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Sector review of UK higher education energy consumption

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ABSTRACT

The UK education and education-related services are said to be one of the fastest-growing export earners in recent years and are known to have had significant impacts at the micro- and macro-levels of the UK. This review looks at energy consumption of this fast growing sector. It concentrates on the energy consumption patterns of the funded higher education institutions in the UK. The findings indicate energy consumption in the sector has been on the increase in the 6 years up to 2006; rising by about 2.7% above the 2001 consumption levels. This increase is, however, not evenly spread across the entire sector. The high energy-consuming institutions appear to be increasing their net consumption, relative to other institutions. Gross internal area, staff and research student full-time equivalent were found to have highest correlation with energy consumption across the sector and may be used as proxy indicators for energy consumption as well as the targets of interventions.

1. Introduction

The review presented here is mostly a descriptive discussion of the UK higher education sector with a shade of exploratory study aimed at providing insights into the internal drivers of energy demand and use in the sector. The study examines key energy consumption characteristics of the UK higher education institutions (HEIs) with a view to identifying patterns, trends as well as areas and issues requiring further investigation. Higher education in the UK refers to academic institutions offering qualifications beyond GCE A levels or its equivalent. This review draws on existing data from various sources but relies heavily on the Higher Education Funding Council of England (HEFCE) Estate Management Statistics (EMS) database. EMS is a statutory reporting format for UK government-funded HEIs.

The institutions included in this report are those covered in the EMS between the years 2001 and 2006. This number corresponds roughly to funded institutions and varied slightly from year to year, but represents over 75% of all HEIs in the UK over the 6-year period. Some of the variation in number of institutions is due in part to mergers that occurred in the sector in the recent past.

Available data includes aggregated energy data for institutions broken down to fuel types, quantities, costs and ratios. Data on 103 out of 111 universities are available for the analysis. Additionally, data for 30 out of a possible 91 colleges of higher education is available and included in the analysis.

The approach to the study has been suggested by the need to answer some of the following questions relating to the energy consumption at a sector level:

- Are there any discernable trends in Higher Education energy consumption.
- What are the consumption levels and how do these compare against existing energy consumption benchmarks for the sector.
- Are there any clearly identifiable drivers to energy consumption.

Access to the EMS database enabled a whole sector reflection on energy consumption and increased the possibility for generalisation of findings. Additionally, the existence of data spanning several years meant that analysis for patterns and trends could be conducted. Such trend analyses flagged up issues requiring attention and provide invaluable insights for future policy or operational interventions. The nature of available data also provided opportunities for assessing and comparing energy consumption against other estate statistics in an attempt to establish critical relationships. Analysis of the data therefore includes the exploration of relationships between energy consumption and several reported estate statistics like floor areas, number of students and staff, number of research student, etc.

2. Sector overview

The Universities UK (2006a, b) on the economic impact of HEIs highlights the extensive scale and economic importance of HEIs at

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the micro- and macro-levels of the UK. Higher education in the UK is a big and growing industry: providing a skilled workforce, creating employment, enkindling innovation, a source of foreign investment with substantial impacts on the economic landscape of UK regions ''Education and education-related services are our fastest-growing export earner and have already eclipsed food, tobacco, drink, insurance, ships and aircraft'' http://www.universitiesuk.ac.uk/speeches/show.asp?sp = 74 says the Diana Warwick, Universities UK chief executive. Based on the 2003/2004 returns from the HEIs, it is suggested that for every 100 full-time jobs in the HEIs, a further 99 full-time equivalent (FTE) jobs were generated through knock-on effects. Similarly, for every £1 million of direct output in the higher education sector, a further £1.5 million was generated in other sectors of the economy related to it. These ratios indicate the overall importance of the downstream segment of the higher education sector, especially in the consideration of indirect energy use and environmental sustainability. In 2006, there was an estimated total of 289,260 full-time staff equivalent engaged by the funded HEIs and a total income of about £19.4 billion. These figures represent the staff numbers as well as the income for the number of funded HEIs contained in the 2006 EMS database and represent about 75% of the UK HEIs.

This dramatic expansion of UK higher education in scale and scope has brought on increasing pressure on the sector to formally integrate sustainable development into policy and practice. This pressure derives from many factors including the financial implications of energy consumption as well as the increasing business profile of HEIs with the corporate responsibilities for sustainable development. Records from different sources indicate there are about 678 further and HEIs in the UK. 70.2% of this number is further education colleges and 13.4% are higher education institutes and colleges. The UK's 111 universities make up the 16.4% balance (Table 1).

Table 1
UK further and higher education institution numbers by region

Region	Further education institutions	HE colleges and institutes	Universities	Total
East Midlands	28	1	8	37
Eastern	37	3	7	47
London	47	45	12	104
North East	22	0	5	27
North West	64	4	11	79
South East	74	5	16	95
South West	35	5	8	48
West Midlands	51	3	9	63
Yorkshire and Humber	37	5	11	53
Northern Ireland	17	2	2	21
Scotland	44	8	14	66
Wales	20	10	8	38
United Kingdom	476	91	111	678

Sources: HEFCE, SHEFC, HEFCW & Higher Education &Research Opportunities Find a university in the UK-British Universities and HE Institutions guide (http://www.hero.ac.uk/uk/universities___colleges/index.cfm) databases.

The university sub-sector alone has recorded an unparalleled growth in the past 15 years. There are about 60 post 1992 universities in the UK, which represents more than 100% increase in the number of universities pre 1992. Even though most of the new universities were polytechnics, the differences in vocations between polytechnics and universities mean significantly different operations, facilities and equipment to the original polytechnic entities.

Over the 10-year period from 1995/1996 to 2004/2005 the higher education sector has recorded a 33% HESA (2005/2006) increases in enrolment. In 2006 alone, a total of more than 1.5 million FTE students were registered for studies in HEIs. This value represents a 14.9% increase above the student FTE numbers in 2001 (Table 2).

There have also been significant variations in the patterns of course enrolment in universities, which would have had impacts on the operations, facilities, equipment and undoubtedly energy consumption patterns of the institutions. Mass communication and documentation, subjects allied to medicine and computer science recorded the highest increases in enrolment over the 10-year period 1995–2005, followed closely by courses in the biological sciences, creative arts and design as well as historical and philosophical studies. These courses have substantial need for equipment and services that are energy intensive (Fig. 1).

The emergence of new institutions as well as the merger of institutions within the sector has resulted in wide variations in the estate make up and sizes in HEIs. The estimated Gross Internal Area (GIA) for the HEIs in 2006 stood at 25.4 million square metres, a rise of 6.3% above the reported 2001 EMS figures. About 22% of the HEIs' building stock GIA is residential; the rest is split between core academic and support facilities. The overall sector median floor use intensity (student FTE to GIA ratios) has been fairly constant at about 15 m^2 over the past 4 years.

3. Trends in HEIs' energy consumption

In 2006, the reported total energy consumption from all sources in the funded HEIs stood at 706.23 Ktoe or 8.2 million kWh; the equivalent consumption of 365,953 average UK households or 30% of households in Wales. The total amount of energy consumed by these institutions in 2006 is about 3.5% of the total energy consumption for the UK service sector, which overall consumption for the year stood at 19,888 Ktoe DTI, 2007.

The 2006 total energy consumption figure corresponds to a 2.7% increase over the 2001 consumption figures. The reported energy consumption in 2001 was 687.9 Ktoe (8.0 million kWh). Energy consumption in the sector showed a steady rise from 2001 till 2004 and then a very sharp drop in 2005. The fall in 2005 saw the sectors energy consumption at one of the lowest levels (just above the 2001 values) in the 6-year period under review. The reasons for this sharp drop are not immediately clear, but may be as a result of a combination of factors. Year 2005 was a comparatively hot, which may have resulted in lower energy demand for heating. An additional probable cause of the drop has to do with gaps in the energy consumption reporting data for the

Table 2
Student full-time equivalent (FTE) numbers in funded HEIs 2001–2006

	2001	2002	2003	2004	2005	2006
Student FTE	1,355,858[a]	1,405,814[a]	1,462,676[a]	1,488,723[a]	1,521,803[a]	1,557,709[a]
% Change over preceding year		3.7	4.0	1.8	2.2	2.4
% Change over 2001		3.7	7.9	9.8	12.2	14.9

Source: EMS Institution Reports (2004, 2007).

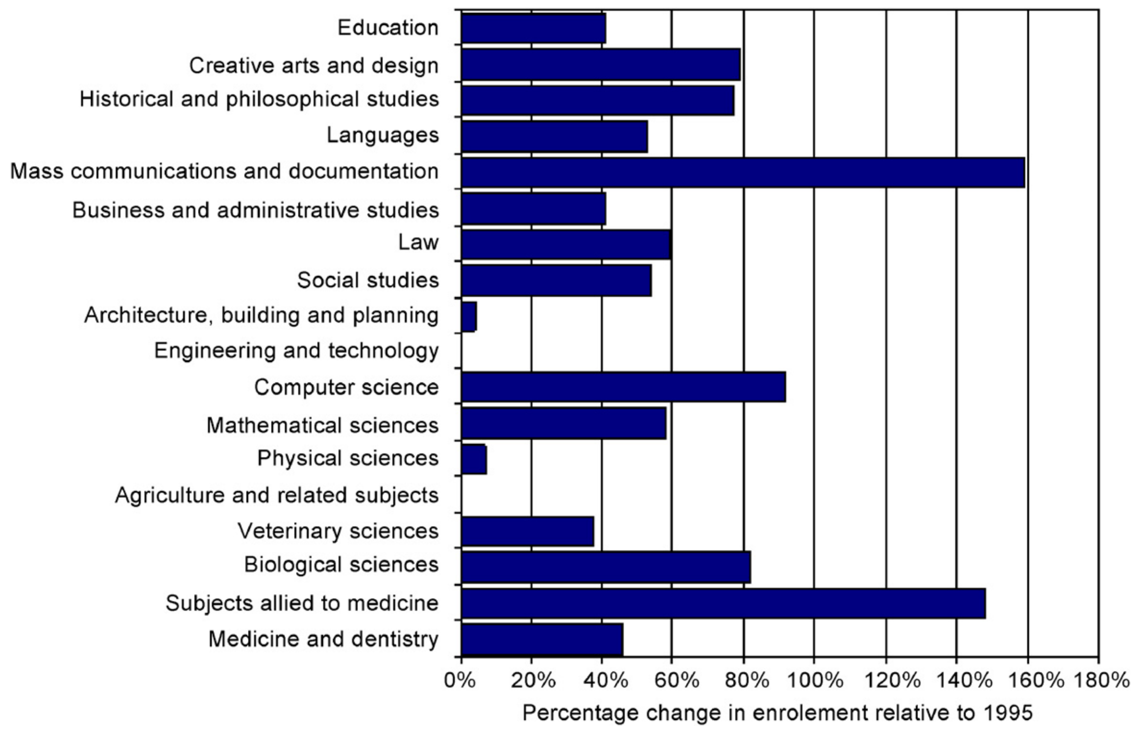

Fig. 1. Changes in pattern of course enrolment between 1995 and 2005 (*Source*: Universities UK (2006a, b): Patterns of HEIs in the UK: Sixth Report, Table 8).

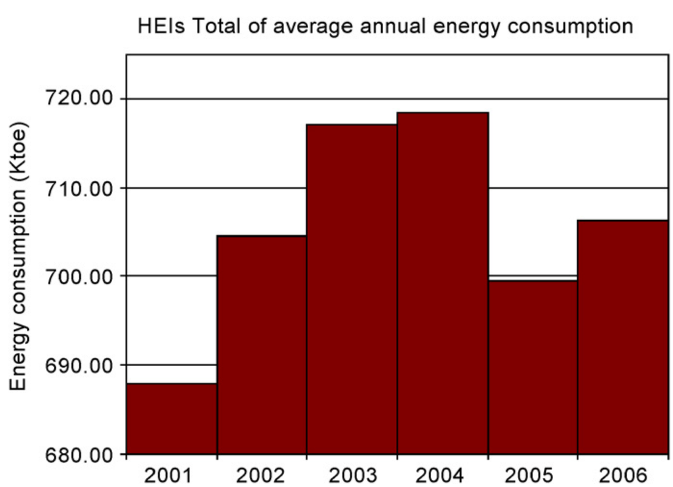

Fig. 2. Total annual energy consumption of HEIs in primary fuel equivalents (ktoe).

particular year. A gradual rise of about 0.95% above the 2005 reported values was, however, recorded in 2006. The graph in Fig. 2 highlights the pattern of energy consumption across the sector from 2001 to 2006. The energy consumption levels appear to have peaked in 2004 with substantial reductions in the subsequent years. The directions of consumption for the 2 years following are mixed and non-conclusive. It will be interesting to see what patterns develop in the next few years.

The overall annual average consumption per institution within the higher education sub-sector was 50,389,381 kWh, while the sector median consumption stood at 33,863,132 kWh (Fig. 3). Whereas the sector's average energy consumption has been on a steady but gradual rise, the median consumption value shows a steady decline from 2002 till 2006. This substantial difference may be attributed to the rise in the total energy consumption of the very high energy-consuming institutions. The range between the lowest and highest consuming institutions was 22,526,109 kWh in 2001 and rose to a peak in 2004 and stood at 313,847,746 kWh in 2006 as shown in Table 3. The histograms in Fig. 4 show a marked increase in the number and overall energy consumption levels of the biggest consumers over the 6-year period in review. In 2001, the largest energy-consuming institutions used less than 250 million kWh of energy per annum. By 2004, however, the biggest consumers were consuming energy in excess of 350 millon kWh per annum. The 2006 records, however, indicate a slight dip in the level of consumption of the biggest energy-consuming institutions from the 2004 and 2005 levels. The increase in the quantities consumed by the biggest consumers is thought to be responsible for the substantial difference between the mean and median energy consumption values across the sector. This is supported by the high kurtosis values of 8.22, 8.79, 9.56 and 5.49 recorded from 2003 to 2006. Kurtosis is a measure of the degree of 'peakedness' of a distribution relative to a normal distribution. A high Kurtosis suggests that more of the variation within a distribution is due to infrequent extreme deviations rather than frequent moderately sized deviations. This appears to be the case within the sector.

Over the period in review, an average of 65% of the HEIs had energy consumption levels below the group mean. Fig. 4 shows the proportion of institutions in different energy consumption bins in mega Watt hours. The number of institutions consuming less than 10 million kWh of energy increased from 19 in 2001 to 31 in 2006, while the number of institutions with over 250 million kWh of consumption increased form 1–3 over the same period. The records suggest that while the smaller consumers are reducing their consumption, the largest consumers appear to be moving in the opposite direction. The positive Skewness values give credence to the notion that some measure of success is being achieved in the reduction of energy consumption within the sector. This trend may have substantial implications in decision making, especially for policies and interventions within the sector.

In 2006, about 46% of HEIs consumed more than 50,000 mWh of energy. This percentage is lower than the proportion of HEIs that consumed more than 50million kWh, which stood at 50%,

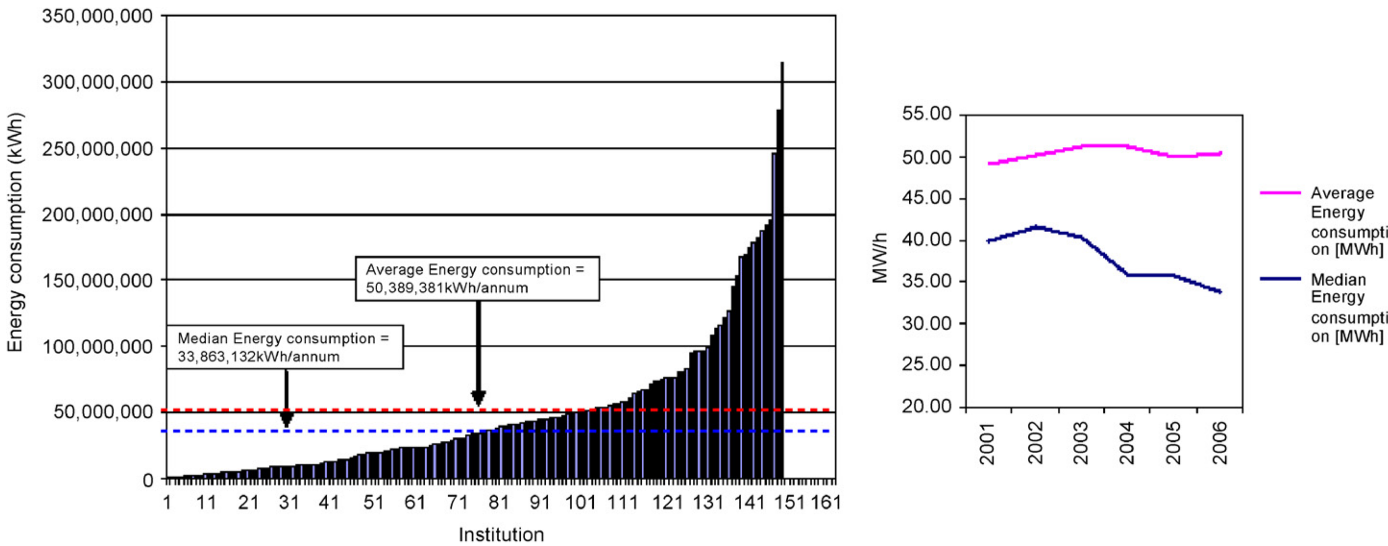

Fig. 3. Average and median energy consumption trends in HEIs.

Table 3
Energy consumption statistics in HEIs 2001–2006

	2001	2002	2003	2004	2005	2006
Mean	49,082,912	50,265,659	49,933,565	51,261,799	49,915,581	50,389,381
Median	39,860,539	41,485,700	38,540,560	35,934,935	35,794,138	33,863,132
Standard deviation	44,844,844	48,745,205	52,323,674	55,859,659	54,462,151	55,985,676
Kurtosis	2.62	4.63	8.22	8.79	9.56	5.49
Skewness	1.57	1.92	2.40	2.42	2.53	2.18
Range	229,526,109	259,920,445	343,172,057	378,203,354	375,847,746	313,277,352
Minimum	1,162,891	1,199,555	1,142,297	1,134,038	1,251,979	1,251,979
Maximum	230,689,000	261,120,000	344,314,354	379,337,392	377,099,725	314,529,331

52%, 49%, 47% and 46% for 2001, 2002, 2003, 2004 and 2005, respectively.

4. Energy consumption ratios

Many factors affect the energy consumption levels within each sector. In the higher education sector, energy consumption has often been associated with floor area and student numbers. An analysis of the energy consumption levels across all the institutions reveals that in spite of the overall increase in energy consumption in the sector, the average energy intensity per square metre GIA decreased from 293 kWh/m^2 in 2001 to 287 kWh/m^2 in 2006 representing a 2.1% reduction across the sector. This average value is substantially far off the HEEPI best practice benchmark of 162 kWh/m^2 HEEPI, 2006. across all activity areas. HEEPI is an acronym for Higher Education Environmental Performance Improvement, a funded initiative aimed at providing information resources, developing environmental benchmarks and running events to promote best practice and networking in the sector. In 2006, just fewer than 3% of funded HEIs reported energy consumption ratios that were below this benchmark.

Altogether, just over 40% of the institutions recorded reductions in their overall energy intensity between 2005 and 2006.

Notable changes also occurred in energy consumption ratios related to student numbers. Average energy consumption per student in 2006 was 6346 kwh, a 0.005% decrease over the 2001 average student consumption levels, which stood at 6349 kwh. However, there was a substantial change in the median consumption values per student. In 2001, the median energy consumption per student was 4496 kWh, but in 2006 the value had dropped to 3664 kWh per student. The increase in student numbers would undoubtedly have led to increases in the intensity of use of facilities and probably accounts for the sharp drop in energy consumption per student.

5. Higher education fuel mix

Gas remains the primary energy source for the sector, accounting for 53.5% of the total energy consumed in 2006. This figure is, however, significantly lower than the 63.0% share it enjoyed in 2003. Electricity and steam/hot water consumption have shown percentage increases of 4.4% and 5.7% above the levels in 2003. In the last record year, the share of electricity and hot water/steam to overall energy consumption in the sector was 37.6% and 6.6%, respectively. Oil consumption has been floating around the 2% mark for the past 4 years and no HEI reported the use of coal as an energy source. One hundred six HEIs (72%) had annual electricity consumption in excess of 6000 mWh. This implies that they are likely to fall within organisations expected to sign up to the proposed UK cap and trade scheme; Carbon Reduction Commitment programme due to be phased in by 2010 (Fig. 5).

6. Renewables uptake and CO_2 emissions

In 2004, 32% HEIs reported using some form of energy from renewable sources. By 2006 the uptake of energy from renewable sources had increased to 42% of HEIs included in the data set.

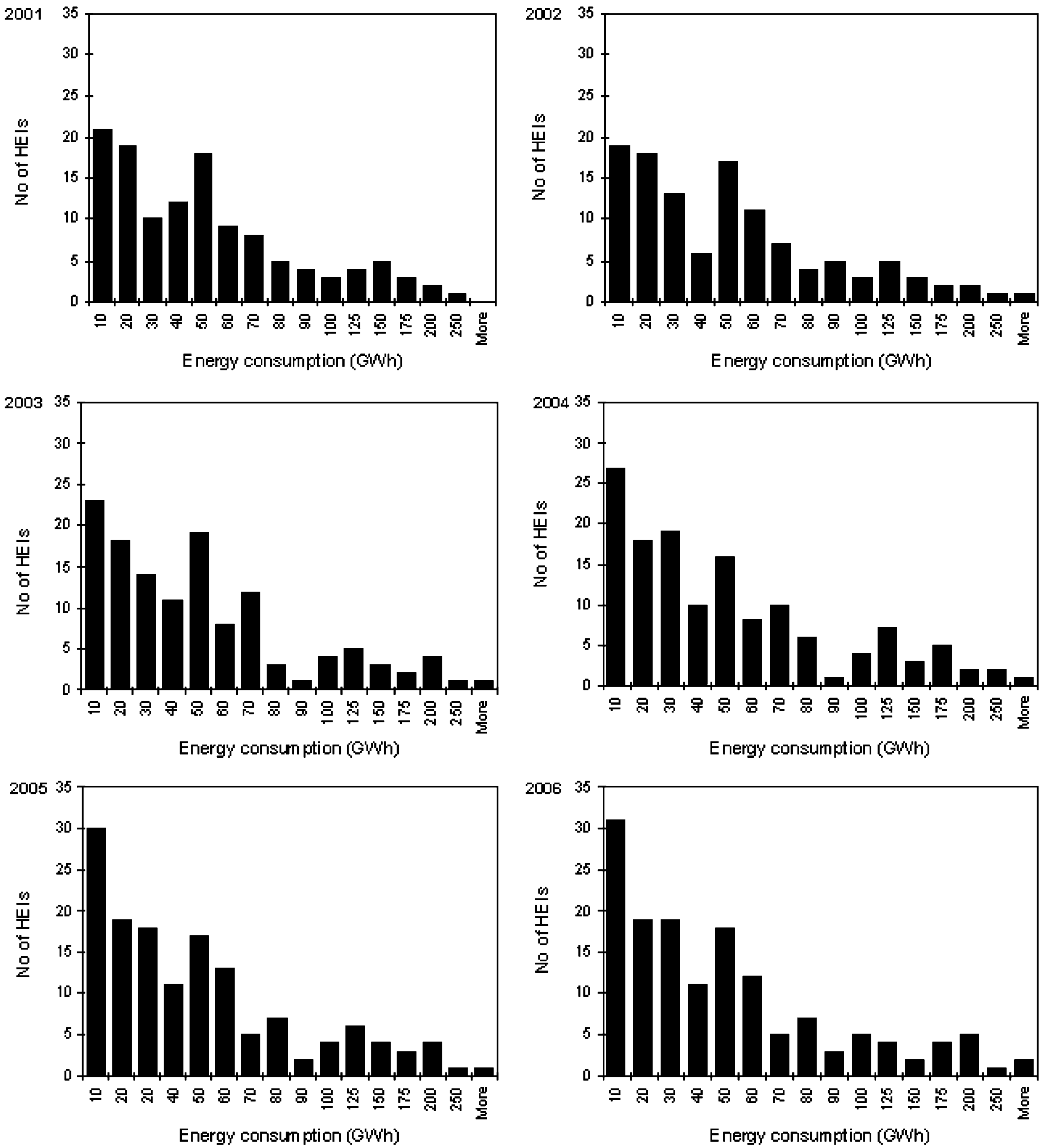

Fig. 4. Distribution of annual energy consumption across UK HEIs.

An average share of Renewable Energy sources to non-renewable sources across the greening HEIs is estimated at about 9%. This value should be viewed with caution since the reported data does not make a clear distinction between low and actual zero carbon technologies.

In 2006, funded HEIs produced an estimated nominal CO_2 emission of 2.16 Mtc. This figure is higher than the 2.15 and 2.07 Mtc recorded in 2004 and 2005, respectively. The increase in emissions in the sector runs contrary to the national plan and is not consistent with expectations following the reported increase in the use of renewable energy sources within the sector in the corresponding years.

7. Energy costs in HEIs

The Institutions under review spent over £300 million on energy, representing about 1.6% of the total income of all the

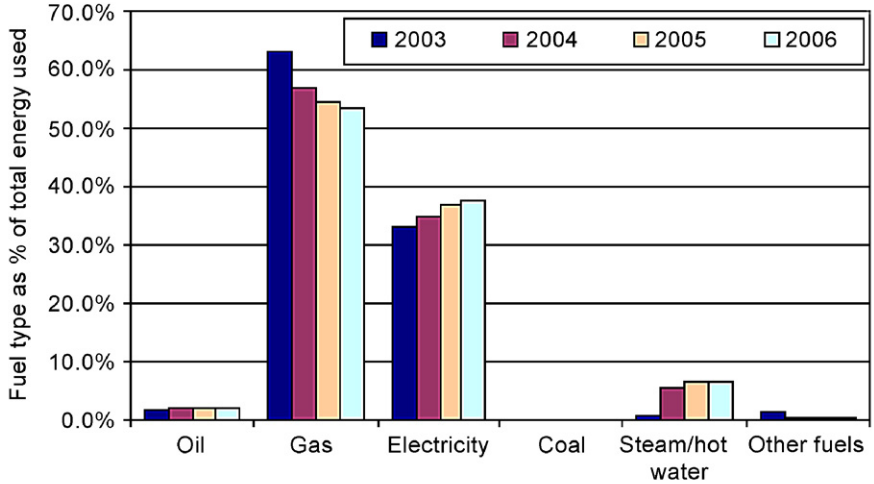

Fig. 5. Energy consumption by fuel type in HEIs 2001–2006.

institutions. This expenditure value is higher than the 1.1% expended on energy in 2001. This increase in expenditure is largely due to increases in costs of gas and electricity. Unfortunately, the rising cost of energy appears to be an enduring trend set to last for a long time yet. Fig. 6 paints a vivid picture of how energy costs per square metre gross internal floor area have changed in the higher education sector within the past 6 years. Notice the change in the direction of the trend lines. In 2001, the median and average energy costs per square metre of GIA in the sector stood at £6.37 and £6.76, respectively. Six years on, in 2006 the sector median and average cost of energy per square metre of GIA has increased by over 70% to £11.00 and £11.54.

The energy cost per 100 kWh consumed has increased across the sector in very large proportions. In 2006, the median energy cost per 100 kWh consumed across the higher education sector was £3.89, reflecting a 74% increase over the 2001 ratio of £2.24 per 100 kWh. There is a noticeable step change in trends, especially from 2005 onwards, which corresponds to the sharp increases in fuel prices experienced about the time. Fig. 8 shows the changes in electricity and gas prices from 1988 to 2006. The higher education energy costs closely tag the domestic energy prices. By 2004, the gas prices had gone beyond the highest level ever achieved since 1988, while the electricity price exceeded previous highest levels in 2005. The number of institutions with higher costs per 100 kWh of energy consumed continued to grow over the period covered by the data (Fig. 7).

Electricity costs represent about 62% of the total energy costs expended by HEIs in 2006. This is followed by gas at 33%, while all other fuels including oil, coal and hot water/steam made up the balance of 6% (Figs. 8 and 9).

In order to further explore the trends in HEIs' energy consumption and bearing in mind the diversity in the characteristics of the HEIs a basic categorisation of the HEIs was adopted. This categorisation reflects the assumption that the building use and stock have direct and indirect impacts on the demand for and use of energy. It draws on information on the period of establishment of the institutions, as proxy for the age of the building stock as well as the overall vocation and *modus operandi* of the institutions. A basic statistical analysis also revealed strong similarities between the member institutions of the various groupings on key statistics like student FTE numbers as well as the overall energy consumption values.

These categorisations are an adaptation of the Wikipedia classification of UK universities (Universities in the United Kingdom).

1. *Ancient universities*: This category refers to pre 19th century universities. There are six universities in this group.
2. *Redbrick universities*: Universities founded in the 19th and early 20th century. Twenty-four universities fall within this category.
3. *Plate glass universities*: This grouping covers the universities founded in the 1960s with buildings characterised by the extensive use of steel or concrete frame and wide areas of plate glass glazing. Twenty-one universities fall within this category.
4. *Institutes and colleges*: These include the University of London institutes as well as the Edinburgh and Glasgow colleges of Art. This category generally falls within the redbrick and ancient categories but is singled out because of the nature the institutions' activities and vocations.
5. *New universities*: Refers to post 1992 founded universities most of which were created out of polytechnics and colleges of higher education. This category also includes a wide variety of building stock with the common denominator being the date of establishment of the institutions.
6. *Colleges*: Refers to colleges of higher education other than the specialist colleges indicated in category 4 above.

The figure below shows the energy consumption levels in the different categories (Fig. 10).

The average energy consumption is highest among the ancient universities. These 'ancient' universities account for about 11% of the total sub-sector energy consumption. They also have the highest average gross internal floor area of 436,530 m^2 and recorded an average energy consumption ratio of 330 kWh per square metre (psm) GIA in 2006 a substantial increase over the 303 kWh psm GIA recorded in 2001. The 24 'redbrick' universities consumed 31% of the sector's energy in 2006; 23% by the 58 'modern' universities; 19% by 22 'plate glass' universities; 13% by 22 specialist institutes and colleges; and 3% by 30 colleges of higher education. The lowest average consumption in the sector is recorded in the colleges of higher education. Table 4 shows the average energy consumption psm GIA across the different categories of institutions as well as other statistics related to energy use in the different categories.

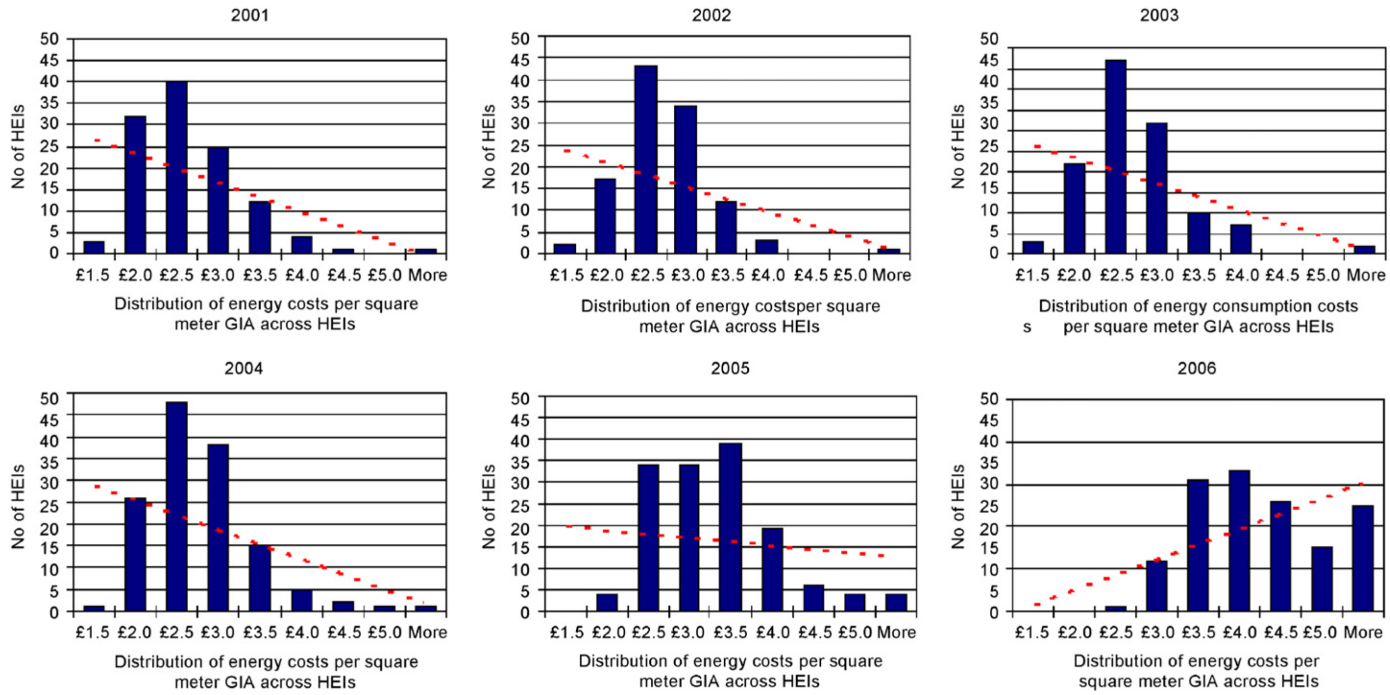

Fig. 6. Distribution of energy costs per square metre GIA across HEIs.

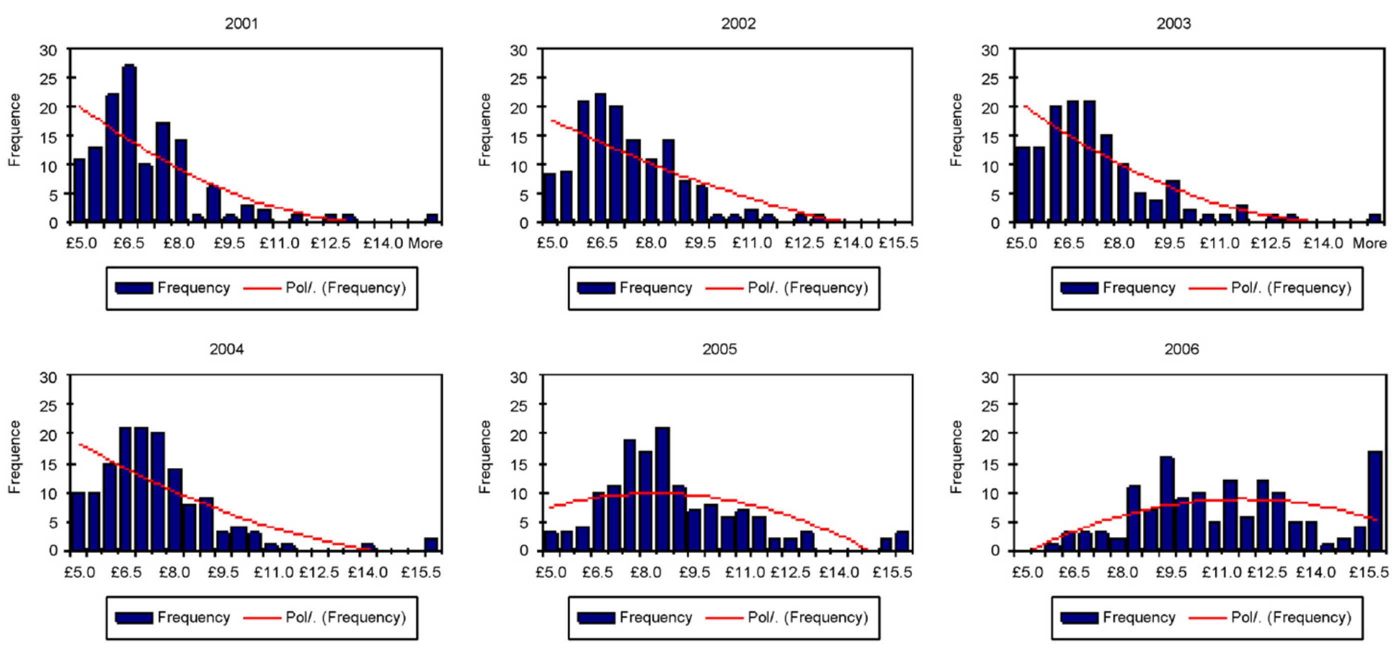

Fig. 7. Energy costs per 100 kWh energy consumed in HEIs.

The non-uniformity in the structure of the different categories is very evident in the energy consumption patterns across the categories. Two categories of HEIs; new universities and colleges of higher education have average energy consumption ratios that are substantially lower than the HEFCE benchmarks while the performances of other categories fall above the benchmarks by varying degrees. This raises the question about the applicability of a single set of benchmarks across the sector.

8. Sector-related drivers to energy consumption

One of the questions that arise from the non-uniformity in the sector is the more fundamental issue of the underlying drivers of energy consumption within the sector. 'Why do some categories consume more than others and can these drivers be moderated in such a manner as to reduce the overall energy consumption of the different institutions without compromising on the quality of delivery of the services?

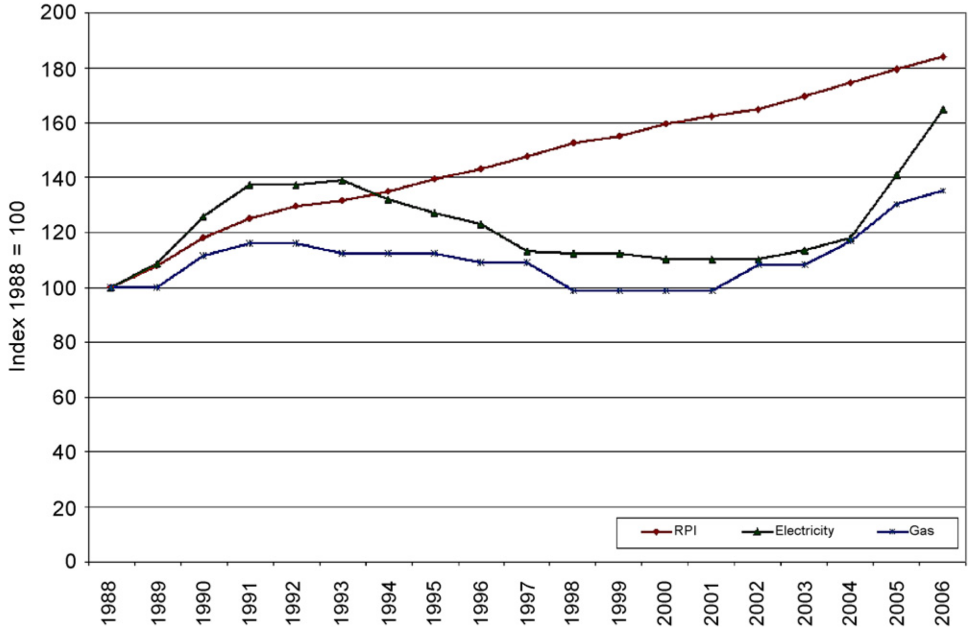

Fig. 8. Retail price index, gas and electricity prices (1988–2006).

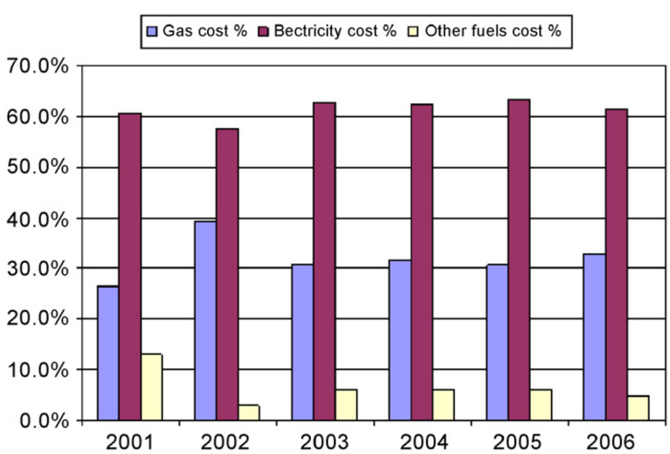

Fig. 9. Proportional costs of energy sources in HEIs (2001–2006).

The approach adopted in this study has been to match certain indices (statistics) in HEIs' estate statistics against energy consumption and assess the degree of correlation that exists between the various parameters and energy consumption. Figure for these indices were derived from existing data sets and widespread reporting formats in HEIs.

Some of the parameters whose relationships with energy consumption were investigated include:

- Student FTE numbers;
- Research student FTE;
- Staff FTE numbers;
- Gross internal area;
- Net internal area;
- Specialist teaching/Research area;
- Age of buildings;
- Percentage of estate stock that is listed.

A cursory look at the data suggests that the above-listed parameters constituted distinguishing factors among member institutions, especially across the different age categories stated earlier.

There has been a substantial increase in the number of students in HEIs and by matching student numbers against energy consumption, it is possible to establish a level of correlation, which may be a pointer to the degree to which this parameter affects energy consumption within the sector. A similar process is used for all the parameters listed above. The results of the correlation analysis are presented in Table 5 and in a series of scatter plot diagrams. It is important to state, that correlation does not effectively establish the causal or consequence relationship; it simply indicates the existence of a relationship and the degree to which one variable is associated to another. Knowing that this relationship exists allows predictions to be made about the variables without necessarily providing explanations to the underlying causes and interactions between the variables. Such levels of understanding or explanations of the interplay of variables require further investigation through more detailed and targeted studies, which fall beyond the purview of the current review. Suffice it to say, however, that the establishment of such relationships is the first step towards the full characterisation of the 'system' variables. The table below indicates the levels of correlation between various proxy variables and energy consumption for the years for which data is available. Column 8 (mean r) indicates the running average correlation for the period under review, while column 9 (mean r^2) indicates the proportion of predictable variance r^2. The accompanying scatter plot charts provide snap shot views of the distribution of variables about a regression line.

The use of FTE numbers provides an opportunity to explore energy consumption in relation to a proxy user base. The FTE for all students, research students as well as staff has been used in an attempt to understand how energy consumption varies in relation to users. There is a moderate correlation ($r = 0.68$) between student FTE numbers and energy consumption. A very high correlation, however, exists between the research student FTE numbers and energy consumption. ($r = 0.91$). This may be a strong indicator of the role of research in HEI energy consumption.

A very strong correlation also exists between the FTE staff numbers and energy consumption ($r = 0.90$). This correlation as strong as that which exists between research student FTE and energy consumption. The import of this high correlation is in

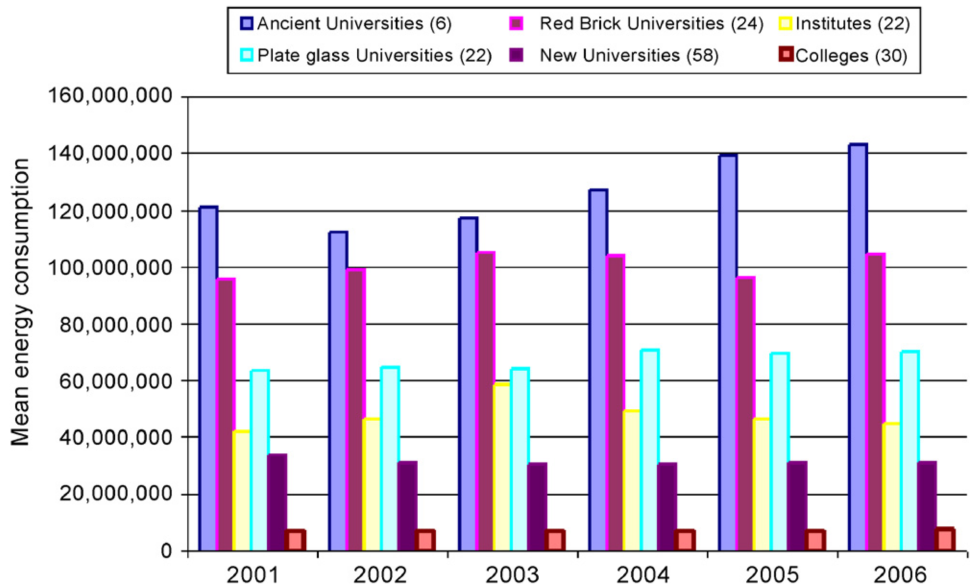

Fig. 10. Average annual energy consumption for different categories of HEIs.

Table 4
Energy consumption ratios in HEI categories

Category	Average GIA (m^2)	Average student FTE	Space intensity (m^2/student FTE)	Energy consumption psm GIA (kWh/m^2)	Energy consumption per student FTE (kWh)
Ancient university	436,530	15,563	28	330	9174
Redbrick universities	336,243	14,450	23	297	7211
Institutes and specialist colleges	112,918	4,932	21	339	9187
Plate glass universities	212,783	10,663	22	318	6591
New universities	122,415	12,564	11	259	2492
Colleges of higher education	31,189	2,435	14	240	3070

Table 5
Correlations between energy consumption and specified parameters

Parameters	2001	2002	2003	2004	2005	2006	Mean r	Mean r^2
Student FTE vs. Energy consumption	0.66	0.68	0.66	0.69	0.68	0.70	0.68	0.46
Research student FTE vs. Energy consumption	0.92	0.92	0.92	0.93	0.89	0.89	0.91	0.83
Staff FTE vs. Energy consumption	0.89	0.89	0.89	0.91	0.89	0.91	0.90	0.80
GIA vs. Energy consumption	0.96	0.94	0.93	0.91	0.91	0.94	0.93	0.86
NIA Total vs. Energy consumption	0.94	0.93	0.90	0.89	0.89	0.93	0.91	0.83
Listed building coverage vs. Energy consumption				0.62	0.63	0.63	0.63	0.40
NIA non-residential vs. Energy consumption	0.90	0.88	0.87	0.88	0.88	0.92	0.88	0.77
NIA residential vs. Energy consumption	0.74	0.75	0.66	0.69	0.67	0.74	0.70	0.49
NIA Teaching area vs. Energy consumption			0.61	0.64	0.64	0.68	0.64	0.41
NIA Research area vs. Energy consumption			0.82	0.84	0.82	0.87	0.84	0.70
Post 1980 buildings/Energy consumption	−0.19	−0.16	−0.12	−0.10	−0.10	−0.06	−0.12	
1960–1979 vs. Energy consumption	0.12	0.11	0.02	0.10	0.08	0.03	0.08	
1940–1959 vs. Energy consumption	0.02	0.00	0.02	0.06	0.05	0.06	0.04	
1914–1939 vs. Energy consumption	0.04	0.11	0.07	0.05	0.06	−0.01	0.05	
1840–1914 vs. Energy consumption	0.00	0.02	0.09	−0.04	−0.04	0.03	0.01	
Pre 1840 vs. Energy consumption	−0.01	−0.09	−0.01	−0.05	−0.05	−0.05	−0.04	

flagging up big drivers to energy consumption within the sector. The high correlation values between staff FTE and energy consumption raises questions concerning hitherto uncharted areas of the relationship between staff activities, energy behaviour to the overall energy consumption in the sector. Some of these questions may require more detailed characterisation of staff operations and behaviour patterns and their direct impact on energy consumption. Specific socio-technical studies in designated activity area may shed more light on these questions.

All the correlations presented in the table are statistically significant at 95% confidence level. The last column in the table shows the values of r^2. The r^2 represents the proportion of predictable variance. In this, case it refers to the variance in the predicted energy consumption values on the correlation regression line. For example, 'r^2' for student FTE against energy consumption is 0.46 or 46%. This suggests that only 46% of the variance in energy consumption can be predicted from the student FTE numbers in each institution. The R^2 provides an additional tool for the evaluation of the magnitude of the correlation values.

The strongest levels of correlation (0.93) exist between GIA and energy consumption. The correlation between Net internal area (NIA) and energy consumption is equally very strong with $r = 0.91$. The strength of these relationships may be interpreted as an indication that space and estate size are major drivers to energy consumption in HEI and support the continued use of space/energy ratios in energy performance reporting and assessments. When compared with the strength of the relationships between student FTE and research student FTE, the impression is that buildings and spaces are the bigger drivers of energy consumption than users. However, further micro-level studies across several HEIs are needed to characterise the magnitude and patterns of building energy use relative to occupants' energy use before such generalisations can be made.

Very weak correlations exist between the age of the building and total energy consumption. The results indicate very limited linear relationship between age of building and energy consumption. In the case of the correlation between buildings constructed post 1980 and pre 1840, negative correlations were recorded. This suggests that as the percentage of post 1980 or pre 1840 buildings increases, energy consumption decreases. Though the strength of this relationship is very weak at less than 0.1, it offers a strong enough indication about the limited impact that building age alone has on energy consumption in the higher education sector. There are other factors associated with building age; like building services systems as well as building use that may have stronger relationships to energy consumption than building age. The data available does not reflect these parameters and so conclusions cannot be drawn on the evidence of available data. However, the apparent decoupling of building age from energy consumption appears to run against conventional assumptions and raises new questions requiring further investigation. A suggested approach to addressing these questions may involve building-level investigations of different buildings with varied ages and locations but with similar use (Table 6).

Across the HEI categories, the parameter correlations show substantial deviations from the sector averages in some instances and vary significantly across the different categories. For instance, student FTE shows very strong correlations with energy consumption in five out of the six categories, whereas the overall sector analysis indicates a moderate correlation. Similarly, whereas five categories indicate moderate to strong positive correlations between NIA of residential areas and energy consumption, one category indicates a weak and negative correlation. Three categories of HEIs show very strong correlations between research student FTE and energy consumption, while the other three indicate just strong correlations. However, the overall sector analyses point towards a very strong correlation between research student full-time numbers and energy consumption.

Very strong correlations exist between the GIA, NIA and energy consumption in all categories.

9. Discussion and conclusions

There has been a gradual but steady increase in the aggregate energy consumption levels of the higher education sector. One of the major insights gained through this analysis is the need for regular sector reviews of energy consumption in order to establish 'figures' coupled with trends, which provide a reliable basis for policy action at a sector or national level. This review reveals that the energy consumption levels in UK HEIs increased by about 2.7% over the 6-year period between 2001 and 2006. The building energy-related CO_2 emissions are estimated to have increased by approximately 4.3% between 2005 and 2006 alone. These trends run contrary to the national plans for emissions reductions in all sectors and are therefore a cause for action.

A key revelation of the review is the absence of emissions reduction targets for the sector. While some individual institutions are known to have emissions and energy consumption targets, the absence of sector wide target(s) may affect the degree of commitment to emissions reduction. There is therefore a need to set CO_2 emissions reduction targets for the higher education sector to drive reductions in CO_2 emissions in line with the national targets. However, the heterogeneity of the institutions in size and vocations suggest that a 'one size fits all' target may not be appropriate. Further characterisation studies are required to identify the drivers and patterns of energy use across different sub-groups within the sector. A major short-term policy decision is, however, needed to set reliable benchmarks for the wide range of building types and functions in the sector.

An approach that may be considered in sector wide emissions reduction is the alignment of incentives to encourage energy carbon emissions reductions. These incentives may be applied at local, sector and national levels. At the local or institution level, available records indicate that some universities currently have energy efficiency competitions in Student Halls of Residence and award various ranges of prizes to encourage energy conservation. Such schemes involving incentives and penalties are known to have recorded various levels of success in energy conservation and emissions reduction programmes in UK higher education institutions (HEIs) and need to be encouraged. At the sector level, it is possible for instance to link funding to energy performance of HEIs, especially since the UK HEIs receive substantial contributions from public funds.

One of the strong correlations relating to energy consumption in the sector is the relationship between the research activity and energy consumption. It is evident also that growth in the sector, especially among the research-led universities is partially driven by research activities and funding. The study revealed that the highest energy consumers appear to be research-led institutions. This strong correlation therefore poses questions about policies that may be adopted to limit the growth in energy consumption in the research-led universities without jeopardising their ability to

Table 6
Energy consumption correlations across categories

Parameters	Ancient	Redbrick	Institutes	Plate glass	New	Colleges	Sector mean
Student FTE vs. Energy consumption	0.91	0.83	0.73	0.49	0.82	0.84	0.68
Research student FTE vs. Energy consumption	0.85	0.90	0.92	0.68	0.69	0.69	0.91
Staff FTE vs. Energy consumption	0.96	0.89	0.89	0.43	0.85	0.91	0.90
GIA vs. Energy consumption	0.97	0.91	0.95	0.88	0.91	0.92	0.93
NIA Total vs. Energy consumption	0.96	0.90	0.95	0.84	0.90	0.92	0.91
NIA non residential vs. Energy consumption	0.97	0.87	0.96	0.70	0.89	0.87	0.88
NIA residential vs. Energy consumption	−0.40	0.77	0.76	0.57	0.53	0.79	0.70
NIA Teaching area vs. Energy consumption	0.82	0.76	0.92	0.55	0.87	0.78	0.64
NIA Research area vs. Energy consumption	0.86	0.84	0.94	0.71	0.41	0.54	0.84

continue to attract research income. A possible approach would be to specifically target the research-led universities with Government initiatives that specifically address the reasons for research energy consumption levels and how this can be reduced.

On the national level, some schemes that promote energy conservation and emissions are already in place and many more are planned. Such schemes need to offer considerable rewards for carbon emissions reductions while placing significant penalties on increased consumption of fossil fuels, electricity and other non-renewable energy sources. There are currently six UK regulated schemes aimed at encouraging carbon reduction across all sectors. These include the European Union Emissions Trading Scheme (EU-ETS), the proposed UK Emissions Trading Scheme (UK ETS), Carbon Reduction Commitment (CRC) Climate Change Levy (CCL) Renewables Obligations (RO) and the Display Energy Certificates (DEC). The details of these schemes fall outside the purview of this review. It is, however, important that these schemes work in sync to provide sufficient impetus for carbon emissions reductions in the higher education and indeed all other sectors.

There is a need for change in the existing energy reporting format to provide disaggregated energy statistics that capture end use consumption levels and patterns. It is essential that information about energy consumption in the sector contains data at a sufficient level of detail to inform interventions as well as aid auditing and effective benchmarking. To achieve such levels of data will invariable require sub metering and may incur significant costs to institutions. However, the long-term benefits to monitoring, auditing and benchmarking would be invaluable. Additionally, the current format records aggregated direct building energy consumption and very little of downstream indirect energy consumption. The downstream sector of the UK higher education sector including suppliers, business and student travels is said to represent about $1\frac{1}{2}$ times the direct energy consumption of the sector Universities UK (2006a, b). There is therefore scope for further investigation of the contribution of the downstream sector to overall emissions level as well as developing methods for its assessment.

Finally, it is believed that in order to advance action on carbon emissions reduction in the sector, institutions require Energy Managers and management teams who are major decisions makers and have the ability to initiate and implement energy conservation programs. Even though these findings have been based on a particular sector of the UK economy, there is little doubt that the issues raised will have more general application across different sectors and may be applicable in other countries.

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See http://www.carb.org.uk for further details.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2008.03.031.

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