38%.

6.1.5 Relative Emissions

Having identified that the quantity of CO_2 emissions are affected by and related to a number of factors including growth and weather severity, the use of alternative metrics for calculating CO_2 baselines and setting targets was considered.

The following specific (or relative) metrics were calculated for individual HEIs both "Welsh" and "English" baseline years by dividing CO_2 emissions data by the "normalising factor" for the relevant year, a median value representative of the Welsh HE estate was also calculated:

- $kgCO_2$ per staff/student FTE
- $kgCO_2$ per £1 income
- $kgCO_2$ per m^2 GIA

The results in table 6.2 below and show large variations around the average values for the Welsh HE sector emphasising Institutional differences.

Institution	2005				2005-2010 Average			
	Total tCO_2	$kgCO_2$ per staff/student FTE	$kgCO_2$ per £1 income	$kgCO_2$ per m^2 GIA	Total tCO2	$kgCO_2$ per staff/student FTE	$kgCO_2$ per £1 income	$kgCO_2$ per m^2 GIA
Aberystwyth	**13,721**	1520	0.1778	0.0779	**13,801**	1481	0.1411	0.0768
Bangor	**14,931**	1603	0.1550	0.0831	**13,911**	1380	0.1265	0.0752
Cardiff	**27,796**	1012	0.0807	0.0681	**34,064**	1230	0.0874	0.0827
Cardiff Metropolitan	**7,568**	874	0.1267	0.0832	**6,956**	760	0.0982	0.0759
Glamorgan	**8,945**	672	0.0876	0.0847	**9,340**	615	0.0754	0.0821
Glyndŵr *	**3,441**	861	0.1260	0.0790	**3,790**	850	0.1411	0.0806
Lampeter	**2,664**	1245	0.2069	0.0915	**2,560**	1451	0.2190	0.0821
Newport	**4,447**	870	0.1239	0.0835	**4,323**	774	0.1008	0.0792
Swansea Metropolitan	**2,863**	590	0.1144	0.0567	**2,722**	550	0.0879	0.0526
Swansea	**17,217**	1356	0.1478	0.1122	**17,053**	1248	0.1220	0.1032
Trinity	**2,604**	1351	0.2222	0.0696	**2,606**	1393	0.1849	0.0728
Welsh HE Sector Totals	**106,198**	**1123.75**	**0.1204**	**0.0827**	**111,127**	**1071.42**	**0.1039**	**0.0813**

Table 6.2 CO_2 emissions baselines for Welsh HEIs – absolute and specific metrics calculated from raw data from the Higher Education Statistics Agency, see appendix A.

As targets for both the Welsh and English sectors are absolute with no weather correction permitted and targets in Wales are against a 5-year average baseline no further consideration has been given to normalising emissions data using degree days within this study.

6.1.6 Quantifying CO_2 Reductions

By applying the relevant percentage reduction targets to the "HEFCE" and "Welsh Governement/HEFCW" baseline years, the required CO_2 saving to 2020 was calculated for each scenario.

From the results it was noted that the Welsh Government's methodology resulted in higher baseline emissions. The cumulative effect of the higher baseline and lower percentage reduction target was that:

- Applying the Welsh Government's methodology identified an annual sectoral CO_2 reduction of 30,004 tonnes
- Wheras if HEFCE's methodolgy were applied the annual sectoral CO_2 reduction would rise to 40,355 tonnes

The calculation was also repeated to differentiate between actual emissions in 2009 and the proposed 2020 level of emissions. When measured on this basis, the majority (7 from 11) of the HEIs in Wales were shown to have greater emissions than for the Welsh Government's baseline.

Whilst this is indicative of a rise in their overall emissions it should be noted that 2009 was the coldest of the five years considered, with degree day values approximately 10% higher in 2009 than 2005 (see tables 5.4 and 5.5). This illustrates the risks associated with HEFCE's methodology of measuring against a single baseline year and highlights the benefit of the Welsh Government's approach of a 5-year average.

Institution	English HEIs Collective Target (38%)			Welsh Government Target (27%)		
	2005 Baseline Emissions tCO_2	2020 Target Emissions tCO_2	2020 Emissions Reduction tCO_2	2005-2010 Ave. Baseline Emissions tCO_2	2020 Target Emissions tCO_2	2020 Emissions Reduction tCO_2
Aberystwyth	13,721	8,507	**5,214**	13,801	10,075	**3,726**
Bangor	14,931	9,257	**5,674**	13,911	10,155	**3,756**
Cardiff	27,796	17,234	**10,563**	34,064	24,867	**9,197**
Cardiff Metropolitan	7,568	4,692	**2,876**	6,956	5,078	**1,878**
Glamorgan	8,945	5,546	**3,399**	9,340	6,818	**2,522**
Glyndŵr *	3,441	2,134	**1,308**	3,790	2,767	**1,023**
Lampeter	2,664	1,652	**1,012**	2,560	1,869	**691**
Newport	4,447	2,757	**1,690**	4,323	3,156	**1,167**
Swansea Metropolitan	2,863	1,775	**1,088**	2,722	1,987	**735**
Swansea	17,217	10,675	**6,542**	17,053	12,449	**4,604**
Trinity	2,604	1,614	**989**	2,606	1,902	**704**
Welsh HE Sector Totals	**106,198**	**65,843**	**40,355**	**111,127**	**81,123**	**30,004**

Table 6.3 CO_2 emissions reductions for Welsh HEIs against HEFCE and HEFCW Targets calculated from raw data from the Higher Education Statistics Agency, see appendix A.

**energy data for Glyndŵr University based on pro-rata estimate.*

Institution	English HEIs Collective Target (38%)					Welsh Government Target (27%)				
	2005 Baseline Emissions tCO2	2020 Target Emissions tCO2	2009-2010 Actual Emissions tCO2	2009-2020 Emissions Reduction tCO2	2009-2020 Emissions Reduction %	2005-2010 Ave. Baseline Emissions tCO2	2020 Target Emissions tCO2	2009-2010 Actual Emissions tCO2	2009-2020 Emissions Reduction tCO2	2009-2020 Emissions Reduction %
Aberystwyth	13,721	8,507	14,697	6,190	**42**	13,801	10,075	14,697	4,622	**31**
Bangor	14,931	9,257	13,589	4,331	**32**	13,911	10,155	13,589	3,433	**25**
Cardiff	27,796	17,234	36,868	19,635	**53**	34,064	24,867	36,868	12,001	**33**
Cardiff Metropolitan	7,568	4,692	6,694	2,002	**30**	6,956	5,078	6,694	1,616	**24**
Glamorgan	8,945	5,546	9,961	4,415	**44**	9,340	6,818	9,961	3,142	**32**
Glyndŵr *	3,441	2,134	4,365	2,232	**51**	3,790	2,767	4,365	1,599	**37**
Lampeter	2,664	1,652	2,499	847	**34**	2,560	1,869	2,499	630	**25**
Newport	4,447	2,757	4,291	1,534	**36**	4,323	3,156	4,291	1,135	**26**
Swansea Metropolitan	2,863	1,775	2,812	1,037	**37**	2,722	1,987	2,812	825	**29**
Swansea	17,217	10,675	17,949	7,274	**41**	17,053	12,449	17,949	5,500	**31**
Trinity	2,604	1,614	2,674	1,060	**40**	2,606	1,902	2,674	772	**29**
Welsh HE Sector Totals	**106,198**	**65,843**	**116,399**	**50,556**	**43**	**111,127**	**81,123**	**116,399**	**35,276**	**30**

Table 6.4 CO_2 emissions reductions for Welsh HEIs against HEFCE and HEFCW targets measured from a 2009-2010 baseline calculated from raw data from the Higher Education Statistics Agency, see appendix A.

**energy data for Glyndŵr University based on pro-rata estimate.*

6.2 Trend Analysis

When total scope 1 and 2 CO_2 emissions for the Welsh HE Estate were considered over the period considered by this study, an upward trend was noted.

The potential effect of the weather was also considered by plotting degree days for the Wales and Severn Valley regions against CO_2 emissions as shown in figure 6.1 below.

Figure 6.1 Total Welsh HE CO_2 emissions v. degree days derived from raw data from the Higher Education Statistics Agency, see appendix A and degree day data shown in tables 5.4 and 5.5).

Whilst this showed that degree days were generally rising between 2005 and 2009 it was observed that the CO_2 emissions profile does not track the degree days profiles closely, indicating that other factors may also be influencing this trend.

An increase in the size of the business would logically be a major factor and so was measured using commonly quoted metrics including the gross internal area (GIA) of the Estate, numbers of staff and students and financial income.

	GIA (m^2)	Staff/Student (FTEs)	Income (£s)	CO_2 Emissions (kg)
2005-06	1,328,003	98,501	909,106,000	106,198,004
2006-07	1,335,996	100,743	995,625,000	106,949,962
2007-08	1,347,992	103,782	1,081,167,000	107,677,190
2008-09	1,362,326	103,409	1,142,203,962	118,411,345
2009-10	1,463,378	112,160	1,220,279,000	116,398,638

Table 6.5 Welsh HE sector absolute growth against 2005-2006 baseline year from raw data from the Higher Education Statistics Agency, see appendix A.

This information was more easily assimilated by considering the percentage change in each of these vaues as shown below:

	GIA	Staff/Student (FTEs)	Income	CO_2 Emissions
2005-06	0.00	0.00	0.00	0.00
2006-07	0.60	2.28	9.52	0.71
2007-08	1.51	5.36	18.93	1.39
2008-09	2.58	4.98	25.64	11.50
2009-10	10.19	13.87	34.23	9.61

Table 6.6 Welsh HE sector percentage growth against 2005-2006 baseline year from raw data from the Higher Education Statistics Agency, see appendix A.

From the above table it can be seen that whichever metric was considered it was evident that the sector has grown in size. The rate of increase in the "growth metrics" was in most instances greater than the increase in CO_2 Emissions.

These results show that the GIA of the Welsh HE estate had similarly expanded to accomodate growth in the staff/student population albeit at a slightly lower rate suggesting a possible improvement in space utilisation.

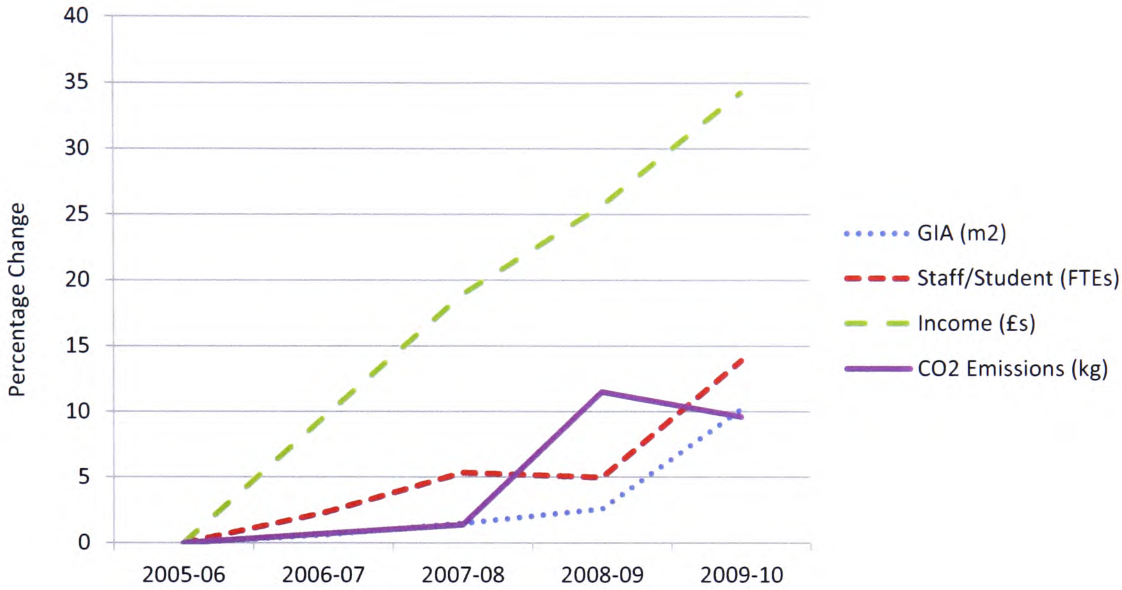


Figure 6.2 Welsh HE sector percentage growth against 2005-2006 baseline year derived from raw data from the Higher Education Statistics Agency, see appendix A.

As can be seen from figure 6.2 for most years there appeared be a limited correlation between CO_2 emissions, GIA and the staff/student population. However, as 2008-09 produced an outlier in CO_2 emissions the underlying data was re-checked but no errors were found.

However, there was little correlation evident between CO_2 emissions and income which increased more rapidly than the other data series. The additional rate of increase in income may be be linked to additional factors that would not be expected to influence energy consumption such as changes to funding mechanisms and inflationary pressures.

6.3 Benchmarking

A benchmarking exercise was conducted to investigate the potential for improvement that exists within the Welsh HE Estate. Fossil fuel and electricity consumption data for 2009 for each of the Welsh HEIs was compared to benchmarks produced by the Chartered Institution of Building Services Engineers (ed.) (2008) used as the basis for Display Energy Certificate (DEC) calculations.

Category 18 "university campus" of CIBSE TM46 provides the following benchmarks:

- Fossil Fuels - 240 kW·h/m^2
- Electricity - 80 kW·h/m^2

However, the literary review had established that in practice the ratio of individual energy sources can be affected by HEI specific factors. For example using combined heat and power which would increase fossil fuel consumption but reduce the use of grid electricity or using heat pumps to provide space heating which would have the opposite effect. Therefore a "total energy" benchmark of 320 kW·h/m^2 was used as the basis form which to assess the energy intensity of individual HEIs.

As there is a marked difference in CO_2 emissions arising from the energy sources within each of these categories and as targets refer to CO_2 reductions, benchmarking was also carried out against Illustrative CO_2 benchmarks to gain a more useful insight into the CO_2 intensity across the Welsh HE estate.

Within CIBSE TM46 "Illustrative CO_2 benchmarks" are quoted alongside "energy benchmarks" from which they have been derived. However, for consistency the Illustrative CO_2 benchmarks have been re-calculated applying CO_2 conversion factors consistently used throughout this study, i.e. 0.18523 kgCO_2/kW·h for natural gas and 0.53909 kgCO_2/kW·h for electricity. Similarly to the approach adopted in TM46 fossil fuel use has been taken to be 100% natural gas.

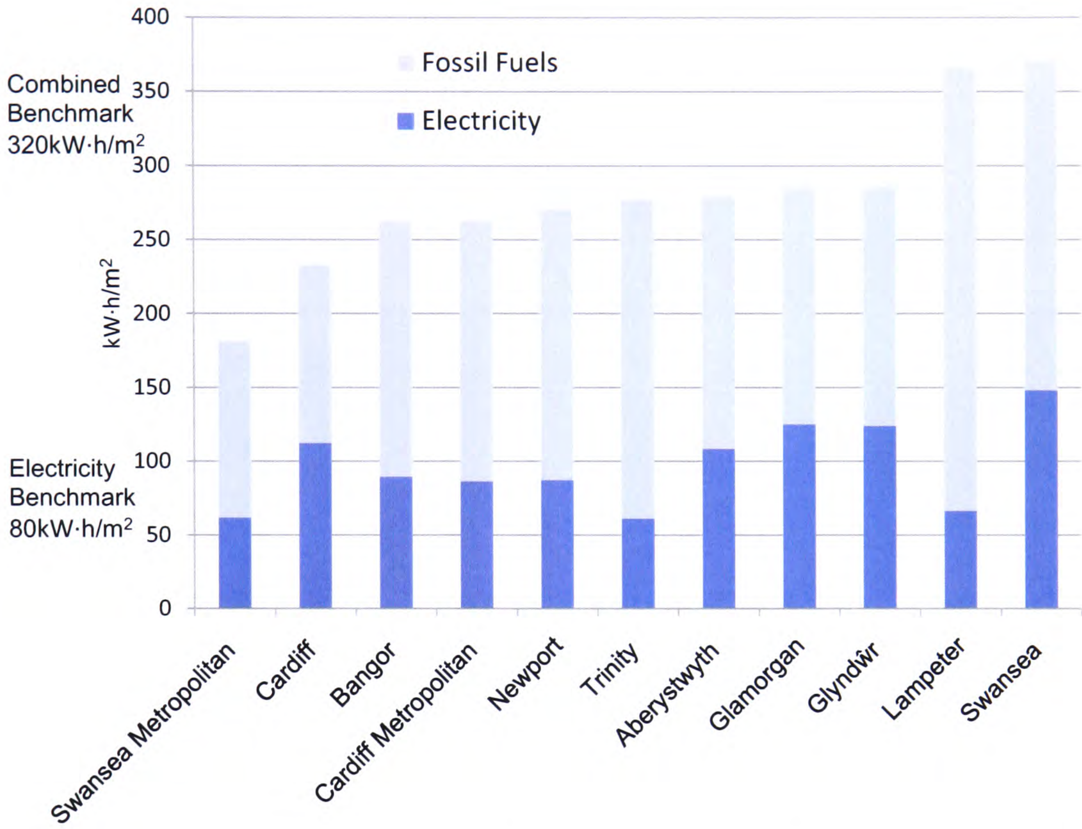


Figure 6.3 Energy consumption benchmarking of Welsh HEIs for 2009-2010 against CIBSE TM46:2008 derived from raw data from the Higher Education Statistics Agency, see appendix A.

Energy Benchmarks		Illustrative CO_2 benchmarks calculated from the energy benchmarks		
Electricity kW·h/m^2	Fossil-thermal kW·h/m^2	Illustrative Electricity $kgCO_2/m^2$	Illustrative Fossil Thermal $kgCO_2/m^2$	Illustrative Total Typical $kgCO_2/m^2$
80	**240**	**43.1**	**44.4**	**87.5**

Table 6.7 Illustrative CO_2 benchmarks derived from CIBSE TM46:2008 benchmark values.

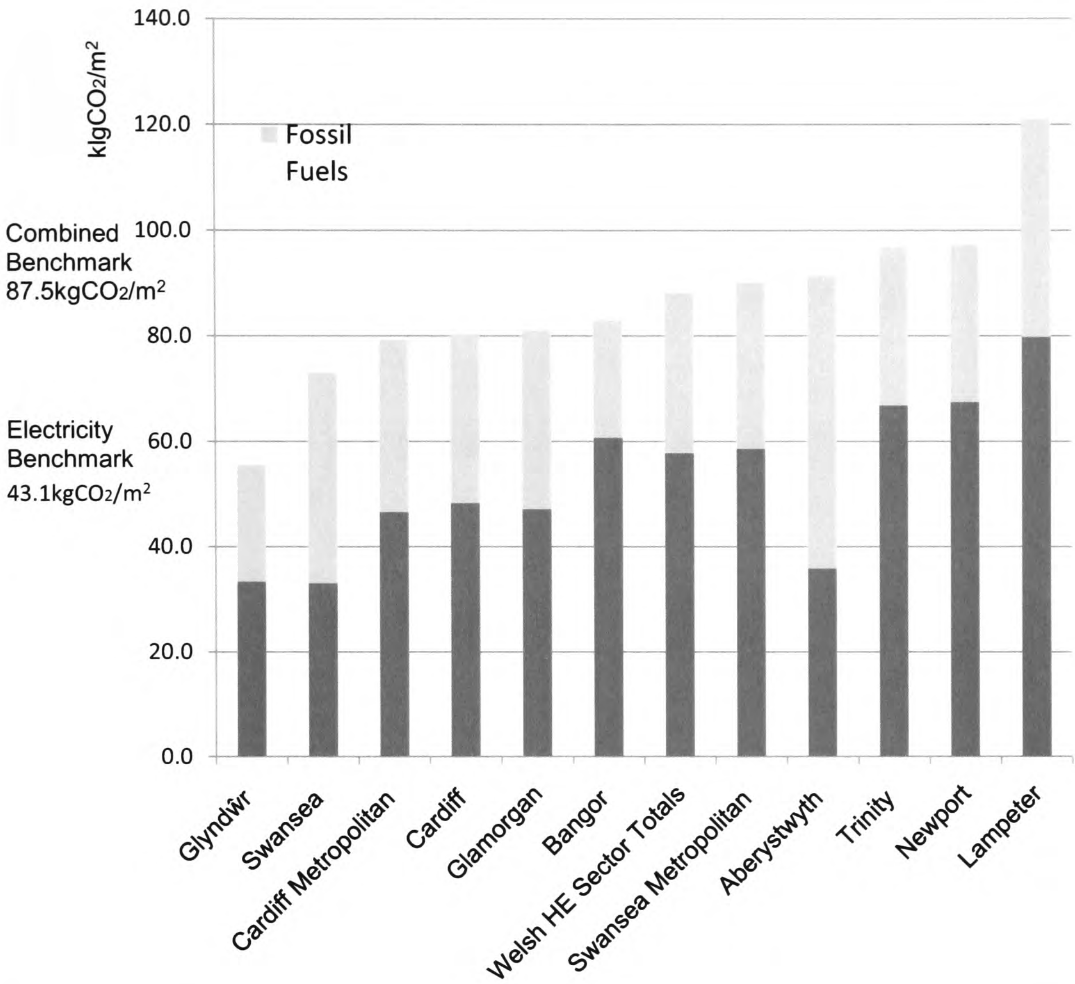


Figure 6.4 CO_2 emissions benchmarking of Welsh HEIs for 2009-2010 against CIBSE TM46:2008 derived benchmarks, from table 6.7, from raw data from the Higher Education Statistics Agency, see appendix A.

Institution	Fossil Fuels			Electricity			Total		
	CIBSE Benchmark kW·h per m^2	Actual Consumption kW·h per m^2	% Difference Against Benchmark	CIBSE Benchmark kW·h per m^2	Actual Consumption kW·h per m^2	% Difference Against Benchmark	CIBSE Benchmark kW·h per m^2	Actual Consumption kW·h per m^2	% Difference Against Benchmark
Aberystwyth	240	171	**-29**	80	109	**36**	320	280	**-13**
Bangor	240	173	**-28**	80	90	**12**	320	263	**-18**
Cardiff	240	121	**-50**	80	113	**41**	320	233	**-27**
Cardiff Metropolitan	240	177	**-26**	80	86	**8**	320	263	**-18**
Glamorgan	240	161	**-33**	80	125	**57**	320	286	**-11**
Glyndŵr *	240	162	**-33**	80	124	**55**	320	286	**-11**
Lampeter	240	300	**25**	80	67	**-17**	320	366	**14**
Newport	240	184	**-24**	80	87	**9**	320	271	**-15**
Swansea Metropolitan	240	223	**-7**	80	148	**85**	320	371	**16**
Swansea	240	120	**-50**	80	62	**-23**	320	182	**-43**
Trinity	240	216	**-10**	80	61	**-23**	320	277	**-13**
Welsh HE Sector Totals	**240**	**164**	**-32**	**80**	**107**	**34**	**320**	**271**	**-15**

Table 6.8 Benchmarking of Welsh HEIs for 2009-2010 consumption against CIBSE TM46 energy benchmearks calculated from from raw data from the Higher Education Statistics Agency, see appendix A.

**energy data for Glyndŵr University based on pro-rata estimate.*

Institution	Fossil Fuels			Electricity			Total		
	Benchmark $kgCO_2$ per m^2	Actual Emissions $kgCO_2$ per m^2	% Difference Against Benchmark	Benchmark $kgCO_2$ per m^2	Actual Emissions $kgCO_2$ per m^2	% Difference Against Benchmark	Benchmark $kgCO_2$ per m^2	Actual Emissions $kgCO_2$ per m^2	% Difference Against Benchmark
Aberystwyth	44.4	31.7	**-29**	43.1	58.5	**36**	87.5	90.2	**3**
Bangor	44.4	32.1	**-28**	43.1	48.3	**12**	87.5	80.4	**-8**
Cardiff	44.4	22.3	**-50**	43.1	60.7	**41**	87.5	83.0	**-5**
Cardiff Metropolitan	44.4	32.7	**-26**	43.1	46.6	**8**	87.5	79.3	**-9**
Glamorgan	44.4	29.7	**-33**	43.1	67.5	**57**	87.5	97.2	**11**
Glyndŵr *	44.4	30	**-32**	43.1	68.8	**55**	87.5	96.8	**11**
Lampeter	44.4	55.5	**25**	43.1	35.9	**-17**	87.5	91.4	**4**
Newport	44.4	34	**-23**	43.1	47.1	**9**	87.5	81.1	**-7**
Swansea Metropolitan	44.4	22.1	**-50**	43.1	33.4	**-22**	87.5	55.6	**-37**
Swansea	44.4	41.3	**-7**	43.1	79.9	**85**	87.5	121.1	**38**
Trinity	44.4	40	**-10**	43.1	33.1	**-23**	87.5	73.1	**-16**
Welsh HE Sector Totals	**44.4**	**30.3**	**-32**	**43.1**	**57.8**	**34**	**87.5**	**88.1**	**1**

Table 6.9 Benchmarking of Welsh HEIs for 2009-2010 consumption against CO_2 benchmarks derived from CIBSE TM46 calculated from raw data from the Higher Education Statistics Agency, see appendix A.

**energy data for Glyndŵr University based on pro-rata estimate.*

As expected, the results shown in table 6.9 indicated the same percentage differences for each HEI against benchmarks for individual energy sources whether measured on an energy or CO_2 emissions basis.

However, when considered against combined or total benchmarks results differed with the Welsh HE estate 15% below the total energy benchmark but a less favourable 1% above the total CO_2 emissions benchmark was considered This was attributed to the fact that the Welsh HE Estate compared less favourably against the more CO_2 intensive electricity benchmark.

Peer group benchmarking (excluding Glyndwr University as data was estimated) was also completed using the other relative emissions metrics identified in 6.2 of this chapter, i.e. Staff/student FTEs and income (£) for the latest year covered by this study.

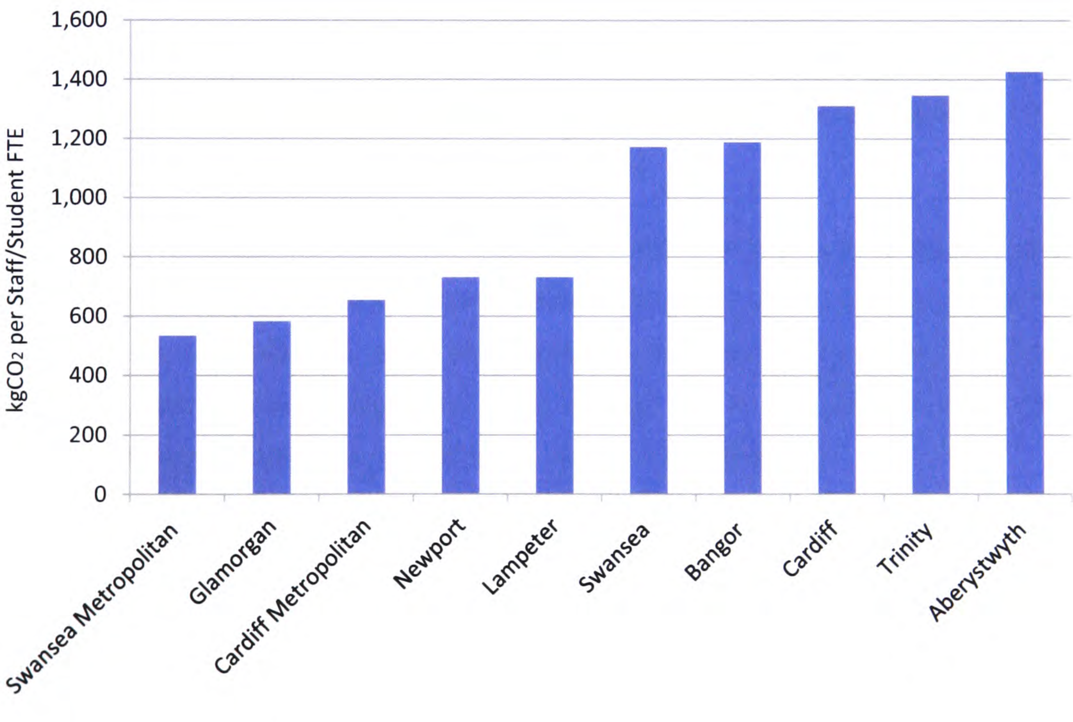


Figure 6.5 Welsh HEIs CO_2 emissions per Staff/Student FTE for 2009-2010, derived from raw data from the Higher Education Statistics Agency, see appendix A.

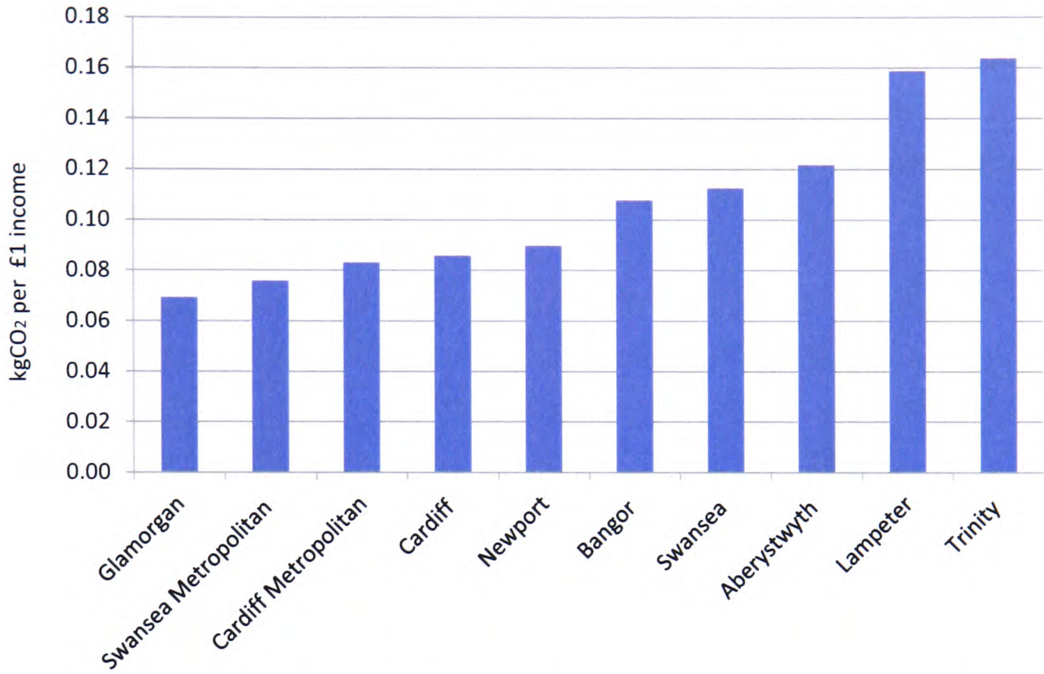


Figure 6.6 Welsh HEIs CO_2 emissions per £1 income for 2009-2010, derived from raw data from the Higher Education Statistics Agency, see appendix A.

The Welsh HE Estate as a whole benchmarked (refer to tables 6.8 and 6.9) at or slightly below "typical" which demonstrated that there was some potential for improvement. The results also highlighted that Welsh HEIs compare least favourably with the electricity benchmark and as this is the also the most CO_2 intensive energy source this should be an area for improvement.

Also noted was that the results showed a significant difference between the best and worst performing HEIs with individual rankings varying depending on the metric used. It is believed that this is indicative of institutional differences.

6.4 Identifying a Single Case Study

The main objective of conducting a single case study was to identify good practice which in this context meant succesfully reducing CO_2

emissions.Therefore in the first instance the percentage change in scope 1 and 2 emissions was plotted over the period 2005-2006 to 2009-2010. This revealed that emissions for the Welsh HE estate as a whole had increased with only 5 of the 11 HEIs managing to reduce emissions with the greatest improvement shown at Cardiff Metropolitan University.

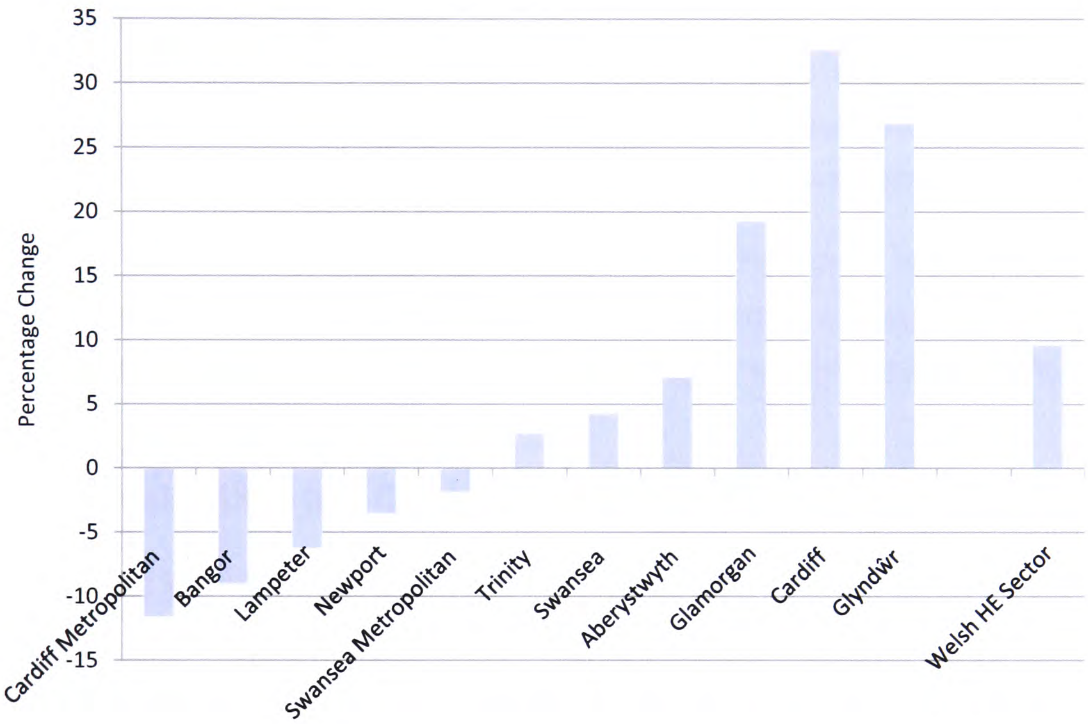


Figure 6.7 Welsh HE sector percentage change in CO_2 Emissions 2009-2010 against 2005-2006 baseline, derived from raw data from the Higher Education Statistics Agency, see appendix A.

The results of the previous benchmarking exercise were used to further inform the selection and again Cardiff Metropolitan performed well, consistently ranking third (equal third for kW·h/GIA) whichever metric was used.

An equally important consideration in the selection of a case study is access to research material and as the subject of several Carbon Trust Case Studies, Cardiff Metropolitan's strategies had been well documented and were backed up with good historical energy consumption data including work to differentiate between the cost effectiveness of interventions which would allow theoretical projections for the sector to be cross-checked with recent real data.

In addition the approach at this HEI which involved using automatic monitoring and targeting to affect behavioural change was non-standard and also offered potential for replication across the sector. This is also of particular interest because it was noted by SQWenergy, SQWconsulting (2009, p.35) that "Whilst technical solutions are currently being widely adopted across the sector, there are few sector-wide projects looking specifically at behavioural change...".,

As the author is also the Energy Manager at this HEI, there were additional benefits to be gained from an in depth and detailed local knowledge. However, it was noted that this would also necessitate self-vigilance to maintain objectivity.

6.5 Evaluating the Cost Effectiveness of Interventions

Reporting their research SQWenergy, SQWconsulting (2009, p. 17) noted that:

> Whilst Institutions have carried out an options appraisal, there are no sources that look at an HE sector level range of carbon-saving options. Such an exercise is possible but would require additional research, which is outside of the scope of this study. The challenge also relates to the fact that both technical and non-technical interventions exist, of which the latter are particularly difficult to quantify with confidence due to their less tangible nature (e.g. behavioural change).

SQWenergy, SQWconsulting (2009, p. 33) emphasised that "...no single solution is available to deliver the targets and a holistic aproach should be adopted".

The Higher Education Funding Council for England (2010a, p.15) identified the "six most viable interventions in terms of scale of impact and cost-effectiveness for the sector to be:

- Lights and electric appliances (including information and communication technologies (ICT))
- Building energy and space management
- Building fabric upgrade
- Efficient energy supply (combined heat and power (CHP)/tri-generation, district heating)
- Renewable energy
- Behavioural change and new ways of working

As highlighted within chapter 5 of this study, a table of "costs and benefits of the six most viable interventions to reduce CO_2 emissions in HE" was published by the Higher Education Funding Council for England (2010a, p.16), the figures within this table were extracted from marginal abatement cost curves produced by the Committee on Climate Change (2008) and assigned to the above categories.

The data contained within HEFCE's original table was adjusted using total scope 1 and 2 emissions for England and Wales in 2005 as the basis for a pro-rata adjustment to account for the lower emissions levels within Wales.

Scope 1 and 2 emissions for 2005 were taken as 2.046 $MtCO_2$ and 0.106$MtCO_2$ respectively given a ratio of 19.3 or 20 as an approximation for the pro-rata adjustment to produce the results as shown in table 6.10 below.

	Cost-effectiveness (lifecycle)* (£/tCO_2)	**Estimated abatement potential for the sector ($MtCO_2$)**	**Investment (£million)**	**Net benefits by 2020 (£million)**
Behavioural change and new ways of working	-300 to -400	**0.01**	**Minimal:** interventions often only require human resources or integration into existing budgets and initiatives, such as staff/student induction, training and internal marketing activities.	**2.5 - 3.5**
Lights and electric appliances (including ICT)	-100 to -200	**0.001 to 0.0175**	**0.015 to 0.25**	**0.15 to 2.5**
Building energy and space management	average of -150	**0.05**	**1.5 to 2.5**	**7.5**
Building fabric upgrade	-50 to -100	**0.014**	**Hundreds of millions ÷ 20**	**0.75**
Efficient energy supply (CHP/tri-generation, district heating)	Average can be taken as neutral (£0/tCO2). Most standard on-site CHP options are cost-effective, but depending on the circumstances (for example location, demand density) these, as well as district heating, could be non-cost-effective	**0.0025**	**Tens of millions ÷ 20**	Marginal, yet positive

	Cost-effectiveness (lifecycle)* (£/tCO_2)	Estimated abatement potential for the sector (MtCO_2)	Investment (£million)	Net benefits by 2020 (£million)
Renewable energy	200 to 300. There is a sub-set of technologies that are more cost-effective, such as biomass boilers, solar water heating and ground-source heat pumps.	**0.15 to 0.03**	**5 to 6.5**	These should be **increasingly cost-effective closer to 2020** due to falling capital costs.

Table 6.10 HEFCE's assessment of costs and benefits of the six most viable interventions to reduce carbon emissions in HE, from Higher Education Funding Council for England (2010a, p. 16).

The net benefits and estimated abatement potential was then extracted and expressed as a percentage of total Welsh HE sector scope 1 and 2 emissions which were taken as being the "Welsh Government baseline" of 111,127 tonnes.

The following results were obtained which indicated that CO_2 reductions of up to 98.3% may be possible with annual financial savings exceeding £14M. The findings of the single case study, detailed within chapter 7, were then used to verify the magnitude of the projected savings and the results are discussed further in Chapter 8.

	Estimated abatement potential for the sector ($MtCO_2$)	**Net benefits by 2020 (£million)**	**% CO_2 Reduction**
Behavioural change and new ways of working	0.01	2.5 to 3.5	9.1
Lights and electric appliances (including ICT)	0.01 to 0.175	0.015 to 0.25	0.9 to 1.6
Building energy and space management	0.05	7.5	45.4
Building fabric upgrade	0.014	0.75	12.7
Efficient energy supply (CHP/tri-generation, district heating)	0.0025	?	2.3
Renewable energy	0.015 to 0.03	?	13.6
Welsh HE Total	**0.0925 to 0.124**	**10.9 to 14.25 +**	**84 to 98.3**

Table 6.11 Benefits of the six most viable interventions to reduce CO_2 emissions in the Welsh HE sector, from Higher Education Funding Council for England (2010a, p. 16).

6.6 Estimation of Required Investment

SQWenergy, SQWconsulting (2009, p. 16) in their report to HEFCE noted that "It is important to establish what carbon savings are possible in practice in the HE sector and what their cumulative impact could be vis-a-vis the carbon baseline..." and that "...in theory, all (100%) of the carbon emissions can be saved – this is ultimately a question of cost."

The abatement measures highlighted by HEFCE as the six most cost effective were shown in the previous section to have the potential to collectively exceed Welsh Government targets to 2020 by a factor of 3, indicating that it would not be necessary to implement all of these measures. Therefore, it was decided to focus on the costs and benefits of the three most cost-effective measures.

	Estimated abatement potential for the sector ($MtCO_2$)	**Investment (£million)**	**Net benefits by 2020 (£million)**
Behavioural change and new ways of working	0.01	Minimal	2.5 to 3.5
Lights and electric appliances (including ICT)	0.01 to 0.175	0.015 to 0.25	0.15 to 2.5
Building energy and space management	0.05	1.5 to 2.5	7.5
Welsh HE Total	**0.025 to 0.235**	**1.515 to 2.75 +**	**10.15 to 13.5 +**

Table 6.12 Costs and benefits of the six most viable interventions in the Welsh HE sector to reduce CO_2 emissions, from Higher Education Funding Council for England (2010a, p. 16).

It was evident that investment levels were covered by a broad range at best or as in the case of behaviour change were poorly defined as "minimal." The intention of this study was to verify the validity of this data and/or provide a more accurate assessment of investment levels based on recent and real work through the case study.

The results of this work are discussed and evaluated within chapter 8.

7.0 Case Study

Cardiff Metropolitan University (2012a) formerly the University of Wales Institute, Cardiff describes itself as providing "education and training opportunities that are accessible, flexible and of the highest quality". Based on data from within the Estates Management Statistics (EMS) it is responsible for 10,000 students within five academic Schools and has a 91,982 m^2 estate arranged over four sites in and around Cardiff.

As detailed within chapter 6, CMU was identified as a single exceptional case study primarily on the basis of percentage reduction in scope 1 and 2 emissions measured between 2005 and 2009. However, the Institution was further distinguished when measured against peers and national standard benchmarks, consistently ranking in the top 3 of the 11 Welsh HEIs whichever metric was selected as shown in chapter 6.

Based on Welsh Government carbon baselines calculated within chapter 6, CMU's 6,956 tonnes of scope 1 and 2 emissions account for approximately 6.25% or $1/16^{th}$ of the Welsh HE sector total of 111,127 tonnes.

7.1 Evaluation of Interventions

In chapter 6, the three most cost effective abatement measures for the HE sector were ranked (see table 6.12) and shown to be:

- Behavioural change and new ways of working
- Lights and electric appliances (including ICT)
- Building energy and space management

CMU was shown to have been active in each of these areas and the data gathered from the Case Study was used to validate HEFCE's calculations and Carbon Trust Guidance for abatement measures in each of these categories.

Energy consumption data was reviewed to quantify reductions in both percentage and absolute terms.

7.2 Lights and Electric Appliances (including ICT)

This is a category of abatement measures that the Carbon Trust refer to as "Invest to Save" or energy efficiency technical projects which they define as including initiatives such as insulation, lighting controls, heat recovery, CHP, fuel policy, plant replacement and new technology. It was decided to consider examples within this category in the first instance as the evaluation of other abatement measures was dependent on the outcome.

Prior to 2006, CMU had been reliant on technical projects to improve energy efficiency, albeit the primary driver was often the need to replace ageing infrastructure. However, during 2005-2009 it was noted that only two significant energy efficiency technical projects were implemented, this was as a result of the level of resources devoted to the installation and commissioning of the aM & T system and the introduction of a structured behavioural change programme.

The two projects implemented were:

- The installation of a new lighting management system (LMS) within the National Indoor Athletic Centre (NIAC).
- The installation of a new lighting control system at the Cyncoed campus Tennis Centre.

7.2.1 Overview of Lighting Management System at the National Indoor Athletics Centre (NIAC)

Cardiff Metropolitan University (2012b) describe the National Indoor Athletics Centre (NIAC) at CMU's Cyncoed campus "as the first purpose built indoor athletics track anywhere in the UK... The facility is fully equipped to international standard and has a seating capacity for 690 spectators."

NIAC is utilised by the School of Sport and is also accessible to the general public and can accommodate other sports including badminton, netball and basketball. The building also accommodates a range of office, changing, training, treatment and sports science facilities.

Lighting within the main arena is a mixture of fluoresecent and metal halide fittings.

This project related to replacement of the existing "Phillips Lightmaster" LMS with a system based upon CMU's Satchwell TAC Micronet Building Energy Management System (BEMS), enabling CMU's Sports Facilities staff to operate the lighting system within the sports arena from an office PC serving as the "front end" in a more user-friendly manner at a cost of £42.9k.

As the new system is supported by a more cost-effective local contractor rather than a lighting manufacturer's specialist engineer, CMU found it affordable to continue to refine the software to satisfy user requirements and further improve energy efficiency. A low level of background lighting is automatically switched on and off to coincide with normal hours of operation and Sports Facilities staff select additional lighting as required using the LMS. Each selection is linked to an activity or area of the arena and programmed to automatically switch off after a pre-determined period.

7.2.2 Overview of Tennis Centre Lighting System

The tennis centre at CMU's Cyncoed campus houses 4 indoor courts and also provides toilets, changing rooms, office and reception area. The facility is used extensively by the School of Sport but is also acessible to the general public on a bookable basis.

The tennis court hall lighting system comprises of 2 rows of T8 fluorescent fittings over the length of each court, originally controlled from the reception desk and it had been noted that lights had often been left on when the courts were not in use. In addition, courts were overlit as the lighting level had originally been designed to meet competition standards and was far higher than required for general recreational use. The new lighting control system was therefore designed to provide a lower level of lighting sufficient for recreational purposes as standard automatically activated by microwave occupancy detectors. The higher "competition" lighting level is achieved by the manual operation of a run-back timer located on individual courts.

Lighting in other areas were operated by localised manual switches leading to similar problems with lights being left on. This was addressed in some of these areas by the installation of passive infra-red (PIR) occupancy sensors in changing rooms and toilets.

7.2.3 Summary of Results for Lighting Projects

Results from the two projects are summarised below:

Project Title	**Pre-project Electricity Cons. (kW·h)**	**Post-project Electricity Cons. (kW·h)**	**Reduction in Annual Electricity Cons. (kW·h)**	**Absolute Reduction in CO_2 emisisions (tonnes)**	**Reduction %**
LMS at NIAC (1)	580,557	527,630	52,927	28.5	9.1
Tennis Centre Lighting Controls (2)	119,614	98,960	20,654	11.1	17.3
Total	**700,171**	**626,590**	**73,581**	**39.6**	**10.5**

Table 7.1 Summary of annual energy consumption and CO_2 emissions reductions for selected energy efficiency technical projects at Cardiff Metropolitan University.

NOTES:

1. Energy consumption data from EMS for 2007 and 2008.
2. Energy consumption data from aM & T system June 2007 to May 2008 and June 2008 to May 2009.

The project implementation costs and financial benefits are summarised in the table below:

Project Title	Project Cost £ks	Pre-project Electricity Cost £ks	Post-project Electricity Cost £ks	Electricity Cost Saving	Simple Payback (years)
LMS at NIAC	42.9	66.2	60.1	6.1	7.0
Tennis Centre Lighting Controls	4.2	13.6	11.3	2.4	1.8
Total	**47.1**	**79.8**	**71.4**	**8.5**	**5.5**

Table 7.2 Financial analysis for selected energy efficiency technical projects at Cardiff Metropolitan University

NOTES:

1. Electricity costs based on average of 11.4p/kW·h.
2. Project costs from CMU financial records.

7.3 Behavioural Change and New Ways of Working

This is an area also referred to by the Carbon Trust as "Good Housekeeping" which Evans (2012) explain they define as including activities such as monitoring and targeting, awareness raising, training, regular inspection and audit and DEC compliance.

CMU has been working to affect behaviour change through a range of initiatives during the period covered by the study but most notably through the introduction of a monitoring and targeting methodology.

This began when a partnering agreement was formed with a local energy management company Remote Utility Monitoring and Management (RUMM) Ltd. and a pilot scale aM & T installation completed in 2006 on behalf of HEFCW which later became the subject of a Carbon Trust Exemplar Visit.

Following the success of the pilot project, HEFCW were able to secure £3.5M of ring-fenced funding from the Welsh Government to roll out full scale systems across the HE sector.

This further funding allowed CMU to build on their system to permit the collection of data from more than 200 utility meters at half-hourly intervals providing coverage at building level for gas, water and electricity.

The data collected is transferred via CMU's data network, an on-site server and external web links to RUMM's web visualisation server to facilitate the user-friendly display of half-hourly data. The capital cost of this installation was approximately £290k with a further £79k spent each year on maintenance, consultancy and bureau services.

The availability of half-hourly data provided CMU with the ability to pro-actively manage energy use. In addition, when reliable historical consumption profiles were established the aM & T system was also configured to raise "out of range" alarms to monitor usage and provide early warning of waste. The recording of accurate energy consumption data at building level also facilitates the creation of meaningful DECs based on actual energy use.

As an outcome of participating in the Carbon Trust's Higher Education Programme and to maximise the return on the investment in the aM & T system, Cardiff Metropolitan University (2012b) implemented a 5-year Strategy and Implementation Plan.The SIP details a "textbook" M & T approach whereby utility reduction targets of 3% per annum are delegated to key managers throughout the HEI.The approach is designed to promote behaviour change through existing line management structures thereby reinforcing ownership.

Each Manager receives a monthly report or scorecard detailing performance against targets within their areas of responsibility. Regular meetings are facilitated by RUMM to support managers in identifying and progressing actions to improve performance.

More conventional awareness raising activities are also carried out within the broader context of sustainability including themed days and "Go Green" weeks. An example being sustainability awareness training was delivered to more than 160 staff in 2006 and is now incorporated into staff inductions sessions for all new starters.

Regular auditing of buildings is carried out through a variety of methods, including DEC Advisory Reports, EPBD Air Conditioniong Inspections, Carbon Trust Opportunities Assessments and "out of hours" Site Audits, the latter often presented as a short video clip for maximum impact.

To quantify the effectiveness of CMU's approach to affecting behaviour change it was decided to identify the reductions achieved from other abatement measures, i.e. energy efficiency technical projects and subtract them from the total reductions in scope 1 and 2 CO_2 emissions.

Whilst the limitations of this approach were recognised, as changes could be attributed to many other factors such as variations in the weather, GIA of the

Estate, staff and student numbers, etc. However, earlier analysis had shown that all of these factors were greater in 2009 than 2005. It was decided that results were more likely to be understated than overstated and that the assessment was likely to be a conservative one.

During the period 2005-2009 it was determined that as CMU's resources were mainly directed at the installation, commissioning and operation of their aM & T system, only two energy efficiency projects were implemented. These projects were evaluated in the previous section and the savings identified have been used to derive the reductions due to behaviour change as shown below.

	Annual Consumption (kW·h)		Absolute CO_2 Emisisions (tonnes/year)		
	Fossil Fuels	**Electricity**	**Fossil Fuels**	**Electrical**	**Total**
2005	16,064,896	8,497,105	2,978.7	4,580.7	7,559.4
2009	13,186,504	7,868,973	2,445.2	4,242.1	6,687.3
Overall Reduction	2,878,392	628,132	533.5	338.6	872.1
Reduction from Technical Projects	0	73,581	0	39.6	39.6
Reduction due to Behaviour Change	**2,878,392**	**554,551**	**533.5**	**299**	**832.5**

Table 7.3 Summary of energy consumption data and CO_2 emissions (excluding own vehicles) for Cardiff Metropolitan University for 2005-2006 and 2009-2010, from raw data from the Higher Education Statistics Agency, see appendix A.

These results demonstrated an 11% reduction in CO_2 emissions (excluding own vehicles) against a 2005 baseline. It was also noted that CMU apply this methodology to water consumption with similar effect. Whilst scope 3 emissions are outside of the scope of this study this does leave the Institution well placed to meet any future requirements and has improved the return on investment.

Chris Cowburn, Estates Consultant at the Higher education Funding Council Wales observed of Cardiff Metropolitan University (2012c) that:

> Behavioural change is a key element of energy efficiency that is often dismissed as being too difficult to embed on a long term basis. Cardiff Metropolitan University have shown that combining the metering and targeting technology funded by the Welsh Government with a concerted and determined effort to change behaviour can deliver significant savings with a very limited capital outlay.

7.4 Building Energy and Space Management

This is an area that is also described by the Carbon Trust as "Design and Asset Management" which Evans (2012) explained they define as including low CO_2 new build and property rationalisation.

A good example of this was found at CMU in the case of the re-provision of the Cardiff School of Management. This involved the construction of a new $7995m^2$ building at CMU's Llandaff campus allowing the existing 1960's built campus at Colchester Avenue to be sold. The capital cost of relocating the CSM to Llandaff after accounting for the resale value of Colchester Avenue was approximately £11M.

The building known as the Ogmore building (or O block) was opened in September 2010. Whilst this is outside of the defined timeframe of this study it was included as an exception, as it provided a valuable opportunity to evaluate this category of abatement measure at CMU. In addition as the analysis is based on a period beyond that covered by the main study it was regarded as a distinct case not likely to affect the integrity of the other results.

The Ogmore Building houses approximately 145 CSM staff and 3000 students over four floors. The building provides a range of office, teaching, catering and hospitality space arranged around a central atrium which runs the length of the building.

Heating is provided by air-source heat pumps supplemented by natural gas-fired boilers serving radiators, fan coils, air-handling units and underfloor heating circuits. The air-source heat pumps also provide mechanical cooling to a large part of the building via air handling units (AHUs), fan coils, underfloor cooling circuits and a variable air volume (VAV) air-conditioning system serving office accommodation over two floors.

The ventilation strategy within the building is described as mixed-mode and therefore incorporates natural and mechanical ventilation systems. Natural ventilation is by a mixture of manually operable windows, passive stacks and electrically actuated windows and louvred wall panels. Mechanical ventilation is provided from a number of air handling units serving both localised and centralised distribution systems.

The lighting system relies predominantly on T5 fluorescent fittings controlled by occupancy detection using microwave sensors and photoelectric dimming in areas which benefit from natural light.

In contrast, the older CSM building at Colchester Avenue was heated by a convential low temperature hot water heating system served by natural gas-fired boilers. With the exception of a large lecture theatre and ICT suites which were mechanically ventilated and cooled the building was naturally ventilated by openable windows.

For the purpose of analysing this building, energy consumption data from the technical tables of the relevant DECs as indicated below were used to differentiate between the two buildings.

Colchester Avenue: Certificate Reference Number 9577-1079-0308-0700-4991 with an issue date of 14 January 2010, (see appendix F).

Ogmore building: Certificate Reference Number 0281-0012-9469-3899-1002 with an issue date of 24 January 2011, (see appendix F).

It should be noted that DECs collate energy consumption data for a 12-month period ending several weeks or more prior to the issue date. The energy consumption figures shown below are the absolute values used to compile the DECs in contrast to the DEC rating which is automatically normalised for weather and occupancy times.

		Annual Consumption kW·h		Benchmark kW·h/m^2/year	
Building	**DEC Rating**	**Fuel & Heat**	**Electricity**	**Heating**	**Electrical**
Colchester Avenue	C - 67	1965443	849221	157	68
Ogmore	C - 72	506099	773518	63	97

Table 7.4 Summary of energy data from display energy certificates for Cardiff School of Management's old and new buildings, see appendix F.

The results indicated a slightly poorer DEC rating for the the newer building despite a significant reduction in overall energy consumption.

This was explained from examining the benchmark values which showed that despite a 60% decrease in the "heating energy" (fossil fuels) benchmark there was a 43% increase in the "electrical" benchmark. This shift in the ratio of the energy sources was largely attributed to the use of air-source heat pumps for space heating. The much higher CO_2 emissions factor for electricity combined with the smaller floor area of the newer building were factors that influenced the poorer DEC rating which is a weather-corrected and occupancy adjusted expression of the CO_2 emissions per m^2 GIA.

However, when absolute energy consumption data shown in table 7.5 was converted to CO_2 emissions using the factors consistently used throughout this study, the following results were obtained:

	Annual Consumption kW·h		Absolute CO_2 emisisions tonnes/year		
Building	**Fuel & Heat**	**Electricity**	**Heating**	**Electrical**	**Total**
Colchester Avenue	1965443	849221	364.1	457.8	821.9
Ogmore	506099	773518	93.7	417.0	510.7
Saving	**1,459,344**	**75,703**	**270.4**	**40.8**	**311.2**

Table 7.5 Summary of energy consumption data and CO_2 emissions for Cardiff School of Management's old and new buildings, from display energy certificates, see appendix F.

These results clearly indicated that despite having obtained a slightly worse DEC rating the new building's CO_2 emissions were 37.9% lower than the building it replaced. It was also observed that the re-provision of the CSM has reduced CMU's overall CO_2 emissions by 311.2 tonnes per annum.

7.5 Summary of Case Study Results

Abatement Measure	% Reduction in CO_2 Emissions	Absolute Reduction in CO_2 Emissions (tonnes)
Lights & Electric Appliances (including ICT)	9.1 – 17.3	39.6
Behaviour Change & New Ways of working	11	832.5
Building Energy & Space Management	37.9	311.2

Table 7.6 Summary of case study results percentage and absolute CO_2 emissions reductions.

These results were used to critically evaluate HEFCE's assessment of the abatement potential within the sector and their estimate of the level of required investment which is examined further within chapter 8.

8.0 Results and Discussion

The results from the Sector Analysis and Case Study were jointly evaluated to inform the aims of the study as outlined in Chapter 2.

8.1 Targets and Baseline Emissions

As highlighted within the Literature Review, both HEFCW and HEFCE were seeking to align themselves with the strategies of their respective Governments when setting targets. However, it was noted that as the collective result of encouraging individual HEIs to set their own targets, HEFCE ultimately accepted a slightly less ambitious target than they had determined was required under UK obligations.

Performance against reduction targets in both England and Wales are similarly measured in absolute terms, without any normalisation for factors such as the weather or growth. However, the two countries are distinguished by the magnitude of their targets and the differing approaches taken to calculate baselines.

To differentiate between the requirements placed on Welsh and English HEIs, scope 1 and 2 emissions baselines and absolute reduction targets were calculated within chapter 6 using both HEFCW and HEFCE methodologies.

A summary of the results for the Welsh HE sector are shown in the table below:

	CO_2 Baseline Emissions (tonnes/year)	Reduction Target to 2020 (%)	Absolute CO_2 Reduction Target (tonnes/year)
HEFCW	111,127	27	30,004
HEFCE	106,198	38	40,355

Table 8.1 Summary of Welsh HE sector baseline emissions, percentage and absolute CO_2 emissions reductions targets based on HEFCW and HEFCE methodologies, from table 6.3.

The analysis detailed within chapter 6 quantified the combined effect of differing targets and methods of calculating baselines. This showed absolute emission reductions to be 25.7% lower overall applying HEFCW's methodology. Indicating that the Welsh Government's aspirations to reduce scope 1 and 2 emissions within the HE sector are demonstrably less ambitious than those pursued in England.

Whilst the effect of a lower percentage reduction target in Wales was straightforward, the effect of the differing methodologies for calculating baselines was less transparent.

It had been established in chapter 6 that emissions had risen within the 5-year period analysed and by 2009, scope 1 and 2 emissions were at a level greater than either baseline. To consider how this would affect absolute CO_2 reduction requirements, a 27% reduction target was applied to both HEFCW and HEFCE baselines and a 2020 "target emissions" figure calculated.

The results are summarised below:

	CO_2 Baseline Emissions (tonnes/year)	2020 Target Emsisions	Absolute CO_2 Reduction from Baseline (tonnes/year)	CO_2 Actual Emissions 2009 (tonnes/year)	Absolute CO_2 Reduction from 2009 (tonnes/year)
HEFCW	111,127	81,123	**30,004**	116,399	**35,276**
HEFCE	106,198	77,525	**28,673**	116,399	**38,874**

Table 8.2 Summary of baseline emissions and absolute CO_2 emissions reductions for a 27% reduction target measured against HEFCW and HEFCE baselines, from table 6.4.

As expected, HEFCW's baseline resulted in a greater absolute CO_2 reduction requirement of 30,004 tonnes as opposed to 28,673 tonnes measured against HEFCE's baseline.

However, when 2020 "target emissions" were evaluated against 2009 emissions, the opposite effect was observed. HEFCW's baseline was less challenging with a CO_2 reduction requirement of 35,276 tonnes as opposed to 38,874 tonnes measured against HEFCE's baseline.

Therefore HEFCW's 5-year average baseline is less challenging in practice than the HEFCE's single year baseline.

HEFCW's approach to establishing a baseline was also noted to have the potential for penalising "early adopters" for whom any reductions in emissions achieved since 2005 would result in a reduction to their baseline.

More positively, HEFCW's approach initially appeared to provide a better representation of average weather conditions. A potential benefit as emission reductions are measured in absolute terms. However, when degree day data for baseline years was evaluated against the 20-year average the advantage was less apparent as shown in table 8.3.

Degree Day Region	20 Year Average	2005	Variation against 20 year Average +/-	2005 - 2009	Variation against 20 year Average +/- %
Severn Valley	1,862	2,016	**8.3%**	1,961	**5.4**
Wales	2,079	2,062	**-0.8%**	2,029	**-2.4%**

Table 8.3 Summary of degree day data for regions in which Welsh HEIs are located from tables 5.4 and 5.5.

In the "Wales" region degree days for the HEFCE single baseline year were closer to the 20-year average whilst in the "Severn Valley" region the opposite trend was observed.

8.2 Benchmarking

In chapter 6, individual HEIs were benchmarked against their peers using a number of specific emissions factors as the basis for identifying the subject of the case study.

In addition and as the basis for quantifying potential improvement within the Welsh HE Estate, HEIs were also benchmarked individually and collectively against industry standard benchmarks i.e. CIBSE TM46.

	Energy Benchmarks		Illustrative CO_2 benchmarks derived from the energy benchmarks		
	Electricity / kW·h/m^2	Fossil-thermal kW·h/m^2	Illustrative Electricity kgCO_2/m^2	Illustrative Fossil Thermal kgCO_2/m^2	Illustrative Total kgCO_2/m^2
CIBSE TM 46	80	240	43.1	44.4	87.5
Welsh HE Estate	**107**	**164**	**57.8**	**30.3**	**88.1**

Table 8.4 Welsh HE estate benchmarked against CIBSE TM46 (2008) derived benchmarks, from table 6.7.

The analysis detailed within chapter 6 showed that the Welsh HE Estate was 15% below a total energy benchmark but slightly above a total CO_2 emissions benchmark.

However, this masked the particularly poor performance for electricity which was 34.1% higher than the typical benchmark. In contrast emissions arising from the use of fossil fuels are 31.7% lower than the benchmark.

Therefore the benchmarking exercise determined that there is potential for improvement within the Welsh HE Estate particularly with regard to electricity consumption.

If electricity use was reduced to the typical benchmark, and even if fossil fuel use remained unchanged total emissions would reduce from 88.1 kgCO_2/m^2 to 73.4 kgCO_2/m^2, which represents a reduction of 16.7%.

This represents more than half the emissions reduction required by 2020 and as the benchmark value is typical of the current building stock within Higher Education, this should be considered a realistic aspiration.

8.3 Evaluation of Abatement Potential

This study has considered an assessment by HEFCE of the abatement potential within the English HE sector and in chapter 6 this was adjusted on a pro-rata basis to derive a similar assessment of potential within the Welsh HE sector. The validity of this approach was examined by referencing the results of the single case study.

HEFCE's assessment of the abatement potential was first considered in terms of a percentage reduction to facilitate evaluation against Case Study results and similar guidance from the Carbon Trust. As can be seen in table 8.5 below, the Case Study results matched HEFCE's assessment very closely with the exception of the Building Energy and Space Management category where the difference was more marked.

The author believed this difference demonstrated that the Ogmore building was not the best example of low CO_2 new build, as evidenced by a DEC rating of C (72). It was noted that a slightly more energy efficient building would have resulted in a much closer match.

Abatement Measures as categorised by Carbon Trust	Abatement Measures as categorised by HEFCE	Estimated Percentage CO_2 Reductions		
		Carbon Trust	SQW/HEFCE	Case Study
Good Housekeeping eg: M&T, Awareness, Training, Regular Inspection & Audit, DEC Compliance	**Behavioural Change and New Ways of Working**	10%	9.1%	11%
Invest to Save eg: Insulation, Lighting, Controls, Heat recovery, CHP, Fuel Policy, Plant replacement, New technology	**Lights and Electric Appliances** (including ICT)	20%	9 to 16%	9.1 to 17.3
	Building Fabric Upgrade		12.7%	-
	Energy Efficient Supply (CHP/tri-generation, district heating)		2.3%	-
Design & Asset Management eg: Low CO_2 new build, Property rationalisation, Procurement changes	**Building Energy and Space Management**	10%	45.4%	37.9%

Table 8.5 Validation of HEFCE's assessment of abatement measures by category (derived from table 5.8) against case study results and Carbon Trust guidance (from fig. 5.2).

The results from the Case Study across all categories were taken as a practical endorsement of the accuracy of HEFCE's assessment of the abatement potential.

Again with the exception of the Building Energy and Space Management/Design and Asset Management category, HEFCE's assessment closely matched Carbon Trust guidance.This mismatch was believed most likely to be due to differences in defining the category.

It should also be noted that HEFCE's assessment of sector abatement potential appears to have been based on an assumption that these percentage reductions could be applied across the whole of the HE estate. With the exception of behaviour change as demonstrated by the CMU Case Study, it became evident that this would not be possible and this study is an attempt to generate a more realistic assessment of abatement potential.

8.3.1 Behavioural Change and New Ways of Working

As can be seen from table 8.5 there was a close correlation between the various assessments of the potential within this category with a 11% reduction in utility consumption within buildings at CMU with a resultant saving of 832.5 tonnes of CO_2 per annum.

As previously established, CMU accounts for $1/16^{th}$ of Welsh HE sector emissions therefore Case Study results were adjusted to create an assessment of 13,320 tonnes or 44.4% of the sectoral reduction requirement.

8.3.2 Lights and Electric Appliances (including ICT)

This is an important area as electricity consumption within the Welsh HE Estate scored poorly in the benchmarking exercise and has been identified as the most CO_2 intensive energy source.

The study's assessment was observed as being similar to HEFCE's albeit providing a narrower range. Importantly, as this range was banded by extremities, it was noted that the true potential would be contained within these values. The mid-value was noted to be 5,860.9 tonnes which equated to 19.5% of the sectoral reduction requirement and may form a more realistic assessment for strategic planning purposes.

Whilst only two "Invest to Save" projects were considered in the Case Study there was again a close correlation with the various assessments of the potential within this category with a range of 9.1-17.3% achieved by these projects with a resultant saving of 39.6 tonnes of CO_2. When results were extrapolated, a potential saving of 635.2 tonnes p.a. was identified across the Welsh HE sector. However, this assessment is based on an unrealistically low level of activity i.e. 32 projects across the eleven HEIs forming Welsh HE sector by 2020 so perhaps should be viewed as the minimum level.

When the upper percentage saving of 17.3 % was applied to HEFCW's baseline for emissions arising from electricity of 71,430 tonnes (derived from appendix G, from average of emissions arising from electricity for each of the five years) to derive anabatement potential of 12,357 tonnes. This was believed to be potentially unrealistic, as it relied on projects being successfully applied to the whole of the sectors electricity consumption and could therefore be regarded as an absolute maximum value using current available technologies.

8.3.3 Building Energy And Space Management

This category was less clearly defined but was noted as including property rationalisation and low CO_2 new build which aligned well with the Case Study example. It should be noted that to maximise the benefit from the construction of additional new buildings the opportunity to improve space efficiency and conduct property rationalisation needs to be taken.

The re-provision of the Cardiff School of Management was shown to have reduced CMU's scope 1 and 2 emissions by 311.2 tonnes which when adjusted for the sector in Wales, indicated an abatement potential of 4979.2 tonnes. For this to be a true representation, the implementation of a further 15 projects to reprovide

192,000m^2 (13.1%) of the current 1,463,378 m^2 Welsh HE Estate by 2020 would be necessary.

However, energy and space efficient refurbishment coupled with rationalisation and the disposal of some buildings could also contribute to making this achievable. The Higher Education Funding Council for England (2010a, p. 20) note that:

> Good space management not only reduces carbon emissions, it also frees up resources that can be used for teaching and research. The Estate Management Statistics provide benchmarks that institutions can use – in 2006-07 the median institution had 7.6 m^2 of non-residential space per full-time student ('Performance in higher education estates: EMS annual report 2008' (HEFCE 2009/28), a level that has declined steadily from 8.9 m^2 in 2001-02. There are reasons for the considerable variation that exists in the sector, notably building age and the needs of particular subjects. It is clear however that there is potential for space to be used more efficiently.

HEFCE's assessment of 50,000 tonnes would appear to have been derived by applying the percentage reduction to the baseline emissions and whilst this may indicate the theoretical maximum long-term abatement potential this is not believed to be possible by 2020.

The 4979.2 tonnes or 16.6% of the sectoral reduction requirement identified by this study is believed to provide a more reliable aid to strategic planning.

8.3.4 Building Fabric Upgrade

The CMU Case Study was unable to provide suitable material to evaluate HEFCE's assessment but based on the evaluation of the other categories, it seemed likely that their assessment of 14,000 tonnes related to the theoretical maximum.

Whilst the Building Regulations include a requirement to upgrade "thermal elements" when completing certain refurbishment works, it was believed that the theoretical maximum long-term abatement potential identifed by HEFCE is unlikely to be realised by 2020.

8.3.5 Energy Efficient Supply

The CMU Case Study was also unable to provide suitable material to evaluate HEFCE's assessment of this category as the requirements for the installation of CHP and tri-generation are site specific. However, it was noted that based on HEFCE's assessment this study placed the abatement potential in Wales at 2,500 tonnes.

8.4 Assessment of Costs

The implementation costs of realising the abatement potential identified by this study have been derived from the Case Study and are believed to constitute a sufficiently reliable estimation to inform strategic planning.

8.4.1 Behavioural Change and New Ways of Working

The operating cost of operating CMU's aM & T based behaviour change programme is £79k per annum which when increased on a pro-rata basis to cover the whole of the Welsh HE estate became £1.26M or a total of £11.38M over the 9 years to 2020. However, it should also be noted that CMU are now working on maintaining reductions in a more cost effective manner than was shown in the Case Study.

The capital cost of the necessary metering and aM & T equipment has already been provided to the whole of the Welsh HE sector as previously highlighted in the form of £3.5M of ringfenced funding from HEFCW.

8.4.2 Lights and Electric Appliances (including ICT)

Case study results from two projects showed an average saving of 39.6 tonnes for an investment of £47.1k.

This could be otherwise expressed as a £1.19k investment per tonne of CO_2 saved which was used as the basis for a high level estimate of the investment needed to achieve the identified abatement potential.

Based on the identified range of 635 to 12,357 tonnes this approach identified the required investment to be approximately £0.75M to £14.7M.

8.4.3 Building Energy And Space Management

Case study results for the re-provision of Cardiff School of Management showed a saving of 311.1 tonnes for an investment of £11m after disposal costs. As previously stated CMU represents 1/16th of the Welsh HE estate therefore applying a simple pro-rata adjustment based on the assumption that other projects would be similarly funded equated to £176M.

8.4.4 Building Fabric Upgrade

As previously stated the Case Study was unable to provide suitable material to evaluate either abatement potential or cost. Further information on construction type and the thermal properties of the Welsh HE Estate would be invaluable in informing any further study.

8.4.5 Energy Efficient Supply

The site specific requirements for the installation of CHP and tri-generation do not support a high level estimation of the required investment. Further work to identify potential projects and conduct case by case evaluations would be necessary to determine required levels of investment.

Abatement Measures as categorised by Carbon Trust	Abatement Measures as categorised by HEFCE	Estimated Abatement Potential for the Welsh HE Sector (tCO_2)		Investment (£million) derived from Case Study	
		SQW/HEFCE	Case Study	Total to 2020	Per Annum
Good Housekeeping eg: M&T, Awareness, Training, Regular Inspection & Audit, DEC Compliance	**Behavioural Change and New Ways of Working**	10,000	13,320	11.4	1.26
Invest to Save eg: Insulation, Lighting, Controls, Heat recovery, CHP, Fuel Policy, Plant replacement, New technology	**Lights and Electric Appliances** (including ICT)	1,000 to 17,500	635 to 12,357	0.75 to 14.7	0.08 to 1.63
	Building Fabric Upgrade	14,000	-	-	-
	Energy Efficient Supply (CHP/tri-generation, district heating)	2,500	-	-	-
Design & Asset Management eg: Low CO_2 new build, Property rationalisation, Procurement changes	**Building Energy and Space Management**	50,000	4.979	176	19.5

Table 8.6 Evaluation of required investment and abatement potential from cost-effective abatement measures.

8.5 A Cost Effective Abatement Strategy

The Carbon Reduction Strategy proposed by this study is an example of a cost effective approach which is also respectful to the "Carbon Hierarchy" and represents one possible solution for the purpose of informing strategic planning within the HE sector in Wales and is based on:

1. Replicating CMU's level of success in behaviour change across the whole of the Welsh HE sector at a cost of up to £11.4M.

2. Reproviding more than 13% of the Welsh HE Estate with buildings possessing greater space and energy efficiency than the existing stock at an estimated cost of £176M.

3. An investment of £14.7M in energy efficiency technical projects.

These costs represent the most cost effective abatement strategy requiring a total investment of £202M by 2020 and should therefore be regarded as the minimum cost of meeting Welsh Government targets.

However, these costs should not be considered in isolation as much of this expenditure may already be planned within the Estates Strategies of the various HEIs and the potential benefits of rationalisation extend beyond CO_2 emissions reductions.

The costs of implementing behaviour change programmes and energy efficiency technical projects may be possible to fund through various mechanisms including loans from savings in energy costs.

Fig. 8.1 below shows that the measures identified by this study can theoretically deliver 30,656 tonnes of savings which are sufficient to meet Welsh Government targets against their specified baseline. However, when recent growth in the sector was considered these measures fell short of the 35,276 tonnes of reductions required against 2009 levels.

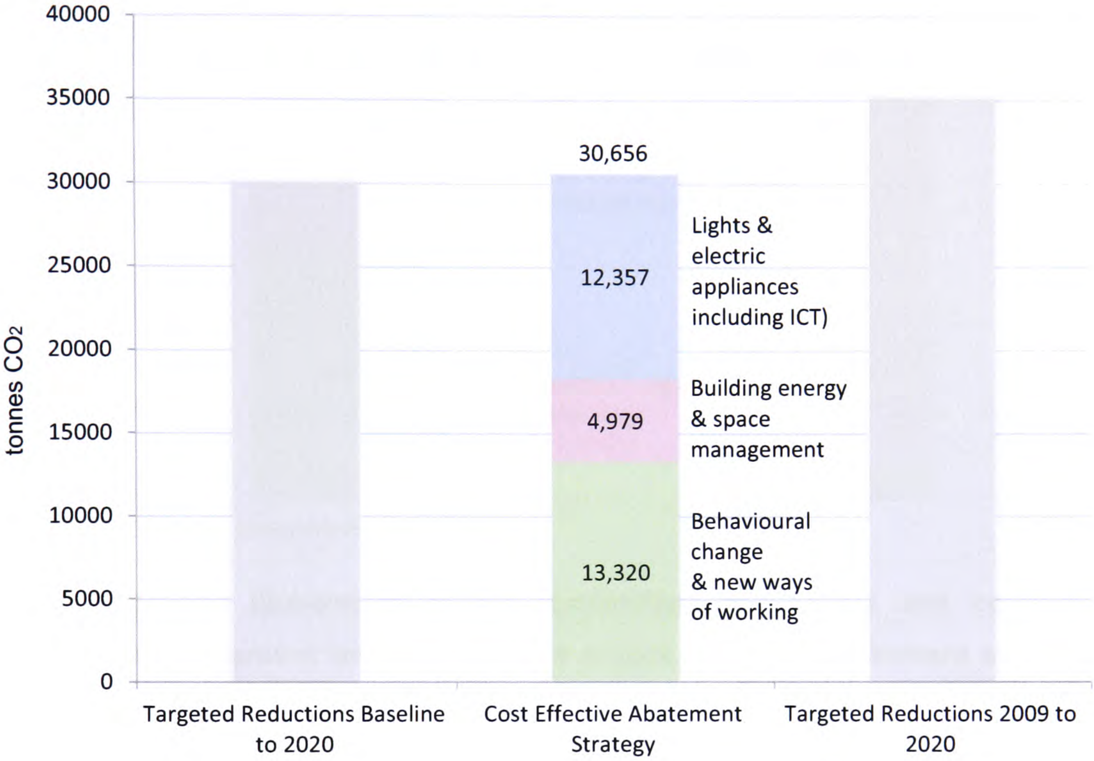


Figure 8.1 An illustration of the potential of a cost effective abatement strategy to enable the Welsh HE sector to meet CO_2 emissions reduction targets.

This study also highlighted that the total 12,357 tonnes of reductions identified from lights and electric appliances (including ICT) may be difficult to achieve by 2020 due to the large number of projects required. Although this could be mitigated through implementing other cost effective measures such as fabric upgrades and energy efficient supply which the CMU case study was unable to evaluate.

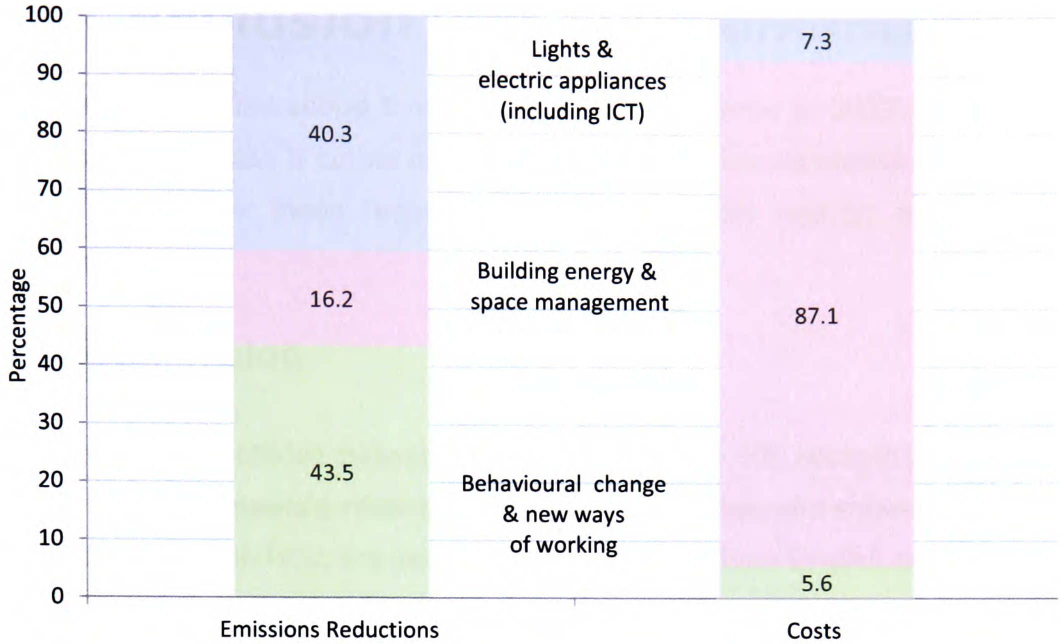


Figure 8.2 An Illustration of the percentage reductions and costs of individual abatement measures within a cost effective abatement strategy for the Welsh HE sector.

Emissions reductions and implementation costs of the various abatement measures were measured as a percentage of the overall strategy to provide an indication of their relative importance.

This showed that behaviour change and energy efficiency technical projects addressing lights and electric appliances (including ICT) were able to deliver 83.8% of the total reductions identified under this Strategy. Therefore it would seem unlikely that the Welsh HE Sector would be able to meet reduction targets cost effectively without fully implementing these two measures.

To more accurately differentiate between the "effectiveness" of individual abatement measures would require a "whole life cost analysis" and is beyond the scope of this study.

9.0 Conclusion and Recommendations

This study quantified scope 1 and 2 emissions reductions to 2020 applicable to the Welsh HE sector. It further outlined a potential Carbon Abatement Strategy to determine whether these requirements can be wholly met by cost effective measures.

9.1 Conclusion

This study differentiated between English and Welsh HE sectors in respect to scope 1 and 2 emissions reduction targets and baselines and showed that those applicable to Welsh HEIs are less demanding than for their English counterparts. Research conducted by SQW Consulting on behalf of HEFCE to quantify CO_2 abatement potential was validated from the critical evaluation of a single case study. It was further shown that applying these predictions on a pro-rata basis to the Welsh HE sector was a justifiable approach.

However, growth in the sector was evident over the period of the study with an increase in income, size of the estate and staff and student numbers noted. These changes were reflected in an increase in emissions in the majority of Welsh HEIs above their baselines.

In chapter 6, when evaluated against CIBSE TM46 derived CO_2/m^2 GIA benchmarks, the Welsh HE Estate was seen to be marginally worse than "typical" overall but identified significant potential to reduce electricity use.

By focussing on abatement measures identified as most cost effective by HEFCE, this Study has demonstrated that it was theoretically possible for the Welsh HE sector to meet Welsh Government targets to reduce scope 1 and 2 emissions by 30,004 tonnes by 2020. The Carbon Reduction Strategy proposed was not only cost effective but also respectful to the "Carbon Hierarchy" and can be summarised briefly as:

1. Replicating CMU's level of success in behaviour change across the whole of the Welsh HE sector at a cost of up to £11.4M.
2. Re-providing more than 13% of the Welsh HE Estate with buildings possessing greater space and energy efficiency than the existing stock at an estimated cost of £176M.
3. An investment of £14.7M in energy efficiency technical projects subject to sufficient numbers of viable projects.

This approach identified an investment of £202M by 2020 which should therefore be regarded as the minimum cost of meeting Welsh Government targets.

However, in chapter 6 it was shown that due to recent growth in the sector this figure has increased the required emissions reductions to 35,276 tonnes and meeting targets will be more difficult in practice and additional measures may also be required in some HEIs.

9.2 Recommendations

1. Welsh HEIs should individually and collectively develop an awareness of the challenge presented by Welsh Government targets. As reductions are to be measured in absolute terms, the sector should select a group of metrics for their own use to measure energy efficiency, mindful of growth and the need to improve space efficiency.
2. Carbon Management Plans at Institutional level should be aligned to Welsh Government targets and focus primarily on cost effective abatement measures and be respectful to the "Carbon Hiearchy". Quantifying the required investment should be seen as a key function of the plan as should identifying funding sources appropriate to the individual Institution.

3. An unexpected outcome of this study was the scale of the importance of behaviour change which accounted for almost half of the identified abatement potential to 2020. The CMU case study showed that it is possible to achieve and maintain behaviour change within the HE sector and other HEIs must adopt similar strategies if they are to meet Welsh Government targets. Whilst dramatic results were evident from the case study, it cannot be assumed that this could not be improved upon and a further study is warranted to determine whether unrealised potential exists.

4. Further work should be carried out to examine HEFCE's assessment of the abatement potential that exists from fabric upgrades, e.g. by an audit of the thermal properties of the existing HE Estate.

5. Similarly, further work should be carried out to examine HEFCE's assessment of the potential from energy efficient supply e.g. by a desktop audit of the Welsh HE Estate to identify appropriate sites for further investigation.

6. Building integrated renewable energy should be considered in conjunction with HEFCW and the Carbon Trust possibly using a case study approach to monitor and evaluate the effectiveness and reliability of existing in-situ installations.

7. Investigate whether opportunities exist for larger off-site renewables possibly through collaborative working between HEIs, energy suppliers or others, e.g. to install wind or tidal turbines.

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Appendix A – Summary of Data from Estates Management Statistics.

NB: includes energy consumption data direct from Cardiff University.

August 2005 – 31 July 2006.

Energy Consumption

Baseline Year	2005-2006				
Consumption	**Electricity (kW·h)**	**Gas (kW·h)**	**Oil (kW·h)**	**Coal (kW·h)**	**All fuels (kW·h)**
Aberystwyth University	15,016,200	30,052,017	80,560	0	45,148,777
Bangor University	15,447,781	28,883,921	2,237,660	0	46,569,362
Cardiff University	34,530,000	49,219,000	0	0	83,749,000
University of Wales Institute, Cardiff	8,497,105	16,016,116	48,780	0	24,562,001
University of Glamorgan	10,010,500	15,836,967	0	0	25,847,467
Glyndŵr University					
The University of Wales, Lampeter	1,924,217	8,722,148	0	0	10,646,365
The University of Wales, Newport	4,865,669	9,780,086	0	0	14,645,755
Royal Welsh College of Music and Drama	715,957	1,115,405	0	0	1,831,362
Swansea Metropolitan University	3,220,803	6,040,536	0	0	9,261,339
Swansea University	20,107,613	34,186,768	0	0	54,294,381
Trinity University College	2,035,351	8,074,785	0	0	10,110,136
Total Welsh HE Sector	116,371,196	207,927,749	2,367,000	0	326,665,945

Energy Costs

Baseline Year	2005-2006				
Costs	**Electricity (£s)**	**Gas (£s)**	**Oil (£s)**	**Coal (£s)**	**All fuels (£s)**
Aberystwyth University	771,599	648,919	2,661		1,423,179
Bangor University	943,584	677,912	76,469		1,697,965
Cardiff University	3,822,870	2,123,315	0		5,946,185
University of Wales Institute, Cardiff	590,513	478,891	1,934	0	1,071,338
University of Glamorgan	805,249	450,599	0		1,255,848
Glyndŵr University	200,660	183,163	0		383,823
The University of Wales, Lampeter	121,869	140,429	0		262,298
The University of Wales, Newport	402,104	283,258	0		685,362
Royal Welsh College of Music and Drama	52,416	29,712	0		82,128
Swansea Metropolitan University	317,000	156,000	0		473,000
Swansea University	1,270,348	671,443	0		1,941,791
Trinity University College	139,663	176,852	0		316,515
Total Welsh HE Sector	9,437,875	6,020,493	81,064	0	15,539,432

Normalising Factors

Baseline Year	2005-2006			
	Student (FTE)	**Staff (FTE)**	**Income (£ks)**	**GIA (m2)**
Aberystwyth University	7,659	1,369	77,185	176,128
Bangor University	7,694	1,620	96,337	179,760
Cardiff University	22,674	4,790	344,437	408,203
University of Wales Institute, Cardiff	7,586	1,071	59,744	90,989
University of Glamorgan	11,116	1,496	94,115	95,531
Glyndŵr University	3,584	414	27,307	43,539
The University of Wales, Lampeter	1,935	204	12,877	29,122
The University of Wales, Newport	4,478	635	35,894	53,283
Royal Welsh College of Music and Drama	549	151	7,994	10,076
Swansea Metropolitan University	4,313	543	25,031	50,539
Swansea University	10,782	1,912	116,467	153,429
Trinity University College	1,648	279	11,718	37,404
Total Welsh HE Sector	84,017	14,483	909,106	1,328,003

1 August 2006 – 31 July 2007.

Energy Consumption

Baseline Year	2006-2007				
Consumption	Electricity (kW·h)	Gas (kW·h)	Oil (kW·h)	Coal (kW·h)	All fuels (kW·h)
Aberystwyth University	14,372,913	26,342,144	21,200		40,736,257
Bangor University	15,613,647	26,972,176	1,830,143		44,415,966
Cardiff University	43,943,000	53,829,000	0	0	97,772,000
University of Wales Institute, Cardiff	7,917,948	12,147,024	24,988		20,089,960
University of Glamorgan	10,120,634	11,380,235	0		21,500,869
Glyndŵr University					
The University of Wales, Lampeter	1,835,660	8,511,379	0		10,347,039
The University of Wales, Newport	4,887,080	8,549,062	0		13,436,142
Royal Welsh College of Music and Drama	637,324	890,138	0		1,527,462
Swansea Metropolitan University	3,258,110	5,005,715	0		8,263,825
Swansea University	18,951,573	30,736,303	42,400		49,730,276
Trinity University College	2,169,201	7,288,553	0		9,457,754
Total Welsh HE Sector	123,707,090	191,651,729	1,918,731	0	317,277,550

Energy Costs

Baseline Year	2006-2007				
Costs	Electricity (£s)	Gas (£s)	Oil (£s)	Coal (£s)	All fuels (£s)
Aberystwyth University	1,078,910	611,899	672		1,691,481
Bangor University	1,433,054	585,109	94,410		2,112,573
Cardiff University	4,715,474	2,392,793	0		7,108,267
University of Wales Institute, Cardiff	686,517	406,360	856		1,093,733
University of Glamorgan	884,745	288,522	0		1,173,267
Glyndŵr University	309,304	196,767	0		506,071
The University of Wales, Lampeter	178,578	131,659	0		310,237
The University of Wales, Newport	413,196	247,500	0		660,696
Royal Welsh College of Music and Drama	56,055	23,772	0		79,827
Swansea Metropolitan University	335,462	129,077	0		464,539
Swansea University	1,500,512	960,279	15,319		2,476,110
Trinity University College	191,441	192,477	0		383,918
Total Welsh HE Sector	11,783,248	6,166,214	111,257	0	18,060,719

Normalising Factors

Baseline Year	2006-2007			
	Student (FTE)	Staff (FTE)	Income (£ks)	GIA (m2)
Aberystwyth University	7,569	1,387	85,937	171,270
Bangor University	7,975	1,502	102,668	178,168
Cardiff University	22,295	4,837	367,257	410,194
University of Wales Institute, Cardiff	7,638	1,084	65,185	91,046
University of Glamorgan	12,525	1,650	113,874	95,532
Glyndŵr University	3,673	460	29,532	44,269
The University of Wales, Lampeter	2,212	219	13,939	31,687
The University of Wales, Newport	4,892	654	39,279	54,403
Royal Welsh College of Music and Drama	560	123	9,048	10,076
Swansea Metropolitan University	4,367	531	27,681	51,099
Swansea University	10,767	2,011	128,511	158,973
Trinity University College	1,535	279	12,714	39,279
Total Welsh HE Sector	86,007	14,737	995,625	1,335,996

1 August 2007 – 31 July 2008.

Energy Consumption

Baseline Year	2007-2008				
Consumption	Electricity (kW·h)	Gas (kW·h)	Oil (kW·h)	Coal (kW·h)	All fuels (kW·h)
Aberystwyth University	14,025,626	25,202,245	63,578		39,291,449
Bangor University	15,159,976	25,172,241	1,087,051		41,419,268
Cardiff University	41,601,000	58,468,000	0	0	100,069,000
University of Wales Institute, Cardiff	8,298,754	13,741,321	0		22,040,075
University of Glamorgan	11,975,684	14,419,362	0		26,395,046
Glyndŵr University					
The University of Wales, Lampeter	1,906,454	8,064,439	0		9,970,893
The University of Wales, Newport	4,717,015	9,487,756	0		14,204,771
Royal Welsh College of Music and Drama	755,312	931,393	0		1,686,705
Swansea Metropolitan University	3,082,099	4,525,883	0		7,607,982
Swansea University	18,439,815	35,211,561	643,536		54,294,912
Trinity University College	2,263,896	7,513,012	0		9,776,908
Total Welsh HE Sector	122,225,631	202,737,213	1,794,165	0	326,757,009

Energy Costs

Baseline Year	2007-2008				
Costs	Electricity (£s)	Gas (£s)	Oil (£s)	Coal (£s)	All fuels (£s)
Aberystwyth University	1,143,082	584,618	2,802		1,730,502
Bangor University	1,367,838	522,780	70,983		1,961,601
Cardiff University	4,718,153	2,208,197	0		6,926,350
University of Wales Institute, Cardiff	665,383	306,560	1,280		973,223
University of Glamorgan	994,106	314,955	0		1,309,061
Glyndŵr University	238,464	164,058	0		402,522
The University of Wales, Lampeter	210,929	153,035	0		363,964
The University of Wales, Newport	349,761	385,196	0		734,957
Royal Welsh College of Music and Drama	62,160	18,496	0		80,656
Swansea Metropolitan University	298,199	125,112	0		423,311
Swansea University	1,344,079	1,049,774	29,221		2,423,074
Trinity University College	170,172	166,624	0		336,796
Total Welsh HE Sector	11,562,326	5,999,405	104,286	0	17,666,017

Normalising Factors

Baseline Year	2007-2008			
	Student (FTE)	Staff (FTE)	Income (£ks)	GIA (m2)
Aberystwyth University	7,530	1,377	95,276	171,270
Bangor University	8,743	1,572	108,339	181,556
Cardiff University	22,572	5,002	393,545	410,238
University of Wales Institute, Cardiff	7,894	1,079	70,597	91,336
University of Glamorgan	14,607	1,892	131,301	107,435
Glyndŵr University	3,881	387	33,969	44,269
The University of Wales, Lampeter	1,193	245	15,897	31,707
The University of Wales, Newport	5,067	682	42,746	54,403
Royal Welsh College of Music and Drama		111		10,496
Swansea Metropolitan University	4,311	498	31,398	50,827
Swansea University	11,311	2,004	143,875	158,973
Trinity University College	1,570	252	14,224	35,482
Total Welsh HE Sector	88,681	15,102	1,081,167	1,347,992

Energy consumption and costs 1 August 2008 – 31 July 2009.

Energy Consumption

Baseline Year	2008-2009				
Consumption	**Electricity (kW·h)**	**Gas (kW·h)**	**Oil (kW·h)**	**Coal (kW·h)**	**All fuels (kW·h)**
Aberystwyth University	19,863,117	26,234,933	155,767		46,253,817
Bangor University	16,008,601	23,226,099	1,985,899		41,220,599
Cardiff University	47,816,949	68,701,502	0	0	116,518,451
University of Wales Institute, Cardiff	8,115,119	13,768,481	21,200		21,904,800
University of Glamorgan	12,308,220	14,973,888	0		27,282,108
Glyndŵr University					
The University of Wales, Lampeter	1,965,234	7,861,587	0		9,826,821
The University of Wales, Newport	4,726,542	9,588,536	0		14,315,078
Royal Welsh College of Music and Drama	728,363	846,487	0		1,574,850
Swansea Metropolitan University	3,079,582	5,221,186	414,333		8,715,101
Swansea University	23,579,274	25,050,374	390,345		49,019,993
Trinity University College	2,139,742	7,758,824	0		9,898,566
Total Welsh HE Sector	140,330,743	203,231,897	2,967,544	0	346,530,184

Energy Costs

Baseline Year	2008-2009				
Costs	**Electricity (£s)**	**Gas (£s)**	**Oil (£s)**	**Coal (£s)**	**All fuels (£s)**
Aberystwyth University	1,651,157	1,057,095	6,713		2,714,965
Bangor University	1,564,671	853,781	126,746		2,545,198
Cardiff University	5,581,423	2,758,242	0		8,339,665
University of Wales Institute, Cardiff	1,239,677	639,332	882		1,879,891
University of Glamorgan	1,587,644	613,359	0		2,201,003
Glyndŵr University	378,766	224,517	0		603,283
The University of Wales, Lampeter	255,147	189,609	0		444,756
The University of Wales, Newport	592,862	256,560	0		849,422
Royal Welsh College of Music and Drama	77,404	33,416	0		110,820
Swansea Metropolitan University	448,500	214,012	17,986		680,498
Swansea University	2,079,871	1,459,978	17,676		3,557,525
Trinity University College	191,580	214,670	0		406,250
Total Welsh HE Sector	15,648,702	8,514,571	170,003	0	24,333,276

Normalising Factors

Baseline Year	2008-2009			
	Student (FTE)	**Staff (FTE)**	**Income (£ks)**	**GIA (m2)**
Aberystwyth University	7,537	1,876	110,054	189,497
Bangor University	8,119	1,736	116,531	185,885
Cardiff University	23,219	4,946	414,359	412,914
University of Wales Institute, Cardiff	8,140	1,079	78,280	92,974
University of Glamorgan	12,358	1,658	119,576	105,455
Glyndŵr University	4,165	444	38,673	47,600
The University of Wales, Lampeter	1,201	223	16,105	31,707
The University of Wales, Newport	5,025	625	48,769	53,917
Royal Welsh College of Music and Drama		113		
Swansea Metropolitan University	4,388	524	33,574	53,270
Swansea University	12,134	2,095	150,792	155,659
Trinity University College	1,551	255	15,491	33,448
Total Welsh HE Sector	87,836	15,573	1,142,204	1,362,326

Energy consumption and costs 1 August 2009 – 31 July 2010.

Energy Consumption

Baseline Year	2009-2010				
Consumption	**Electricity (kW·h)**	**Gas (kW·h)**	**Oil (kW·h)**	**Coal (kW·h)**	**All fuels (kW·h)**
Aberystwyth University	19,125,918	23,152,666	271,402		42,549,986
Bangor University	16,114,213	20,489,802	1,988,009		38,592,024
Cardiff University	45,972,070	64,784,856	0		110,756,926
University of Wales Institute, Cardiff	7,868,973	13,144,104	42,400		21,055,477
University of Glamorgan	13,225,699	15,174,577	0		28,400,276
Glyndŵr University					
The University of Wales, Lampeter	1,939,686	7,790,832	0		9,730,518
The University of Wales, Newport	4,659,573	9,538,264	0		14,197,837
Royal Welsh College of Music and Drama			0		0
Swansea Metropolitan University	3,132,933	6,020,069	0		9,153,002
Swansea University	22,727,107	30,539,642	616,761		53,883,510
Trinity University College	2,295,216	7,702,341	0		9,997,557
Total Welsh HE Sector	137,061,388	198,337,153	2,918,572	0	338,317,113

Energy Costs

Baseline Year	2009-2010				
Costs	**Electricity (£s)**	**Gas (£s)**	**Oil (£s)**	**Coal (£s)**	**All fuels (£s)**
Aberystwyth University	1,496,215	975,940	12,884		2,485,039
Bangor University	1,819,802	462,439	120,580		2,402,821
Cardiff University	4,746,030	2,391,600	0		7,137,630
University of Wales Institute, Cardiff	716,012	382,329	1,960		1,100,301
University of Glamorgan	1,247,032	376,558	0		1,623,590
Glyndŵr University	442,523	177,694	0		620,217
The University of Wales, Lampeter	294,491	229,831	0		524,322
The University of Wales, Newport	425,477	228,150	0		653,627
Royal Welsh College of Music and Drama			0		0
Swansea Metropolitan University	327,958	272,109	0		600,067
Swansea University	1,471,737	1,400,026	33,506		2,905,269
Trinity University College	210,038	194,782	0		404,820
Total Welsh HE Sector	13,197,315	7,091,458	168,930	0	20,457,703

Normalising Factors

Baseline Year	2009-2010			
	Student (FTE)	**Staff (FTE)**	**Income (£ks)**	**GIA (m2)**
Aberystwyth University	8,437	1,855	120,763	190,242
Bangor University	9,667	1,759	126,166	199,675
Cardiff University	23,114	4,982	429,230	418,011
University of Wales Institute, Cardiff	9,130	1,079	80,557	91,982
University of Glamorgan	15,157	1,898	143,723	134,202
Glyndŵr University	4,698	580	43,508	55,427
The University of Wales, Lampeter	1,171	219	15,739	31,707
The University of Wales, Newport	5,166	698	47,812	56,985
Royal Welsh College of Music and Drama				
Swansea Metropolitan University	4,745	518	37,071	52,830
Swansea University	13,198	2,105	159,378	198,849
Trinity University College	1,730	255	16,332	33,468
Total Welsh HE Sector	96,212	15,948	1,220,279	1,463,378

Appendix B - Energy consumption data as supplied by Cardiff University.

EMS Statistics - Estimated annual consumptions

		2001/2	2002/3	2003/4	2004/5 (Aug)	2005/6 (Aug)	2006/7 (Aug)	2007/8 (Aug)	2008/9 (Jul)	2009/10 (Jul)
D38A	Energy Consumption C1 Total - Gas			67,604,000.00	45,814,000.00	49,219,000.00	53,829,000.00	58,468,000.00	68,701,501.51	64,784,856.00
D38A	Energy Consumption C1 Total - Electricity			41,253,000.00	34,993,000.00	34,530,000.00	43,943,000.00	41,601,000.00	47,816,949.43	45,972,070.00
	Total - Residential Gas				20,161,000.00	20,319,000.00	18,113,000.00	18,909,000.00	17,274,745.45	16,934,761.00
	Total - Residential Elec				6,992,000.00	8,686,000.00	8,262,000.00	8,149,000.00	6,918,988.68	6,969,365.00
D38A	Energy Consumption C13 Total Non-residential	55,568,000.00	67,843,000.00	81,784,000.00	53,654,000.00	83,749,000.00	71,397,000.00	73,011,000.00	23,623,215.30	
D38A	Energy Consumption C14 Total Residential	26,687,000.00	27,549,000.00	27,073,000.00	27,153,000.00	29,005,000.00	26,375,000.00	27,058,000.00	24,193,734.13	
D38B	Water consumption C13 Total Non-residential	180,509.00	183,709.00	194,993.00	169,976.00	156,975.00	167,196.00	144,883.00	141,222.00	125,730.00
D38B	Water consumption C14 Residential	136,634.00	154,815.00	146,769.00	154,682.00	143,868.00	152,502.00	148,523.00	150,000.00	149,000.00
D38C	Energy Emissions C1 Total - Gas			13,114,980.00	8,704.66	9,351,610.00	10,227,510.00	11,108,920.00	13,053,285.29	12,309,122.64
D38C	Energy Emissions C1 Total - Electricity			17,408,766.00	15,046.99	14,847,900.00	18,895,490.00	17,888,430.00	20,561,288.25	25,008,806.08
	All Electricity emmissions Statistics retrospectively revised based upon 0.55tCO/MWh			22,024,113.27	19,036.19	18,784,320.00	23,904,992.00	22,630,944.00	26,012,420.49	25,008,806.08
D38C	Energy Emissions Total Non-residential			30,583,550.00	16,914,500.00	16,603,920.00	22,128,870.00	21,900,570.00	14,303,921.49	30,308,989.57
D38C	Energy Emissions C14 Residential				6,837,150.00	7,595,590.00	6,994,130.00	7,096,780.00	6,257,366.77	7,008,939.15
D72b	% Total energy (D38a(c1)) consumed from renewable energy sources				Unknown	Unknown	0.25%	0.25%	0.25%	0.25%
							Not UHW site	Not UHW site	Including UHW Site as follows	

Natural gas based upon 0.19 tonnes of Carbon per MWh from DEFRA up to 2007/8
Electricity based upon 0.43 tonnes of Carbon per MWh from DEFRA up to 2007/8

Total UHW Gas - 1,234,596
Total UHW Elec - 1,823,596
Total UHW Water - 4,222

Natural gas based upon 0.19 tonnes of Carbon per MWh from DEFRA for 2008/9 - substantial increase in this factor for 2009/10
Electricity based upon 0.43 tonnes of Carbon per MWh from DEFRA for 2008/9 - substantial increase in this factor for 2009/10

Appendix C – Estimation of energy consumption data for Glyndwr University.

Approximation of percentage GIA (m^2) for Glyndwr University of total Welsh HE estate from EMS raw data for 2005, see appendix A.

$$\frac{43{,}539}{1{,}328{,}003} \times 100\% = 3.28\%$$

Electricity and gas consumption calculated pro-rata from Welsh HE sector totals using GIA for individual years as below:

	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Glyndwr University GIA	43,539	44,269	44,269	47,600	55,427
Welsh HE Estate Total GIA (m2)	1,328,003	1,335,996	1,347,992	1,362,326	1,463,378
Welsh HE Estate GIA (exc. Glyndwr) (m2)	1,284,464	1,291,727	1,303,723	1,314,726	1,407,951
Welsh HE sector electricity consumption (kW·h)	116,371,196	123,707,090	122,225,631	140,330,743	137,061,388
Welsh HE sector gas consumption (kW·h)	207,927,749	191,651,729	202,737,213	203,231,897	198,337,153
Glyndwr pro-rated electricity consumption (kW·h)	**3,944,591**	**4,239,587**	**4,150,273**	**5,080,711**	**5,395,716**
Glyndwr pro-rated gas consumption (kW·h)	**7,048,050**	**6,568,130**	**6,884,111**	**7,358,064**	**7,807,968**

Appendix D – Carbon Trust (2011) Degree day Data.

[no longer available online]. Originally available at:

https://www.carbontrust.co.uk/SiteCollectionDocuments/Jan10_Degree_Days.pdf (Accessed 21 February 2011).

CARBON TRUST
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2006 (15.5 degrees centigrade base):

	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	306	335	339	288	334	350	360	351	338	358	345	350	342	343	336	324	325	291
Feb	299	334	333	295	325	331	318	310	300	306	319	325	298	312	318	303	306	272
Mar	291	321	319	292	300	337	341	344	352	353	336	343	350	356	381	308	322	340
Apr	166	191	197	185	188	206	202	227	235	221	213	222	244	248	252	221	237	256
May	75	96	110	115	95	113	100	146	177	147	113	109	165	185	203	143	154	198
Jun	24	39	46	39	32	35	32	59	85	58	44	54	71	70	80	56	62	99
Jul	4	7	13	10	9	11	6	25	35	26	12	11	30	32	34	18	27	43
Aug	17	27	29	19	20	29	23	45	40	37	27	31	53	51	49	32	45	59
Sep	9	22	24	15	27	27	23	30	43	34	23	19	48	53	57	25	44	49
Oct	59	82	72	54	67	104	91	109	114	102	86	75	129	132	132	83	109	123
Nov	177	207	219	166	197	218	182	231	228	225	221	217	242	257	240	202	251	233
Dec	252	268	276	213	245	283	262	303	302	306	284	290	294	328	343	251	297	265

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2007 (15.5 degrees centigrade base):

	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	233	268	259	213	248	273	257	282	282	274	266	274	288	309	308	250	295	299
Feb	231	258	248	200	242	276	241	285	269	281	266	274	272	286	296	248	276	264
Mar	216	260	249	211	242	260	238	267	277	264	255	252	272	280	269	260	282	278
Apr	93	124	126	111	120	155	165	154	171	161	135	144	162	169	172	152	148	176
May	83	109	113	93	105	128	140	148	164	131	128	118	159	173	185	129	143	198
Jun	26	38	41	35	33	49	50	65	106	66	49	51	71	99	114	51	71	112
Jul	20	31	42	33	29	45	51	58	57	44	36	34	60	61	60	51	53	68
Aug	22	39	45	32	29	44	61	69	63	51	35	40	57	66	71	40	45	82
Sep	44	67	70	54	64	78	86	98	85	84	60	68	106	98	110	60	81	123
Oct	115	166	139	95	128	145	152	151	158	162	131	148	147	156	163	117	119	135
Nov	215	248	241	184	227	245	251	241	222	234	236	263	238	245	249	197	213	239
Dec	293	332	320	235	307	328	341	338	331	346	328	321	338	359	351	289	293	290

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2008 (15.5 degrees centigrade base):

	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	237	271	267	224	242	270	280	320	303	288	275	280	327	338	341	256	310	325
Feb	255	296	278	235	281	298	294	278	283	316	295	285	289	299	281	258	281	288
Mar	250	280	280	247	258	292	314	318	302	292	291	298	314	316	337	274	299	327
Apr	187	214	215	201	219	239	250	260	261	243	229	229	247	252	271	232	224	258
May	66	83	82	64	86	104	97	116	163	133	100	95	109	157	160	92	100	136
Jun	32	48	61	59	45	68	79	78	87	80	53	65	90	90	99	86	82	118
Jul	18	29	38	30	24	39	43	42	54	42	29	38	40	47	50	40	41	66
Aug	12	19	31	18	15	23	23	32	36	31	19	24	31	44	50	29	34	53
Sep	43	59	72	56	65	81	95	107	80	76	63	73	104	90	97	75	84	107
Oct	140	159	167	138	146	175	184	235	186	193	169	179	223	217	218	156	199	221
Nov	218	237	243	195	226	257	270	284	259	266	252	255	282	292	294	223	259	257
Dec	334	354	366	295	369	371	400	416	340	381	370	373	388	376	358	313	342	323

2009 (15.5 degrees centigrade base):

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	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	360	381	384	303	357	378	376	413	355	374	378	411	364	378	362	343	348	311
Feb	292	306	318	272	301	304	319	354	289	307	315	323	323	306	321	296	279	279
Mar	232	259	260	232	235	270	267	287	286	279	268	274	291	295	304	263	278	302
Apr	125	150	175	173	170	172	184	196	219	198	171	153	197	203	218	194	183	203
May	76	92	105	114	117	128	140	150	145	134	113	108	178	166	174	143	136	169
Jun	35	48	46	51	47	73	79	85	86	83	63	69	75	101	110	72	71	109
Jul	15	23	9	16	20	37	39	36	37	42	25	30	38	47	48	37	36	55
Aug	13	20	6	18	16	30	33	43	35	32	24	24	40	47	42	35	37	58
Sep	30	42	56	46	77	67	86	74	73	77	50	55	76	82	88	68	77	85
Oct	87	106	132	79	139	135	160	150	141	143	126	126	128	158	169	108	123	166
Nov	190	210	192	189	217	217	255	245	226	236	207	208	236	266	262	198	246	260
Dec	372	392	376	337	396	395	412	401	372	393	394	381	414	427	423	340	384	441

2010 (15.5 degrees centigrade base):

CARBON TRUST
Making business sense

	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	436	457	448	389	434	440	477	446	408	440	416	454	438	428	418	387	414	446
Feb	340	358	330	314	323	348	388	384	351	376	352	369	358	376	382	336	365	385
Mar	288	308	314	290	277	292	326	306	294	297	287	284	308	314	315	300	308	320
Apr	180	200	200	212	177	205	218	257	223	207	204	202	205	231	283	216	211	233
May	146	175	146	150	132	164	182	222	195	195	164	173	181	197	217	173	168	208
Jun	40	60	47	47	31	64	68	84	91	78	60	62	54	81	125	73	56	82
Jul	12	21	15	14	17	23	25	56	33	32	17	17	29	40	82	28	38	64
Aug	34	46	9	30	30	48	63	91	67	64	40	38	62	72	134	42	66	82
Sep	74	79	24	61	53	69	76	104	68	71	61	62	69	96	151	61	64	103
Oct	154	162	96	120	151	173	192	210	176	188	148	162	172	188	268	149	174	202
Nov	298	308	228	247	287	323	332	358	298	324	288	312	329	331	330	283	324	362
Dec	442	476	390	396	472	508	530	529	452	483	490	491	500	514	556	415	494	524

CARBON TRUST
Making business sense of climate change

20 year UK averages for 2010

Averaging data from 1991-2010

	1 London (Thames Valley)	2 South Eastern	3 Southern	4 South Western	5 Severn Valley	6 Midland	7 West Pennines	8 North Western	9 Borders	10 North Eastern	11 East Pennines	12 East Anglia	13 West Scotland	14 East Scotland	15 North East Scotland	16 Wales	17 Northern Ireland	18 North West Scotland
Jan	307	335	322	276	302	345	339	351	336	352	346	350	349	361	356	309	335	324
Feb	275	303	287	254	269	306	298	310	296	306	302	311	308	314	319	281	298	298
Mar	236	263	263	237	239	274	272	290	289	283	272	277	294	299	308	266	281	303
Apr	166	192	197	184	178	206	202	223	235	216	200	204	221	234	246	214	215	239
May	95	118	117	113	103	132	128	150	174	150	130	129	155	175	184	143	147	191
Jun	36	54	57	53	40	62	65	80	96	76	62	63	83	92	104	76	77	118
Jul	16	27	30	23	18	32	33	44	52	40	32	31	48	54	59	39	44	76
Aug	17	27	30	21	17	32	35	48	50	44	31	31	52	56	63	35	46	69
Sep	43	62	60	46	47	68	69	86	85	79	64	62	91	94	104	62	81	103
Oct	118	145	133	107	126	161	157	178	166	170	151	149	183	183	196	137	168	186
Nov	217	243	224	188	213	252	249	259	252	264	251	254	264	275	282	216	251	255
Dec	311	339	319	270	310	351	349	363	339	361	351	352	361	370	372	301	334	332

Appendix E – Copy of original "HEEPI, Energy – best practice", web page [no longer available online].

Higher Education - Environmental Performance Improvement

Energy - best practice

The Carbon Trust's Higher Education Carbon Management Programme has already helped 18 universities save £3 million and 55,000 tonnes carbon dioxide and 16 universities have signed up for Phase 2 running from May 2006 to April 2007. The programme is designed to deliver improved energy management of academic, accommodation and leisure buildings and vehicle fleets. It also provides practical support to HEIs by helping them identify carbon saving opportunities, providing software to analyse energy consumption and delivering workshop support for staff and senior managers to improve their awareness of energy efficiency. Any university that would like to be considered for phase three of the programme should email richard.rugg@thecarbontrust.co.uk.

The Carbon Trust's Energy Efficiency Accreditation Scheme provides useful guidelines on what should be done. These excerpts from the full checklist summarise the main features of a good energy management programme:

MANAGEMENT COMMITMENT TO ENERGY EFFICIENCY

There is a clearly stated energy policy, which has been promulgated to all employees.

There is a clear organisational structure, with a member of senior management having overall responsibility for the organisation's energy policy.

There are systematic procedures for monitoring and controlling energy consumption, with a planned approach to the improvement of overall energy performance.

There are quality control mechanisms, to ensure that the correct operating procedures of all plant and equipment reduce both the energy cost and environmental impact.

There are / have been awareness programmes for all staff, including new employees, and training programmes for those with energy responsibilities. Assessments for the NVQ in Managing Energy have been considered/carried out.

Energy efficient technology and best practices are incorporated into services, buildings and products, capital purchases and refurbishment programmes.

CO_2 emissions are calculated and publicly reported.

The Institute of Energy's Standards for Managing Energy been used in developing the above

INVESTMENT IN ENERGY EFFICIENCY MEASURES

There is provision in financial plans and budgets for energy efficiency investments, including allowance for the Climate Change Levy and Emissions Trading.

Capital investments have been made over the last 3 to 5 years, either in plant or equipment specifically for energy measures.

Energy efficiency measures have formed part of investments made for other purposes.

Investment in people has been made either internal of external, to improve management practises, for instance implementing an M&T system, organizing training or Vocational Qualifications.

There are plans for further investment.

ENERGY EFFICIENCY IMPROVEMENTS

The organisation has identified and actively uses an appropriate measure of specific energy consumption (SEC) e.g. GJ per m^2 or unit product.

Account is taken of changes in business size or activity levels.

There is analysis of consumption patterns in the case of larger organisations or more complex processes, to provide adequate detail.

A number of universities and colleges have achieved accreditation:

- Coventry University
- Glasgow Caledonian University
- Keele University
- King's College London
- Liverpool John Moores University
- Thames Valley University
- University of Bath
- University of Dundee
- University of Edinburgh
- University of Glasgow
- University of Manchester

- University of Sheffield
- University of Warwick

Other examples of good energy efficiency practices can be found at:

University of Leicester - click here

University of Essex – click here

University of Southampton – click here

University of Edinburgh – click here .

There is also a HEEPI case study on energy metering at UMIST.

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Created by Peak Sites

Appendix F - Display Energy Certificate Technical Tables for Cardiff Metropolitan University, Colchester Avenue campus and Ogmore building.

Full Technical Table

DEC RRN: 9577-1079-0308-0700-4991
University of Wales Institute Cardiff
Colchester Avenue Campus, Colchester Avenue
Penylan
CARDIFF
CF23 9XR

Annual energy use, CO_2 emissions and performance indicators	**Fuel and heat**	**Electricity**	**Units for energy**	**CO_2 emission**	**Units for CO_2**
Total energy use in the year concerned	1965443	849221	kWh	848.4	tonnes CO_2
Calculated performance indicators	157	68	kWh/m² pa	68	kgCO_2/m² pa
Reference performance benchmarks corrected	254	93	kWh/m² pa	101	kgCO_2/m² pa
Benchmark ratios and Operational Rating (lower is better)	62	72	Typical = 100	**67**	Typical = 100
Operational Rating grade (A is best)	Not applicable	Not applicable	Not applicable	**C**	**A to G**
Displaced energy	**Fuel and heat**	**Electricity**	**Units for energy**	**Percentage kWh displaced**	**Units**
Fossil Fuel Energy Displaced	0	-	kWh	0%	% of total
Grid Electrical Energy Displaced	-	0	kWh	0%	% of total

Building types	**Area (m²)**
University campus	12535.68
Total Usable Floor Area (TUFA)	**12536**
Total accessible unconditioned area	383

Separable energy use areas	**Area (m²)**
Total area for DEC assessment (TADA)	**12536**

Notes:

(a) 'Fuel and heat' includes imported combustion fuels (e.g. fossil) and heating and cooling from community systems, nett of exports

(b) Electricity includes electricity used for all purposes, including heating, cooling, small power, etc., nett of exports

(c) Where applicable, the 'total energy use in the year concerned' includes 'fuel and heat' and 'electricity' generated from LZC energy sources

(d) TADA is the area used in the OR calculations and the technical table calculations; it includes accessible unconditioned spaces, but excludes separable energy use areas

(e) TUFA determines whether the building exceeds the 1,000 m² threshold for a DEC being needed, and is the area shown on the DEC

(f) Only separable energy uses applicable to the building benchmark type may be deducted providing suitable evidence is available

(g) Up to five benchmark categories may be shown in the technical table; some sites may have more and alternative software should be used. Building types classed under the same benchmark category are not shown

(h) Benchmarks are corrected for weather and hours of occupancy during the assessment period

(i) 'Displaced energy' is energy generated by on-site renewable (OSR) and low & zero carbon (LZC) sources, consumed by the building, nett of exports

Full Technical Table

OGMORE BUILDING
Cardiff Metropolitan University
Llandaff Campus, 200 Western Avenue
CARDIFF
CF5 2YB

DEC RRN: 0281-0012-9469-3899-1002

Annual energy use, CO2 emissions and performance indicators	Fuel and heat	Electricity	Units for energy	CO2 emission	Units for CO2
Total energy use in the year concerned	606099	773518	kWh	523.6	tonnes CO2
Calculated performance indicators	83	97	kWh/m² pa	65	kgCO2/m² pa
Reference performance benchmarks corrected	241	80	kWh/m² pa	91	kgCO2/m² pa
Benchmark ratios and Operational Rating (lower is better)	26	121	Typical = 100	**72**	Typical = 100
Operational Rating grade (A is best)	Not applicable	Not applicable	Not applicable	**C**	**A to G**
Displaced energy	**Fuel and heat**	**Electricity**	**Units for energy**	**Percentage kWh displaced**	**Units**
Fossil Fuel Energy Displaced	0	-	kWh	0%	% of total
Grid Electrical Energy Displaced	-	0	kWh	0%	% of total

#	Building types	Area (m²)
1	University Campus	7995.17
	Total Usable Floor Area (TUFA)	**7995**
	Total accessible unconditioned area	**378**

#	Separable energy use areas	Area (m²)
	Total Area for DEC Assessment (TADA)	7995

Notes:

(a) 'Fuel and heat' includes imported combustion fuels (e.g. fossil) and heating and cooling from community systems, nett of exports
(b) Electricity includes electricity used for all purposes, including heating, cooling, small power, etc., nett of exports
(c) Where applicable, the 'total energy use in the year concerned' includes 'fuel and heat' and 'electricity' generated from LZC energy sources
(d) TADA is the area used in the OR calculations and the technical table calculations, it includes accessible unconditioned spaces but excludes separable energy use areas
(e) TUFA determines whether the building exceeds the 1,000 m² threshold for a DEC being needed, and is the area shown on the DEC
(f) Only separable energy uses applicable to the building benchmark type may be deducted providing suitable evidence is available
(g) Up to thirty benchmark categories may be shown in the technical table. Building types classed under the same benchmark category are not shown
(h) Benchmarks are corrected for weather and hours of occupancy during the assessment period
(i) 'Displaced energy' is energy generated by on-site renewable (OSR) and low & zero carbon (LZC) sources, consumed by the building, nett of exports

Appendix G – CO_2 Emissions for Welsh HEIs.

Calculated from CO_2 conversion factors shown in table 6.1:

Baseline Year	2005-2006				
kg CO_2	Electricity	Gas	Oil	Vehicles	Total
Aberystwyth University	8,095,008	5,566,535	19,885	39,664	13,721,091
Bangor University	8,327,667	5,350,169	1,206,289	46,551	14,930,675
Cardiff University	18,614,605	9,116,835	0	64,730	27,796,170
University of Wales College of Medicine	0	0	0	0	0
University of Wales Institute, Cardiff	4,580,662	2,966,665	0	21,063	7,568,390
University of Glamorgan	5,396,510	2,933,481	0	20,828	8,350,820
Glyndŵr University	2,126,470	1,305,510	0	9,269	3,441,249
The University of Wales, Lampeter	1,037,317	1,615,603	0	11,471	2,664,391
The University of Wales, Newport	2,623,009	1,811,565	0	12,862	4,447,437
Royal Welsh College of Music and Drama	385,962	206,606	0	1,467	594,035
Swansea Metropolitan University	1,736,287	1,118,888	0	7,944	2,863,119
Swansea University	10,839,713	6,332,415	0	44,960	17,217,088
Trinity University College	1,097,227	1,495,692	0	10,619	2,603,539
Total Welsh HE Sector	**64,860,436**	**39,819,967**	**1,226,174**	**291,428**	**106,198,004**

Baseline Year	2006-2007				
kg CO_2	Electricity	Gas	Oil	Vehicles	Total
Aberystwyth University	7,748,222	4,879,355	5,233	34,681	12,667,491
Bangor University	8,417,083	4,996,056	986,603	42,477	14,442,219
Cardiff University	23,689,012	9,970,746	0	70,792	33,730,550
University of Wales College of Medicine	0	0	0	0	0
University of Wales Institute, Cardiff	4,268,447	2,249,993	0	15,975	6,534,415
University of Glamorgan	5,455,882	2,107,961	0	14,967	7,578,809
Glyndŵr University	2,285,498	1,216,615	0	8,638	3,510,750
The University of Wales, Lampeter	989,577	1,576,563	0	11,194	2,577,333
The University of Wales, Newport	2,634,552	1,583,543	0	11,243	4,229,337
Royal Welsh College of Music and Drama	343,572	164,880	0	1,171	509,623
Swansea Metropolitan University	1,756,398	927,209	0	6,583	2,690,190
Swansea University	10,216,509	5,693,285	0	40,422	15,950,216
Trinity University College	1,169,384	1,350,059	0	9,585	2,529,028
Total Welsh HE Sector	**68,974,134**	**36,716,264**	**991,835**	**267,728**	**106,949,962**

Baseline Year	2007-2008				
kg CO_2	**Electricity**	**Gas**	**Oil**	**Vehicles**	**Total**
Aberystwyth University	7,561,005	4,668,212	15,693	33,256	12,278,165
Bangor University	8,172,516	4,662,654	268,317	35,010	13,138,497
Cardiff University	22,426,475	10,830,028	0	76,893	33,333,396
University of Wales College of Medicine	0	0	0	0	0
University of Wales Institute, Cardiff	4,473,734	2,545,305	0	18,072	7,037,110
University of Glamorgan	6,455,912	2,670,898	0	18,963	9,145,773
Glyndŵr University	2,237,350	1,275,144	0	9,054	3,521,547
The University of Wales, Lampeter	1,027,741	1,493,776	0	10,606	2,532,123
The University of Wales, Newport	2,542,872	1,757,417	0	12,478	4,312,767
Royal Welsh College of Music and Drama	407,177	172,522	0	1,225	580,924
Swansea Metropolitan University	1,661,513	838,329	0	5,952	2,505,795
Swansea University	9,940,628	6,522,237	158,844	47,436	16,669,145
Trinity University College	1,220,432	1,391,635	0	9,881	2,621,948
Total Welsh HE Sector	**68,127,354**	**38,828,158**	**442,854**	**278,824**	**107,677,190**

Baseline Year	2008-2009				
kg CO_2	Electricity	Gas	Oil	Vehicles	Total
Aberystwyth University	10,707,908	4,859,497	38,448	34,775	15,640,628
Bangor University	8,629,997	4,302,170	490,179	34,026	13,456,372
Cardiff University	25,777,400	12,725,579	0	90,352	38,593,331
University of Wales College of Medicine	0	0	0	0	0
University of Wales Institute, Cardiff	4,374,739	2,550,336	5,233	18,145	6,948,452
University of Glamorgan	6,635,177	2,773,613	0	19,693	9,428,483
Glyndŵr University	2,738,935	1,362,934	0	9,677	4,111,546
The University of Wales, Lampeter	1,059,428	1,456,202	0	10,339	2,525,969
The University of Wales, Newport	2,548,008	1,776,085	0	12,610	4,336,703
Royal Welsh College of Music and Drama	392,650	156,795	0	1,113	550,558
Swansea Metropolitan University	1,660,156	967,120	102,270	7,593	2,737,139
Swansea University	12,711,233	4,640,081	96,349	33,629	17,481,291
Trinity University College	1,153,503	1,437,167	0	10,204	2,600,874
Total Welsh HE Sector	**78,389,134**	**39,007,578**	**732,479**	**282,154**	**118,411,345**

Baseline Year	2009-2010				
kg CO_2	Electricity	Gas	Oil	Vehicles	Total
Aberystwyth University	10,310,496	4,288,568	66,990	30,924	14,696,978
Bangor University	8,686,931	3,795,326	1,071,706	34,556	13,588,518
Cardiff University	24,782,853	12,000,099	0	85,201	36,868,153
University of Wales College of Medicine	0	0	0	0	0
University of Wales Institute, Cardiff	4,242,045	2,434,682	0	17,286	6,694,014
University of Glamorgan	7,129,776	2,810,787	0	19,957	9,960,519
Glyndŵr University	2,908,750	1,446,270	0	10,269	4,365,288
The University of Wales, Lampeter	1,045,656	1,443,096	0	10,246	2,498,997
The University of Wales, Newport	2,511,906	1,766,773	0	12,544	4,291,223
Royal Welsh College of Music and Drama	0	0	0	0	0
Swansea Metropolitan University	1,688,917	1,115,097	0	7,917	2,811,932
Swansea University	12,251,842	5,656,858	0	40,164	17,948,864
Trinity University College	1,237,317	1,426,705	0	10,130	2,674,151
Total Welsh HE Sector	**76,796,488**	**38,184,261**	**1,138,696**	**279,193**	**116,398,638**