ENERGY BENCHMARKS FOR PUBLIC SECTOR BUILDINGS IN NORTHERN IRELAND

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Summary

This paper presents the preliminary results of a study throughout the Northern Ireland public sector estate aimed at improving energy monitoring & targeting by developing local energy benchmarks for a range of public buildings. Benchmarks play a key role in promoting energy efficiency in buildings and are fundamental to the work of building designers, operators and energy managers. Energy benchmarks are shown for 16 types of building based on an analysis of roughly 2,000 properties including offices, schools and libraries. The results are summarised as benchmarks in Section 4 and a typical analysis of one building sector is shown in Section 5. It is hoped that these preliminary results will become more robust and reliable as further data is collected and a new energy reporting system becomes more established.

1. Introduction

The energy efficiency campaign in the Northern Ireland public sector covers some 4,000 buildings across a variety of building types including schools, hospitals, offices and police stations. The campaign has already made significant progress, with energy savings of 13% between 1990 and 1997 against a target of 20% to be achieved by 2000[(1)]. However, the campaign now requires fresh impetus and is also changing its focus towards reducing CO_2 emissions.

In order to re-stimulate the campaign, and to gain a more focussed view of the strengths and weaknesses within the estate, a software system has been developed to report on the campaign. This system provides league tables, benchmarks and graphical outputs in a variety of reports to both senior management and departmental energy managers. A key objective was to develop 'local' benchmarks based on data from Northern Ireland in order to highlight good and poor performing buildings. These local benchmarks also allow comparison with existing UK wide benchmarks to establish if there are special factors affecting Northern Ireland buildings.

This paper presents the preliminary results of an ongoing energy management and benchmarking exercise carried out across the whole of the Northern Ireland public sector estate covering roughly 4,000 buildings. The project is still at an early stage and has recently collected data from about half the estate which has provided this preliminary view of consumption patterns. Annual energy consumption and floor area data was collected, analysed and reported. The resulting simple energy benchmarks ($kWh/m^2/yr$) provide a useful first indicator for those managing buildings[(2-4)]. The benchmarks are summarised in Figure 1 and Table 1 and these add to benchmarks shown in earlier work[(5-8)]. A typical analysis of one building sector is shown in Figures 2 to 6 although the preliminary nature of the figures makes this inappropriate at this stage.

2. Data collection

This paper is based on the early findings of an ongoing energy management programme in the Northern Ireland public sector. The introduction of a new energy reporting system has recently allowed more detailed data to be gathered than in previous years and the preliminary results of this are presented in this paper. It is hoped that the ongoing process of data collection, analysis and reporting will provide more data and improve the reliability of the data.

Information was gathered on about 2,000 buildings in the Northern Ireland public sector. Data covered a wide range of building types and sub-sectors. The data collected was in the form of annual fossil fuel and electricity consumption along with floor area figures. This was obtained from the established monitoring and targeting systems currently being operated by about 50 energy managers throughout the Northern Ireland public sector estate.

It is normally necessary to reach sample sizes greater than 100 buildings in each building category as this usually provides acceptable frequency distributions and hence reasonably reliable benchmarks. Although this was achieved for some building types, many groupings had much fewer properties, some with less than 20 premises. The benchmarks presented should therefore be viewed with this in mind as those based on less than 100 properties should be classed as less reliable. However, some data are better than none at all and the results are therefore provided for all the main sectors where useful data was collected.

3. Data analysis

The data were checked analytically and visually to remove that which was obviously spurious and unreliable. The techniques used are similar to those used in earlier benchmarking work[6,8]. Where buildings consume both electricity and fossil fuel, the fuel data have been separated to show the building's performance for each fuel individually. The two fuel types have different costs, primary energy use, CO_2 emissions etc. and should always be kept separate. Buildings which use electricity only have been analysed separately.

The main objective of the new reporting process is to help energy managers in the public estate. This paper presents the data submitted by energy managers and it is raising issues about the source of the data and, in particular, the different floor area definitions used. In general, agents letting area is used as the normalising factor in the offices as this is the most commonly used indicator of building size in the public sector office estate. At this early stage, it is understood that most other buildings use gross floor area. However, this is an area for further investigation as the reporting process becomes more refined.

Benchmarks were developed by sorting, banding and extracting the data using spreadsheet techniques. The analysis focused on typical levels of annual energy usage per square metre of floor area (energy intensity, in kWh/m^2/yr) in each building type. An example output for one sector is shown in Figures 2 to 6 and Table 2. The data analysis did not adjust the raw data in any way e.g. weather correction, as this kind of normalisation can often bring in more inaccuracies than it removes, masking the true trends in consumption.

The benchmarks generated for each of the 16 building sectors were based on:-

- a TYPICAL level of energy usage - half of the sampled buildings use less energy per m^2 than this (the median of the sample)
- a GOOD PRACTICE level of energy usage - only one quarter of the sampled buildings use less energy per m^2 than this (the 25% quartile).

A key objective was to provide a qualitative visual representation of the data alongside a wholly quantitative analysis. This visual check on the sample has become an important criterion for checking the validity and suitability of the data.

4. Overall Results

Figure 1 and Table 1 summarise the benchmarks in kWh/m^2 per year.

Figure 1 - Energy benchmarks in Northern Ireland public sector buildings (kWh/m^2/yr)

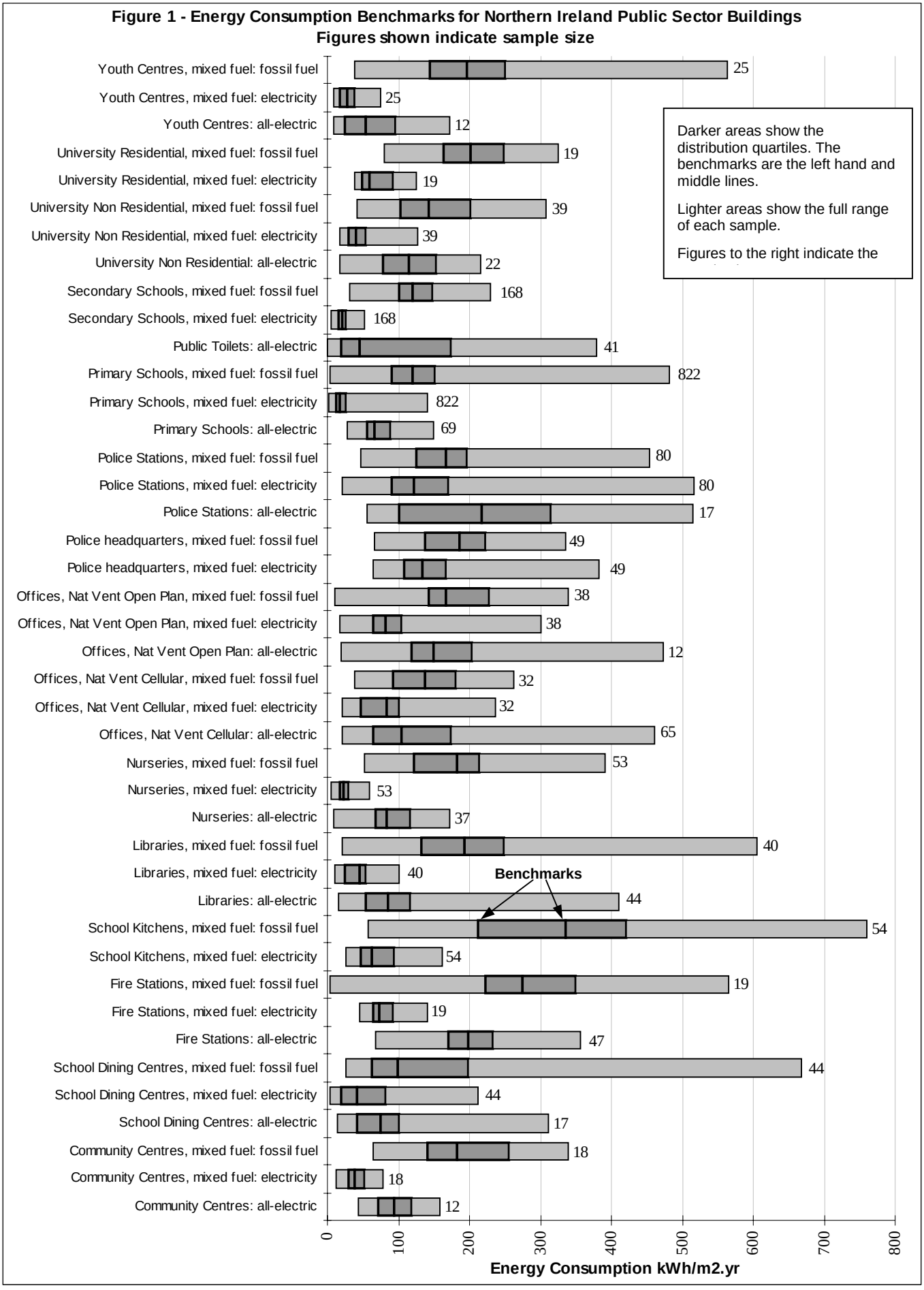


Table 1 - Energy Benchmarks in Northern Ireland Public Sector Buildings (kWh/m^2/yr)

Building Type	Mixed Fuel Buildings					All-Electric Buildings		
	Electricity kWh/m^2/yr		Fossil Fuel kWh/m^2/yr		Sample Size	Electricity kWh/m^2/yr		Sample Size
	Good	Typical	Good	Typical		Good	Typical	
Community Centres	29	39	140	183	18	72	94	12
School Dining Centres	19	42	63	99	44	42	74	17
Fire Stations	64	74	223	275	19	171	197	47
School Kitchens	47	63	213	336	54			
Libraries	24	45	133	192	40	54	86	44
Nurseries	17	23	121	183	53	68	84	37
Offices, Naturally Ventilated Cellular	47	83	92	138	32	65	104	65
Offices, Naturally Ventilated Open Plan	65	81	143	166	38	118	149	12
Police Headquarters	108	135	138	187	49			
Police Stations	91	121	125	167	80	101	218	17
Primary Schools	12	18	91	119	822	56	66	69
Public Toilets						20	44	41
Secondary Schools	16	22	101	120	168			
University Non Residential, mixed fuel: electricity	29	39	103	142	39	79	115	22
University Residential, mixed fuel: electricity	50	60	164	201	19			
Youth Centres, mixed fuel: electricity	17	28	145	197	25	24	54	12

Although most of the benchmarks provide a strong indication of the likely consumption of typical public sector buildings, it should be recognised that many of the sample sizes are smaller than benchmarks presented in the past. Care should therefore be taken when comparing a particular building with the benchmarks based on smaller samples. The sample size, shown to the right in Figure 1, is a very important indicator of the reliability of the data. Using the results from small samples e.g. less than 50 buildings may be unrepresentative of the whole sector. It should also be noted that, when placed against the overall building stock, the benchmarks have been derived from relatively small samples and particular buildings may have significant differences in management, hours of use, services, occupancy patterns etc.

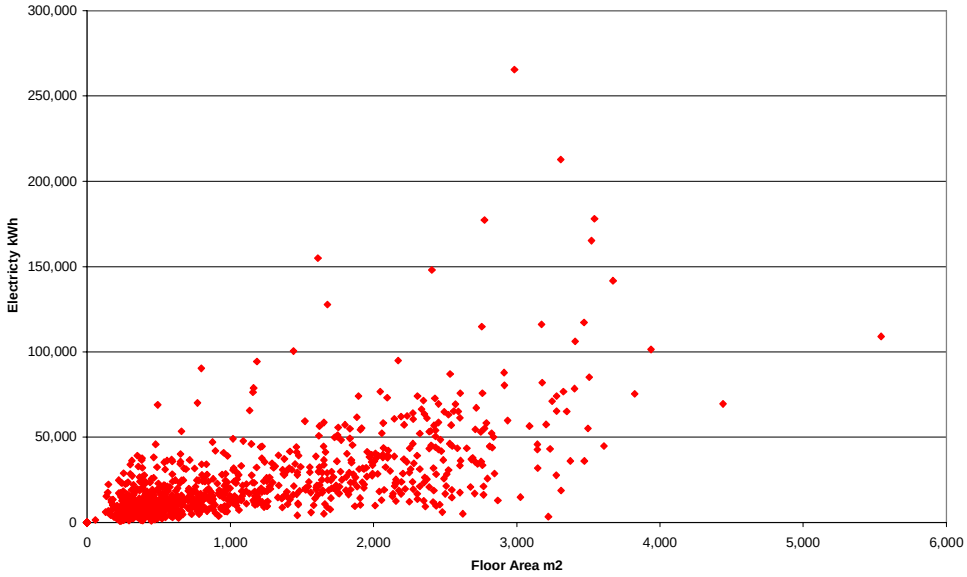
Other energy managers with large stocks of buildings could follow this approach and use this form of presentation and analysis to assess the performance of their organisations. This can provide a more detailed understanding of the buildings involved and could form a tool for managing their own overall stock. In particular, it can help in highlighting excessive consumption, well performing buildings and unreliable data.

Some of the general principles developed in working on the Energy Assessment and Reporting Methodologies study[2-3] and CIBSE TM22[4] have underpinned this benchmarking exercise. For example, attempting to ensure the quality/accuracy of data, establishing the floor area definitions being used, not adjusting raw data and separating electricity and fossil fuels. In particular, 'cleansing' the data is vital and in some cases has highlighted detailed monitoring and targeting being carried out by organisations on highly unreliable data samples that were not included in this analysis.

5. Typical building sector analysis (Primary Schools)

Figures 2 to 6 and Table 2 show a typical analysis of a building sector, in this case primary schools. Data for 822 primary schools was submitted covering the year 1998/99. 56 of these sites comprised all-electric buildings with no fossil fuel being used. Figures 2 and 3 show the variation of energy with building floor area, each point representing one building.

Figure 2 - Variation of electricity usage with floor area



In general, electricity and fossil fuel consumption were analysed separately as they have quite different uses, costs and CO_2 emissions. The data show a reasonable correlation between energy use and floor area. Most samples have indicated this correlation as a general trend to varying degrees although it is not always the case. The data with zero fossil fuel consumption provide an indication of the spread of all-electric buildings.

Figure 3 – Variation of fossil fuel with floor area

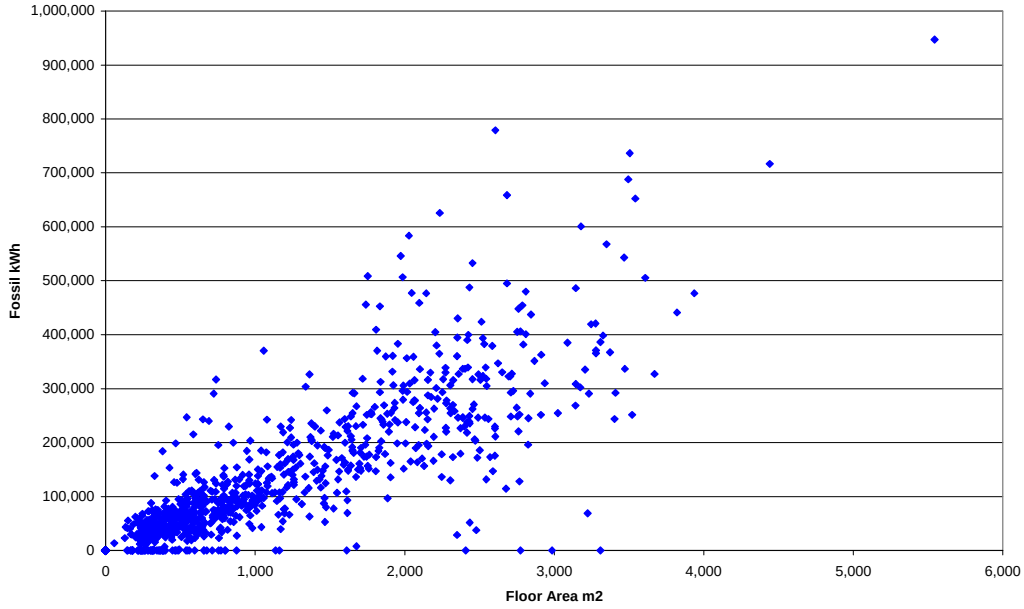


Figure 4 - Variation of electricity per m^2 with floor area

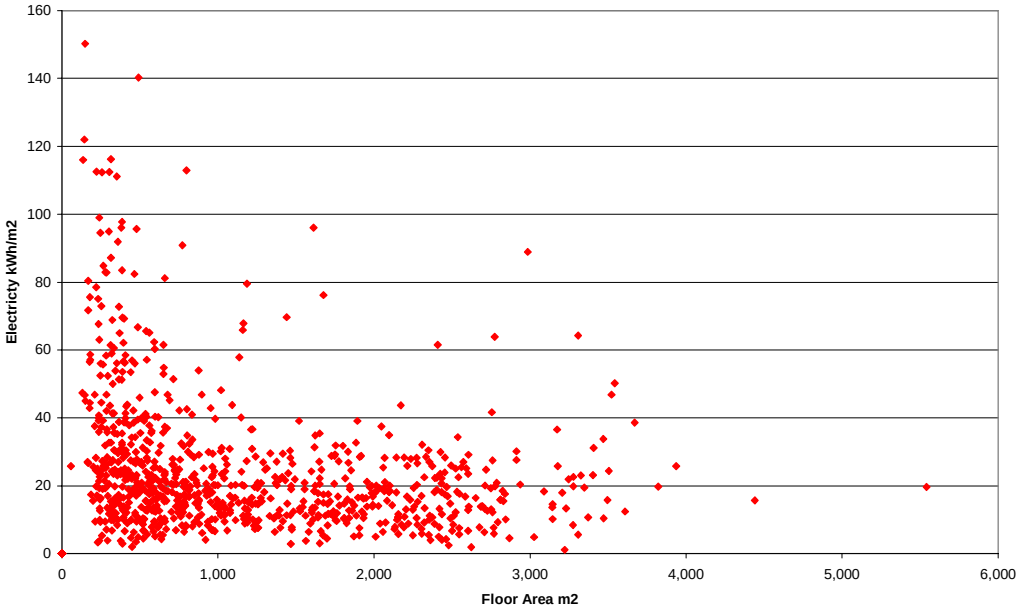


Figure 4 shows the variation of electricity usage per square metre (electricity density) with floor area within this sector. If the points lie mainly within a flat band, the energy density is independent of floor area, emphasising the simple relationship shown in Figure 2. If energy density is seen to vary with floor area, it may be the case that premises above a certain size have extra equipment installed which affects the total load, for example a primary school with additional catering facilities that supply other schools. This is an area for further investigation and may result in more closely defined building classifications in future.

Electricity density for the primary schools sector tends to lie within a flat band between approximately 5-35 kWh/m^2/yr, and this is shown to be largely independent of the size of the premises. Figure 5 shows a similar graph for fossil fuel which tends to lie within a band 50-200 kWh/m^2/yr.

Figure 5 – Variation of fossil fuel per m^2 with floor area

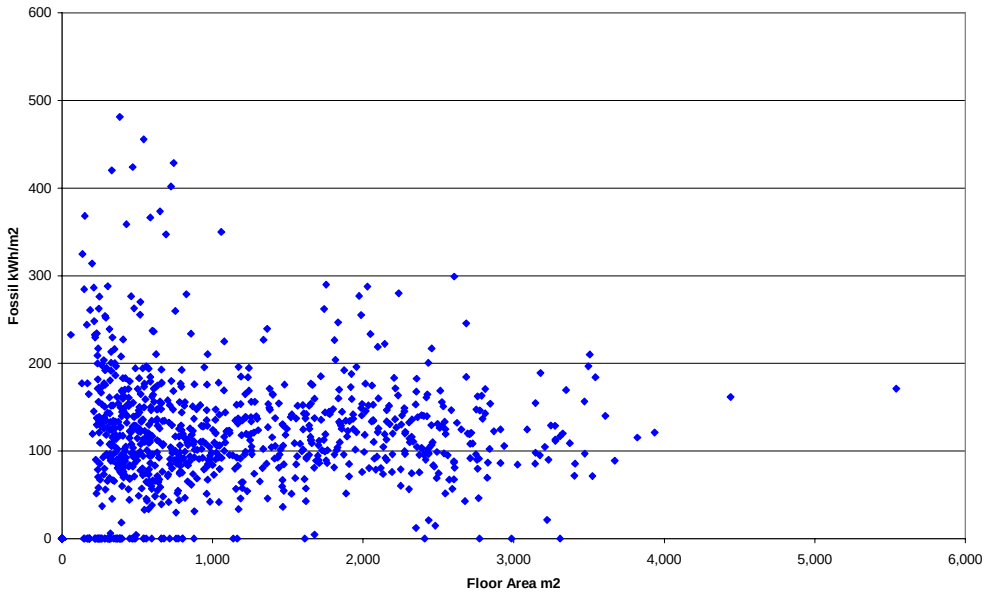


Figure 6 - Comparison of electricity per m^2 and fossil fuel per m^2

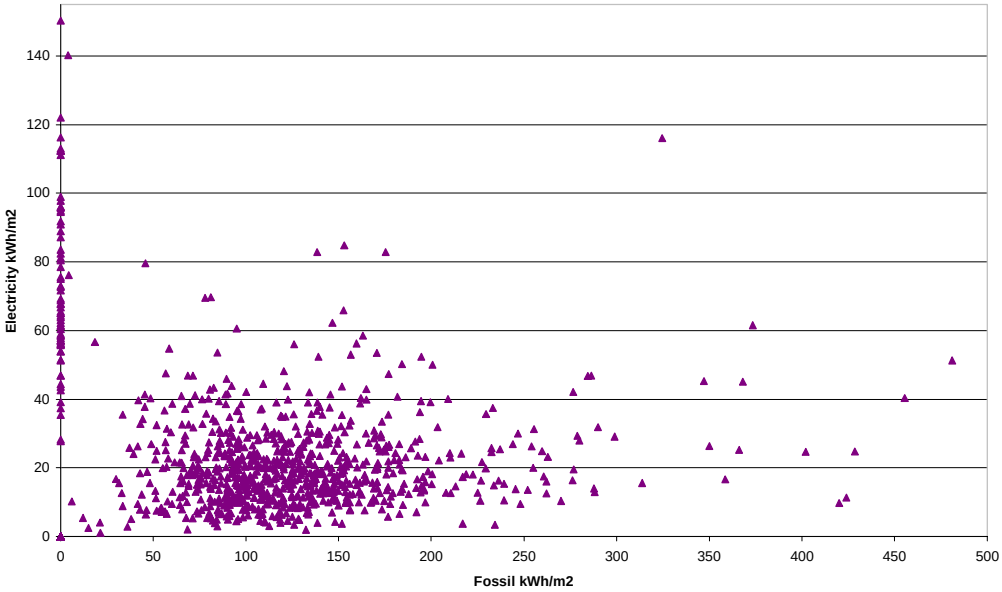


Figure 6 shows the mix of fuel types being used in premises that use both fossil fuel and electricity. The data with zero fossil fuel consumption shows the spread of all-electric buildings. The plot demonstrates the wide spread in the ratio of fuels used, ranging from 2 to 20 times as much fossil fuel as electricity per square metre in the majority of primary schools. Interestingly, the ratio for primary schools is the opposite of that found in supermarkets where electricity density is 3 to 5 times that of fossil fuel[8]. Figure 6 is also a particularly useful graph in providing an overview of the whole estate and in highlighting spurious and unreliable data.

Table 2 - Statistical analysis of primary schools

	ELECTRICITY (ALL ELECTRIC) kWh/m2	ELECTRICITY (MIXED FUEL) kWh/m2	FOSSIL (MIXED FUEL) kWh/m2	Floor Area m2
Sample Size	69	822	822	891
Mean	71.90	20.79	128.03	1,167
Std. Deviation	24.42	13.26	60.12	882
Minimum	27.74	1.07	4.03	57
Maximum	150.25	140.23	481.15	5,543
25th Percentile	56.48	12.19	91.12	447
50th Percentile	65.55	18.23	119.41	836
75th Percentile	88.94	25.97	151.73	1,766

Table 2 shows a summary of a typical statistical output that was carried out as part of the analysis. Following common practice on much of the DETR's Best Practice Programme, the GOOD and TYPICAL benchmarks are the 25^{th} and 50^{th} percentile (median) respectively. This table also shows the full range of each sample and the sample size which is a strong indicator of the reliability of the benchmarks. The benchmarks, sample range and sample size for primary schools are summarised graphically in Figure 1 alongside the other categories of building analysed.

6. Conclusions and observations

This study has been successful in establishing preliminary energy consumption benchmarks for a range of Northern Ireland public sector buildings. In some cases, benchmarks have been developed for buildings types that have never previously been reported in the UK.

These benchmarks can help managers to rate the energy performance of their buildings. In particular, they should help energy managers to highlight both good and bad performing buildings in an even handed way. It is hoped that energy managers with large stocks of buildings outside the Northern Ireland public sector will use or adapt the analysis approach and presentation described in this paper to form an individually tailored representation of their own stock.

At this early stage in the ongoing project it is apparent that:-

- the overall approach using a reporting system based on benchmarking is practical and provides vital feedback to energy mangers whilst allowing the overall campaign to be monitored centrally
- the preliminary data has provided some useful energy benchmarks but many of the sample sizes need to be increased to improve the reliability of the benchmarks
- the preliminary data has also indicated a significant proportion of unreliable data (removed from the analysis) that may not have been identified without this more detailed analysis. This feedback process will gradually improve the reliability of the data
- the early reporting and feedback being provided should help energy managers further their efforts on the energy efficiency campaign. In particular, management summary reports showing the benchmarks should promote greater involvement of senior management.

The authors hope to present more reliable benchmarks in coming years as the quantity and quality of the data improves.

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