University of Strathclyde
Department of Mechanical Engineering

Carbon Footprint of the University of Strathclyde

MSc in Energy Systems and the Environment

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Abstract

This project presents the detailed estimation of the carbon footprint of one of the halls of residence (James Goold Hall, Block A) of the University of Strathclyde while at the same time it provides the remaining halls of residence carbon footprints of the John Anderson Campus. This effort was necessitated by the demand arising from the future development of the University of Strathclyde's Environmental Management System (E.M.S.) in response to the universal increase in environmental awareness and the resulting legislative and governmental policy developments coming into force related to the reduction in carbon emissions in the atmosphere. This project follows a procedure using the Higher Education Carbon Management (H.E.C.M.) toolkit provided by the Carbon Trust to the University of Strathclyde; the first step is the identification of the sources contributing to the carbon release followed by their assessment and finally their management. The Carbon Trust was established by the Department of Trade and Industry to help the development of low carbon profile businesses. The flow chart in Appendix X illustrates the process approached, and this can be used for future applications for the establishment of a building's carbon footprint.

It was found that the carbon footprint of James Goold Hall comprises the building's contribution of 52%, 144 tonnes of CO_2 emissions, the transportation influence on the remainder of the carbon footprint, corresponding to 135 tonnes of CO_2 emissions, while student commuting is estimated to be negligible.

Chapter 1 presents the background and the drivers developed to address environmental pollution while Chapter 2 discusses the literature review introducing the various environmental management systems as an attempt towards continuous improvement, resulting in low carbon profile organisations. Chapter 3 presents the data provided and the process followed in order to use the H.E.C.M. toolkit for the carbon footprint evaluation. Furthermore, it includes the estimation of the environmental awareness of students occupying the James Goold Hall building. Additionally, a sensitivity analysis was conducted examining the transportation contribution to the James Goold Hall carbon footprint. In Chapter 4 the energy data for all the halls of residence and the CO_2 emissions released are illustrated using the Geographical Information Systems (G.I.S.) for the academic periods between 1999 and 2005, in order to make monitoring easier. In Chapter 5 an assessment was made to identify any mistakes occurring among the main electricity meters and the sub-meters for the years between 1999 and 2004. In Chapter 6, conclusions and criticism on H.E.C.M. toolkit are provided.

1. Global warming and climate change

1.1 The greenhouse effect

Earth temperature is a result of the energy transmitted by the sun (sunlight), the reflected energy from the earth's surface and the heat contribution from the earth itself. The sun's energy passes through the atmosphere to the ground, while part of the infrared radiation is absorbed and the rest is reemitted by the greenhouse gases, which mainly include carbon dioxide and water vapour, again to the atmosphere. This causes what is commonly termed the greenhouse effect illustrated in Figure 1.1.

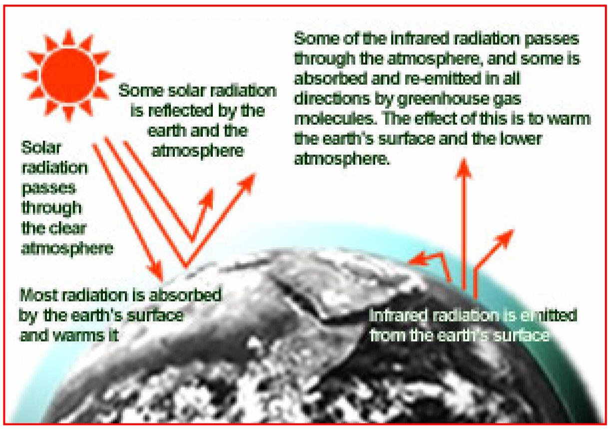


Figure 1.1: The greenhouse effect (EPA, 2004)

Without the naturally occurring greenhouse effect, the earth may not be habitable due to the low temperatures. As concentrations of greenhouse gases are increased by human activities, precautions must be taken to avoid the deterioration of the atmosphere which will change the balance necessary for the natural greenhouse effect.

Impacts of climate change include rising sea levels, resulting in floods and droughts, as well as influences on the flora and fauna therefore exposing humans to great difficulties. The years that have the highest temperatures ever recorded are all during the 1990s, where the surface temperature rose by 0.6°C and the sea level increased by 10 - 20 cm. Predictions by the Intergovernmental Panel on Climate Change (IPCC), in its Third Assessment Report published in 2001, showed that the temperature will rise by an additional 1.4 to 5.8°C, shown in Figure 1.2, while the mean sea level will increase by 9 to 88 cm by the end of the 21^{st} century, depending on the actual rate of emissions (DEFRA, 2005a).

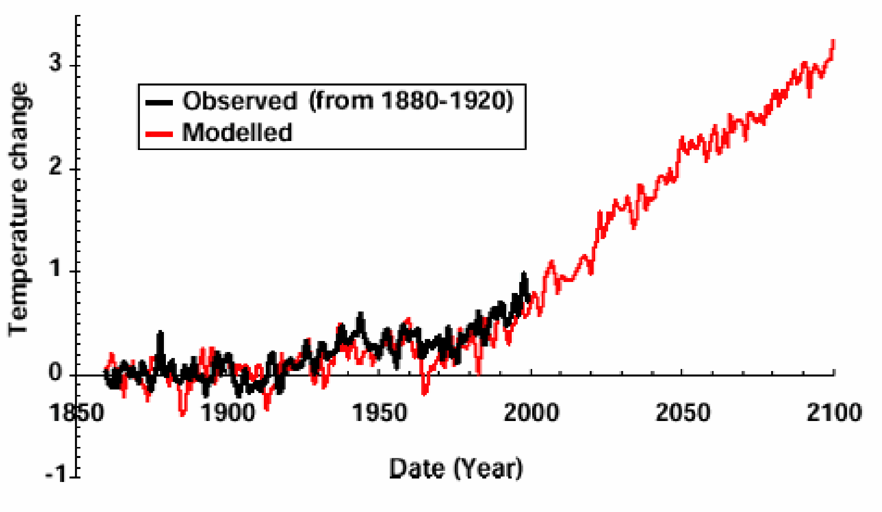


Figure 1.2: Global temperature change (DEFRA, 2001)

1.1.1 Different global scenarios

As there is an interconnection among population increase, the CO_2 emissions and the energy demand, the IPCC conducted a study and developed six emission scenarios illustrating future possibilities, shown in Figure 1.3.

Scenario A1, comprising three sub-scenarios, examines the possibility of population increases until 2050, reaching its peak, and afterwards decreases globally. Advanced technologies are introduced, while the economic development among the regions is equal. The sub-scenarios have the technology, economic assumptions and base population in common, while their difference is focused on energy supply. Specifically:

- ⇨ A1FI assumes that energy is supplied by fossil fuels.
- ⇨ A1T considers a supply by non-fossil fuel sources.
- ⇨ A1B encompasses equilibrium in supply between fossil and non-fossil fuel sources.

In scenario A2 the population increase during the 21st century is described, the economic situation is focused locally and the technology development is assumed to be less advanced compared to other scenarios.

Scenario B1 illustrates the population growth reaching its peak value in 2050, followed by a decrease, similar to scenario A1. The economy alters and becomes focused on service and information, while social equality is evident and non-fossil fuel supply is encouraged.

The population growth during 21st century is also outlined in the scenario B2, but at a lower rate than in scenario A2. Furthermore, economic expansion is slower than the one described in scenario B1, although it is not so concentrated on service, information or energy sectors compared with scenarios B1 or A1, while the equality in economic growth is more apparent at the local and regional level (IPCC, 2001).

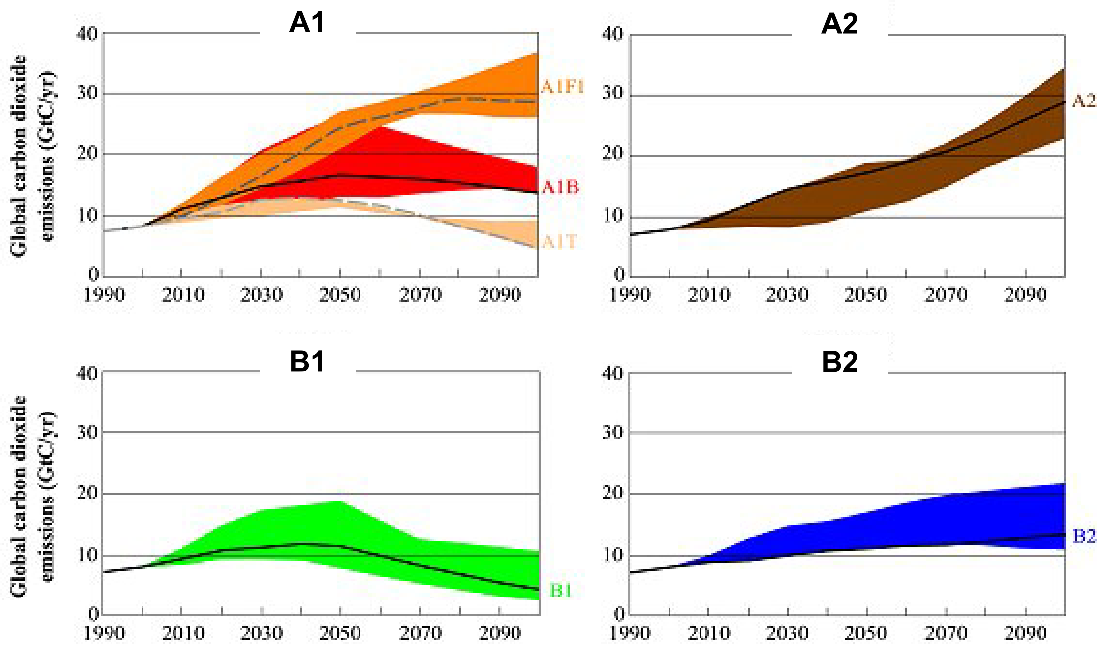


Figure 1.3: Total global annual CO_2 emissions from all sources (IPCC, 2000)

1.1.2 Different UK scenarios

DEFRA developed two scenarios, illustrated in Figure 1.4, which may be experienced in the future, depending on the concentrations of greenhouse gases. These indicate that temperature increase in the UK will fluctuate between 2 - 3.5°C until 2080, while the highest temperatures will be at the eastern and the southern regions. Summers will be warmer as well as the winters. There will also be an effect on the rainfalls. That is to say, the summers and the winters, apart from warmer, will be wetter (DEFRA, 2005a).

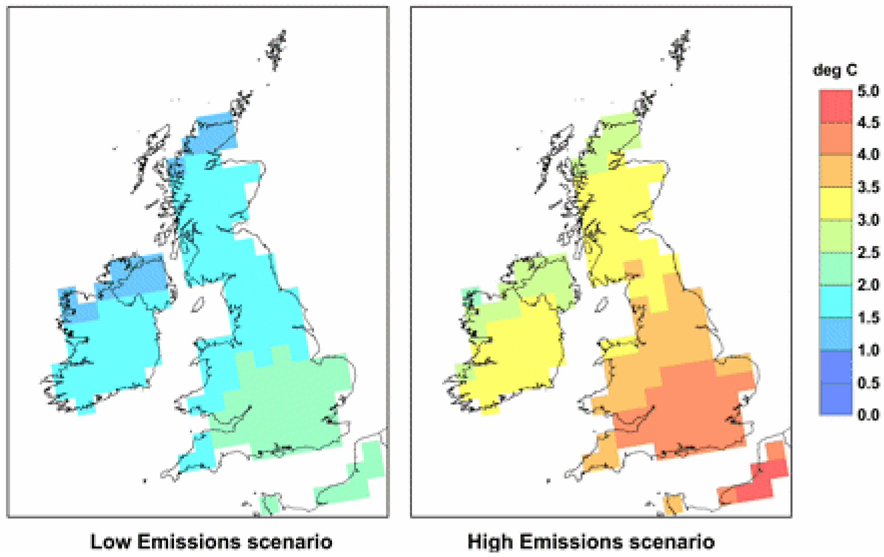


Figure 1.4: Change in annual average daily temperature until 2080s (DEFRA, 2005a)

1.2 Sustainability

The principle of sustainability is that the present generations should meet their needs, without compromising the ability of the future generations to meet their needs. A radical climate change will provide difficulties for future generations such as food availability, weather alterations or even poverty from the shortage of plants and animals.

Another issue is that the consequences will affect mainly people whose contribution is minimal to the changes occurred; such as fishermen and farmers. That is to say, people whose life is completely dependent on the land or sea exploitation (Moomaw, 2002).

1.3 United Nations Framework Convention on Climate Change

An international agreement launched in 1992, to address the climate change issue, the United Nation Framework Convention on Climate Change is ratified by 188 countries, which commit to reduce the emission of greenhouse gases by the year 2000, to levels lower than the ones of the year 1990. However, a more detailed policy should be developed that requires a higher reduction of gas emissions. That was the reason for the establishment of the Kyoto Protocol (DEFRA, 2005b).

The countries that agreed to comply with the Convention have to collect and share their greenhouse gases records and their policies at a national level. These countries have to evolve strategies to achieve the targets posed by Convention, to adapt to the expected consequences, and to become familiar with the climate change effects through collaboration. Another responsibility resulting from the agreement is to support financially and technologically the developing countries.

Negotiations and all decisions are taken in an annual intergovernmental conference known as the Conference of the Parties (COP). Until now ten COPs have taken place with the eleventh forthcoming on December 2005. Moreover, the COP has the responsibility of assuring the on-going effort in addressing the issues covered for the climate change. In addition, COP is in charge of reviewing the Convention implementation, evaluating the Parties' compliance in parallel with the Convention and examining the impacts of the existing policy applications. Its task also includes the appraisal of national communications as well as emissions records by the Parties. As a result, the outcomes from the reports are evaluated and continuous progress is ensured (UNFCCC, 2005).

The UK is one of the countries that has successfully fulfilled the Convention objectives and reduced CO_2 emissions between the period of 1990 to 2000 by 8.7%, while the emissions of overall greenhouse gases decreased by 15.3% (DEFRA, 2005b).

1.4 The Kyoto Protocol

The Kyoto Protocol was agreed on 11 December 1997, trying to address the climate change issue by the reduction of the greenhouse gases. In order to become law, the Protocol should be ratified by no less than 55 countries. In 1999, it was signed by 84 governments (UNFCCC, 2005). The Annex I countries, which were responsible for 55% of CO_2 emissions in 1990, as shown in Figure 1.5, signed it, setting their targets to reduce the overall emissions by 5.2%, and the CO_2 emissions by 13.7%, against the 1990's benchmark. These targets have to be met by 2012 (DEFRA, 2005b).

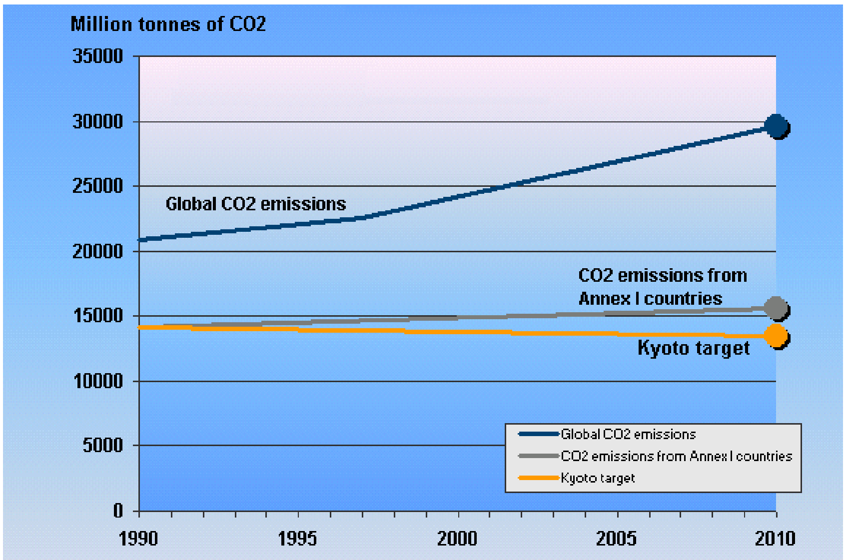


Figure 1.5: Global and Annex I countries' CO_2 emissions (UNEP, 2005)

1.5 The UK's Climate change programme

The UK's government policy was introduced in November 2000. It explains the way that the UK approaches and addresses its emissions' reductions, so as the commitment to the Kyoto Protocol is ensured. Moreover, it discusses how the CO_2 reduction in the domestic sector will be achieved i.e. 20% below the 1990 levels by 2010. Specifically, this programme seeks to reinforce renewable energy generation, reduce the emissions caused by the forestry, agriculture and transport sector. It also seeks to boost the energy efficient use in the domestic sector, improve the requirements of the Building Regulations related to energy efficiency and energy use in businesses (DEFRA, 2005b).

1.6 The Energy White Paper

The Energy White Paper, our energy future - creating a low carbon economy, was published in February 2003, introducing a long term approach to reduce the CO_2 emissions by up to 60% until 2050. This Paper specifies the policy targets related to the environment and states that while the UK attempts to reduce its emissions by a certain percentage, the contribution from renewable sources will increase and consequently increase overall energy efficiency.

The four targets are specified as:

- A reduction in emissions of CO_2
- Increased in the reliability of energy supplies

- Promotion of competitive markets in the UK and beyond
- Assurance of sufficient and affordable heat for the domestic market

This ensures that “the energy, the environment and the economic growth are properly and sustainably integrated” (DTI, 2003), illustrated in Figure 1.6.

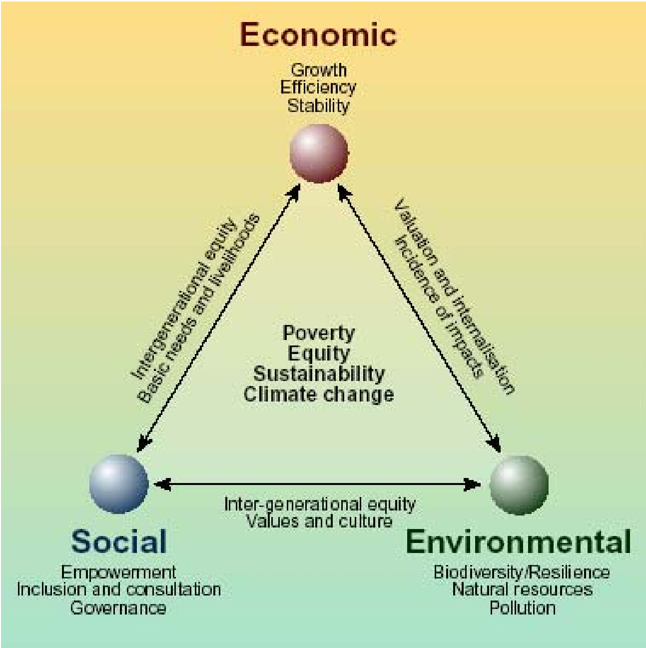


Figure 1.6: Key elements of sustainable development (IPCC, 2005)

Critics point out that the Paper omits to state firmly the energy generation from renewable sources and it does not consider the fact that, unless the renewable energy supply is adequate to cover demand, the result will be an increased dependence on imported energy (from coal or gas), thus increasing global carbon emissions (BBC, 2005).

1.7 The need for estimation

While the above actions are to be implemented, the breakdown estimation of organisations' carbon footprint is required. This will help further in setting targets for each sector, by evaluating and reducing the CO_2 emissions associated with every organisation.

2. Literature review of the carbon footprint

2.1 What is a carbon footprint?

There are many definitions of an ecological footprint but only a few of a carbon footprint. In this thesis, an ecological footprint as described by the Stockholm Environment Institute (Barrett, 2003) and a carbon footprint as proposed by the World Resource Institute (WRI, 2005) will be adopted. The World Resource Institute's definition describes the carbon footprint as:"a representation of the effect you, or your organisation, have on the climate in terms of the total amount of greenhouse gases produced (measured in units of carbon dioxide)". As this definition is compact, one purpose of this thesis is to develop a more extended explanation of the carbon footprint and provide a better understanding.

The carbon footprint of a building can be defined as the amount of CO_2 emitted into the environment based mostly on the activities requiring the combustion of fuels that take place. These activities cover all the energy requirements of the building e.g. lighting, hot-water, heating, ventilation, cooking and I.T. equipment purposes. Moreover, the daily commuting of building occupants burden the carbon footprint significantly. Additionally, the suppliers' and contractors' transport is included e.g. transport of goods (consumables and non-consumables) and waste. The amount of landfilled waste, including the percentage of recycled materials, is a significant factor taken into account. Lastly, another environmentally friendly attribute to be considered is the sequestration of CO_2 through tree planting, etc. The overall carbon footprint is a quantification of the net CO_2 which is the metric widely used to alter the contribution to global warming and climate change.

The carbon footprint can easily be confused with the ecological footprint. However, the ecological footprint covers wider aspects. It is defined as "the bioproductive area (land and sea) of a region or community that would be required to maintain sustainably current consumption, using prevailing technology" (Barrett, 2003) and it is measured in a world average productive hectare (abbreviation of global hectares or gha). This unit allows comparison among countries, while measurements can be expressed also in hectare per capita.

2.1.1 Factors affecting the carbon footprint

The main contributors to carbon emissions are energy use, transport involved for the services and waste generation.

The combustion of fossil fuels for electricity production releases greenhouse gasses into the environment and especially as electricity prices are currently rising, energy efficient use can result in cost savings and pollution prevention. UK universities spend more than £200 million per year on their energy requirements, while there is a great potential for demand side management, thus conserving primary resources.

All means of transportation, apart from walking and cycling which are negligible, cause emissions. The worst transportation means are planes and cars where the gases emitted are calculated according to the number of passengers, the efficiency of the mode and the distance travelled (HEEPI, 2005).

Waste minimisation and management by recycling materials is more environmentally friendly than disposal to landfills. Moreover, landfill taxes are also increasing, and therefore, alternative sophisticated ways should be introduced. Many products are eco-friendly, thus saving the energy required to generate new materials.

2.1.2 Differences among L.C.A., carbon and ecological footprints

Life cycle analysis (L.C.A.) as used by Scheuer et al. (2003) goes further than the carbon footprint by taking into account the impacts that occur during all the stages of a building's lifetime. That is to say, from extraction of raw materials used to their manufacture, transport and use in construction, extending to the maintenance, operation, renovation, demolition of the building and the final disposal or recycling of the materials used. However, the complexity of analysis that is appropriate can vary according to the time the estimation is undertaken. That is to say, some issues during the construction of the building may not be considered as their evaluation is unfeasible, such as the waste generation through its lifetime, their recycling and their transportation. Figure 2.1 illustrates the steps involved in the life cycle assessment diagram of a new building.

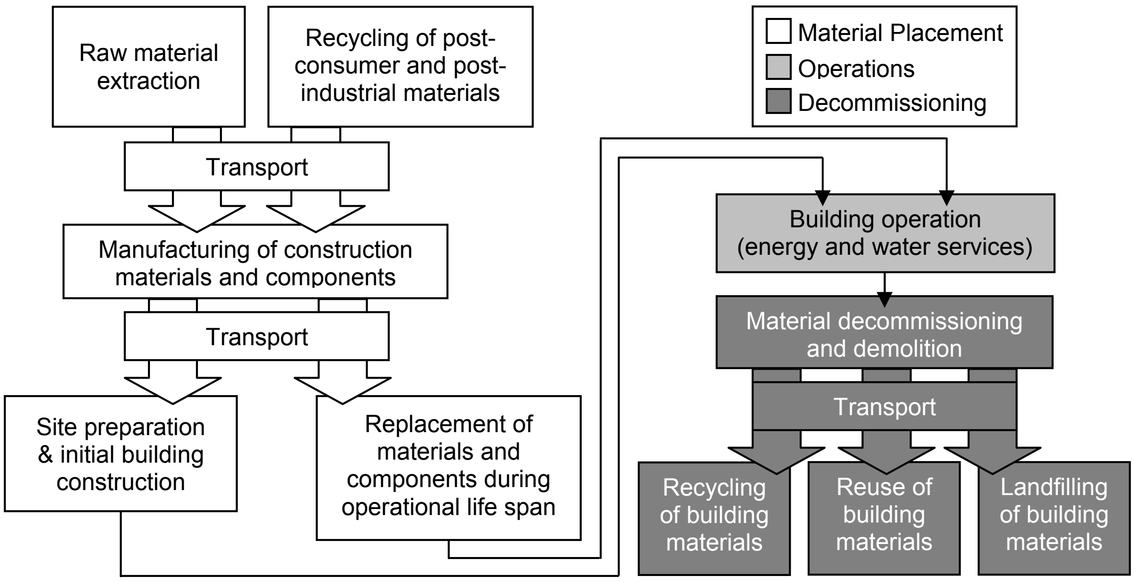


Figure 2.1: New building's life cycle assessment diagram

Table 2.1 gives in detail the author's definition of a carbon footprint compared to the issues included in the new building's life cycle analysis (Scheuer et al., 2003) and its ecological footprint (Barrett, 2003).

Aspects	Life Cycle Assessment	Carbon Footprint	Ecological Footprint
Material production of building	Yes	No	No
Material transportation of building	Yes	No	No
Material placement of building (design, construction, renovation)	Yes	No	No
Construction of building	Yes	No	Yes
Land required to sequester CO_2 from building construction	No	No	Yes
Maintenance of building	Yes	No	No
Renovation of building	Yes	No	No
Demolition of building	Yes	No	No
Energy consumption (including hot water, equipment)	Yes	Yes	Yes
Land required to sequester CO_2 from domestic energy consumption and water energy use	No	No	Yes
Waste generation through lifetime	No	Yes	No (Debatable)
Waste generation from demolition and decommission phases	Yes	No	No
Waste transportation	Yes	Yes	No
Waste decomposition	Yes	Yes	No (Debatable)
Recycling of materials	No	Yes	Yes
Goods production (consumables)	Yes	No	Yes
Goods production (non-consumables)	Yes	No	No
Land used for goods production (non-consumables)	Yes	No	Yes
Goods transportation (consumables)	No	Yes	Yes
Goods transportation (and non-consumables)	No	Yes	No
CO_2 emissions through lifetime	Yes	Yes	Yes
Other emissions (ozone depletion, acidification, nutrification potential)	Yes	No	No (Debatable)
Water pumped /treated (including sewage)	Yes	No	No (Debatable)
Plantation	Yes	Yes	Yes
People's transportation	No	Yes	Yes
Vehicles' manufacture	No	No	Yes
Vehicles' maintenance	No	No	Yes
Land used for transport (roads, car parks)	No	No	Yes
Pasture or crop land area used to produce goods (e.g. food, drinks)	No	No	Yes
Land area required to sequester CO_2 from goods embodied energy	No	No	Yes
Sea area to produce fish	No	No	Yes
Energy used for service delivery	No	No	Yes
Goods' packaging	Yes	No	Yes
Units measurement	Units of J/m^2 over buildings life cycle	Units of CO_2 annually	gha or gha/capita annually

Table 2.1: Differences of L.C.A., carbon and ecological footprints

Some common areas are identified among the three analyses. However, each one focuses on different aspects. That is to say, the carbon footprint is an estimate which helps to lead to further improvements, while the ecological footprint concentrates on the environment's recovery from the emissions.

2.2 Introduction to definitions related to standards

Some years ago, the higher education sector started to focus on environmental performance. This action was driven, not only by the increased environmental consciousness, but also by the cost benefits that this progress could result in. Many standards exist to which an institution's environmental management system (E.M.S.) can be aligned with, evaluated against and awarded credits for fulfilment (Simkins and Nolan, 2004). However, an institution can adopt the framework of such standards without having the willingness to be certified for its continuous environmental performance. If an organisation lacks an E.M.S., the progress may be slower. An E.M.S. can be applied either to individual departments to identify its potential before it is adopted by the entire organisation or to improve specific aspects. A number of steps should be undertaken in advance so as to assure its compliance as shown in Figure 2.2 below.

Figure 2.2: Steps required for a standard registration (EUROPA, 2005)

An initial environmental review assesses a company's environmental performance at a specific period in time. It includes gathering information on a company's environmental impact and the management structures available to deal with this impact. Overall appraisals provide the basis for developing a record of environmental impacts and an environmental programme.

An environmental policy is the framework of the basic principles and targets which assist a company to put into practice its environmental commitment. It is the foundation on which the constant improvement of the environmental performance and the environmental management system can be based.

An environmental management system (E.M.S.) is the part of a company's overall management system that specifies, explains and provides documentation about:

- ⇨ The environmental policies, objectives, actions and official requirements to be complied with.
- ⇨ The roles, responsibilities and willingness of employees to make sure that environmental policies, objectives, actions and legal obligations are complied with.
- ⇨ The ways a company determines the capability of the employees related to their environmental awareness.
- ⇨ The environmental impacts of a company's activities and methods adopted for monitoring and assessment.
- ⇨ The company's confirmation of compliance with the E.M.S. and alternative solutions if it is not.
- ⇨ The continual improvement of its environmental performance.

An environmental programme is a set of specific targets and measures for further improvement of the company's environmental performance, by using the initial environmental review estimate.

An environmental statement can be considered as an official environmental report. This step involves the publicity given to the company's environmental performance, stating the achievement of targets set in the past and the objectives to be met in the future. Additionally, it provides stimulus to staff to be actively involved, it monitors the success, ensures on-going improvements and aids the overall planning (INEM, 1998).

2.3 Alternative approaches to E.M.S.

In order to develop the environmental management system, identification of the sources that emit carbon dioxide is required. Furthermore, the estimation of the quantities emitted by each source is essential. That is to say, the carbon footprint evaluation is the first step before proceeding with the development of an E.M.S. Otherwise, unless the sources and the quantities are accurately evaluated, their management becomes more and more difficult. Therefore, the more detailed the quantification of emissions by the sources, the better the E.M.S. evolvement covering all the aspects and consequently the better the results following. Dr. Galbraith (2004) of University of Glasgow has recently reviewed a range of different approaches to E.M.S.

ISO 14001

ISO 14001 is an international standard that defines a process for monitoring and reporting on the environmental performance of a company, requiring that an organisation implements a series of procedures to deploy an environmental management system. Moreover, ISO 14001 is not considered to be a technical standard, therefore, technical requirements cannot be substituted and it does not set prearranged standards of performance. The most important requirements of an E.M.S. under ISO 14001 comprise of:

- A policy statement that makes a company comply with the pollution prevention, with any legislation that is applicable and with the constant improvements of its environmental performance.
- Recognition of an organisation's activities and services that burden the environment.
- Setting performance objectives and targets for its environmental management system and performance, related to the commitments declared in the policy statement.
- Deployment of the E.M.S. (including training and methods to monitor the progress against targets set).
- Periodical audits ensuring the operation of the E.M.S.
- Monitoring, corrective actions and prevention of any deviations from the E.M.S.
- Evaluation of the environmental management system.

The environmental management system assessment is carried out by an external auditor periodically and when the company is found to have fulfilled the requirements then an ISO 14001 certificate can be issued.

BS8555 – Project Acorn

Project Acorn offers a five-step approach for the implementation of an E.M.S. in line with ISO 14001. The sixth level requires external assessment and registration to the European Eco-Management and Audit Scheme (EMAS). Its indicators and performance appraisal techniques are in parallel with the ISO 14000 series.

Many organisations have been supported via various grants all the way through to the implementation process, mainly for staff training. Each of five stages is evaluated by external supervision and awarded separately. As a result of the successful completion of the fifth step, an audit is conducted to determine the level to which the E.M.S. meets the requirements of ISO 14001, so that certification can be issued.

Eco-Management and Audit Scheme (EMAS)

The Eco-Management and Audit Scheme has been established by European Regulation to help the companies improve their environmental performance. EMAS recognises organisations that surpass the minimum legal requirements. Many features are in common with ISO 14001 and the underlying E.M.S. must either be accredited or meet the requirements of ISO 14001. However, this scheme requires that the environmental statement is publicly available. The public statement information must be independently validated in advance. It is usual that ISO 14001 certification is a step towards EMAS registration.

WebEMS

WebEMS is an outcome of the work of the University of Strathclyde (Safety and Environmental Management Unit, Department of Architecture) and has recently been introduced to the Universities of Stirling and St. Andrews. Its aim is to provide a framework for organisations to control their environmental management issues corporately and was designed for higher education organisations with various departments. In addition, it can be suitable for organisations that operate from central headquarters and control several sites geographically spread.

The system helps to minimize the activity for each site and requires its concentration at one centre, where information is collated and analysed to constitute a corporate overview. Locally tailored information is sent to multiple sites, followed by the required actions to meet the corporate objectives and targets. WebEMS can lead to the implementation of ISO 14001. The categories that the system utilises are as follows:

- Air emissions.
- Releases into water.
- Waste management.
- Land contamination.
- Natural resources and raw materials exploitation.
- Other local environmental and community issues.

A private conversation was conducted with the Director of the Safety and Environmental Management Unit (SEMU) of the University of Strathclyde, Dr. Paul Yaneske and the exploration through the WebEMS was undertaken (www.webems.co.uk). The system works like a database requiring each organisation’s department to complete the webpage fields and send the information to the central department. It is a quick process as it requires only descriptive information and not numerical. The system then examines and identifies the significant factors affecting an organisation’s carbon footprint, and provides prioritisation for the actions, sending a report to each site based on the activities conducted. The prioritisation covers the organisation’s risk to the environment and not to the organisation itself, as these two are usually confused. Furthermore, it provides the whole organisation’s report. A further expansion of the system will cover the design process of new buildings.

EcoCampus

EcoCampus is a national environmental management scheme that has been supported and funded by the government for its development and piloting. As its funding stopped, the formal innovative layout of the scheme has not been met. This system can provide a methodology followed by tailored software to institutions, so as to conduct an initial evaluation of their environmental performance. It focuses on the curriculum consisting of a number of themes such as resource use (including energy and water), build environment, waste, transport, raise of awareness, curriculum greening, etc.

Once the review process has been completed and the main contributors of impacts have been identified, the use of software will help to set the targets, ensuring the continuous improvement and enabling the institutions to improve their performance according to their priorities. This, in turn, allows each stage of the progress to be recognised.

An institution can be EcoCampus awarded as long as the benchmark process confirms that the institution has met the predetermined benchmark level of improvement and also after external verification. The process involves five steps, each one awarded independently, and the highest can provide the route for an ISO14001 certification.

SIGMA (Sustainability: Integrated Guidelines for Management)

This project was sponsored by the Department of Trade and Industry (DTI) and while most management tools focus on the environmental impact and improvement of an organisation, this provides a uniquely wider approach encompassing sustainability issues. It is a set of guidelines aiding organisations in their understanding of the principles of sustainability and their influence on it. The two core elements included within SIGMA are:

- The management of five different capitals; natural, human, manufactured, social and financial.
- Responsible practice - reflecting their transparency to stakeholders and compliance with related rules.

Its framework consists of four stages including leadership and vision, planning, delivery and monitoring, review and report.

SIGMA can represent a stand-alone framework or can be used with existing management systems. The guiding principles are flexible and can be tailored to each organisation’s requirements and circumstances, while the organisation can work through it at different speeds. Unlike other E.M. systems, its aim is not the certification award. SIGMA does, however, support the use of a system of “assurance”, to reinforce the procedures; “assurance” should be guaranteed in cooperation with stakeholders. In a higher education organisation this process might be supervised by a team representing key interests such as students or local residents. SIGMA reflects the flexible approach to the management of sustainable development that the tertiary education sector necessitates.

2.3.1 Differences between EMAS and ISO 14001

Even though ISO 14001 and EMAS have the same targets i.e. both of them are contributors to ensure the continuous improvement of environmental performance, they are usually considered as competitors. Minor alterations must be undertaken for an ISO registered organisation to be awarded by the EMAS. Table 2.2 shows their differences.

	EMAS	ISO 14001
Initial environmental review	Initial review verification.	Review is not required.
External communication and verification	Publicity of the environmental policy, the objectives, the environmental management system and the details of the organisations performance.	Publicity of the environmental policy.
Audits	Frequency and methodology of the environmental management system and of environmental performance audits.	Environmental management system audits (frequency or methodology not specified).
Contractors and suppliers	Requires evidence of the influence over contractors and suppliers.	Relevant procedures are communicated to contractors and suppliers.
Commitments and requirements	Involvement of the employee, continual improvement of the environmental performance and compliance with environmental legislation.	Commitment to continual improvement of the environmental management system instead of a demonstration of continual improvement on environmental performance.

Table 2.2: Differences between EMAS and ISO 14001 (European Commission Environment Directorate, 2001)

2.3.2 Motivation for E.M.S. implementation

The EU Directive on the energy performance of buildings was introduced on 4 January 2003. Its main objective is outlined as follows:

- ⇨ The promotion of building energy performance improvements, considering weather conditions and indoor environmental requirements (Cox and Boel, 2002).

Hence, it covers the requirement of all the buildings to be certified, to apply energy performance standards, to adopt a step-by-step process to calculate their energy performance and additionally, to frequently inspect their cooling and heating systems. All the Member States of the United Nations should comply with the Directive by 4 January 2006, though a three-year extension has been given for compliance with Article 7 (Energy performance certificate), Article 8 (Inspection of boilers) and Article 9 (Inspection of air-conditioning systems) (DEFRA, 2003).

2.3.3 Pros and cons of E.M.S.

Certainly, the way to implement an environmental management system has both advantages and disadvantages for an institution. Below, the benefits and the barriers throughout this procedure are outlined in depth.

Motives:

- Reduce operational costs - which constitute a significant driver.
- Raise staff awareness and improve morale, by encouraging them to participate in the development of the E.M.S.
- Boost students' education to protect the environment, by "greening" the curriculum.
- Bolster environmental prestige and improve the institutions' overall image, while discouraging people from quitting and attracting high profile staff.
- Increase cooperation among the various departments and other institutions, by having a common target.
- Assure compliance with the regulators.
- Attraction of a higher percentage of students, by spreading its reputation.

Obstacles:

- Staff inertia.
- Conflict in views among people involved and lack of consistency.
- Capital required for initial and further changes.
- Long-term payback periods, while the short-term benefits influence and motivate people to be active and focused by providing incentives.
- Education of staff is a time-consuming procedure.
- Loading staff with additional responsibilities.

The latter point can cause great problems occasionally ceasing the procedures. Subsequently, it is essential that this process is carried out by people that have strong interest, willingness and incentives, as well as proper education (Simkins and Nolan, 2004).

A good way of addressing all the problems that may arise is to appoint a competent person with adequate influence, an environmental manager, who will be entitled to make sure that the process is progressively on-going and the duties are separated in such way as to ensure continuous improvement.

2.3.4 Existing University policies

Many policies have been developed among UK universities, trying to operate to reduce their costs effectively. Most universities have developed webpages where their environmental performance, environmental and management policies, actions undertaken for further improvements and general tips are available. Additionally, some universities send literature to prospective students that includes a leaflet related to actions for improvements on the University operation and the environment. This is an approach to raise student and staff awareness and sensitise them.

Other, less common but noticeable ways, that have helped various University profiles are described below:

The University of Derby, as part of the MSc in Environmental Management course, requires audits around the University buildings. The data gathered by the students provides essential material to the assigned person required for the overall environmental performance estimation and for future actions. The students are required to conduct audits of professional standards, having attended tutorials in advance associated with this purpose. Moreover, another benefit is the time saved from such a time-consuming procedure. Furthermore, the student awareness is raised directly of the University’s impacts (University of Derby, 2005).

The University of Bradford purchased video conferencing equipment in its attempt to reduce emissions and cost related to staff travel, for example to deliver lectures for a course in the University department in another country, within and beyond Europe. Consequently, the need for travel has been substantially minimised if not completely. Additionally, another advantage is the effective use of staff work time (Winsum and James, 2003a).

Leeds Metropolitan University changed the procedure of the prospectus. It shifted from sheet fed to web fed and reduced the paper weight, thus, decreasing the cost associated not only with printing but also with postage expenses. Leeds Metropolitan University is the first one which is partly accredited to ISO 14001 and is planning to be fully certified in the future (Winsum and James, 2003b).

The three universities above (Derby, Bradford and Leeds Metropolitan) have the common policy of “pay by weight” instead of “pay by volume” for their waste removal, thus reducing the cost when the skips are not full. Additionally, the latter two have a joint tender for their waste disposal. The contract was a consequence of their dissatisfaction with the previous provider. This new collaboration has, as a result, better service due to its high value contract. Moreover, the profit of their recycled materials is offered to the contractor as an incentive (Winsum et al., 2005)

The University of Oxford organises events throughout the year which last from one up to four days, achieving a number of targets with activities taking place around the University. The voluntary participants, students and staff, are awarded with various prizes. Furthermore, it has developed a car-share scheme together with other registered organisations (Oxford Brookes University), which involves people who share their route to work (University of Oxford, 2005). This car-sharing facility has also been developed by the University of Cambridge (University of Cambridge, 2004).

Oxford Brookes University and the University of Sheffield have an Environment and Sustainability Week respectively, organising seminars, exhibitions and workshops reinforcing the student and staff awareness (Oxford Brookes University, 2005), (University of Sheffield, 2003).

The University of Glasgow conducts an Energy Awareness Day. This has shown a reduction in energy use of 13% in one day. As a consequence, the University increased the duration of this campaign to a week and by the collaboration among the departments, a website was developed to receive suggestions with the best proposal being awarded £50. This event showed a constant 10% reduction in energy use (DETR, 1999a).

The University of Leicester tailored its own energy management matrix (University of Leicester, 2004) based on the original by BRECSU (Government of South Australia, 2005) to visualise its performance.

Kingston University has developed a student guide which includes tips for energy and water management. The detailed mapping of the University provides information about the recycling bins for each recyclable material across the University as well as cycle routes and parking (Kingston University, 2005).

Liverpool, York, Coventry, Bangor, Edinburgh and Dundee Universities have installed combined heat and power (C.H.P.) plants, cutting their carbon dioxide emissions by 50%; C.H.P. units are of high efficiency by using 30% less primary energy than conventional ways of production. Furthermore, financial savings have been achieved of up to £400,000 annually (DETR, 1996a).

The Universities of Coventry, Aberdeen University as well as the University of East Anglia have installed a building management system (B.M.S.), providing monitoring and control of their building services. The annual cost savings vary from £15,000 to £250,000 due to the specifications that have been laid out in advance to gain its highest efficient operation. Some of the factors that influence its effective use consider the site suitability and the existing control systems (DETR, 1999b).

Cardiff University achieved savings of more than £60,000 annually by investing in energy efficiency and developing a monitoring and targeting system, to have better control over the energy consumed. The identification of the most high-cost buildings was important initially and their focus on them of high priority (DETR, 1996b).

The University of Strathclyde has made available its environmental policy statement online. No further information is provided for the current work undertaken by the Estates Management Department to develop an environmental management system. This attempt is in its initial stages and as it is a time-consuming process, voluntary help is needed. Moreover, the University runs limited environmental awareness programs.

2.4 Environmental manager duties

The environmental manager has the responsibility to make the institutions performance more efficient, by identifying the potential for further improvements. Moreover, the appointed person assures legal compliance while introducing an environmental management system to which commitment is ensured and encourages the sustainable development so that the current changes have an effect in the future. Additionally, other responsibilities involve data gathering for assessment and assurance of their quality, progress monitoring and establishment of new targets, benchmarking of improvement, support collaboration among people engaged, development of environmental reports as well as capability to increase peoples' consciousness while the manager satisfactorily responds to any queries (EAUC, 2004).

2.4.1 Problems confronted

Many problems related to manager responsibilities which should be addressed may arise, although it is a time-consuming procedure. These include the collection of data; as many institutions lack historical information availability and their integrity is doubtful. However, if data exists collection may be inconsistent and therefore the monitoring stage is delayed. The lack of data resolution is another parameter that causes hurdles, depending on the level of analysis required to be developed. Furthermore, data may not be accessible. The monitoring of the performance becomes complex once the gathering of data is progressed and therefore the development of a database or the purchase of software is required at this stage.

2.4.2 Energy Management Matrix (E.M.M.)

The development of an energy management matrix is a high priority to outline the organisation's profile as shown in Figure 2.3. This tool shows the up-to-date improvements in the six elements it is focused on, while it highlights the aspects that should primarily be addressed. Moreover, by creating the profile, the potential in each issue for further improvement can be determined. Level 0 shows poor performance with the best performance being Level 4.

Level	ENERGY POLICY	ORGANISING	MOTIVATION	INFORMATION SYSTEMS	MARKETING	INVESTMENT
4	Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy.	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption.	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it.	Positive discrimination in favour of "green" schemes with detailed investment appraisal of all new-build and refurbishment opportunities.
3	Formal energy policy, but no active commitment from top management.	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board.	Energy committee used as main channel together with direct contact with major users.	M & T reports for individual premises based on sub-metering, but savings not reported effectively to users.	Program of staff awareness and regular publicity campaigns.	Same payback criteria employed as for all other investment.
2	Unadopted energy policy set by energy manager or senior departmental manager.	Energy manager in post, reporting to ad-hoc committee, but line management and authority are unclear.	Contact with major users through ad-hoc committee chaired by senior departmental manager.	Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting.	Some ad-hoc awareness training.	Investment using short term payback criteria only.
1	An unwritten set of guidelines.	Energy management the part time responsibility of someone with only limited authority or influence.	Informal contacts between engineer and a few users.	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department.	Informal contacts used to promote energy efficiency.	Only low cost measures taken.
0	No explicit policy.	No energy management or any formal delegation of responsibility for energy consumption.	No contact with users.	No information system. No accounting for energy consumption.	No promotion of energy efficiency.	No investment in increasing energy efficiency in premises.

Figure 2.3: Energy Management Matrix (BRESCU,1995)

To create the profile the appointed person has to mark in every column the present situation that best expresses the organisations level and by joining these marks the profile is completed, showing the strengths and the weaknesses in each element. The next step is to improve the aspects that are the least advanced, as shown in Figure 2.4, in order to have equilibrium, achieving a flat line across the columns, as illustrated in Figure 2.5.

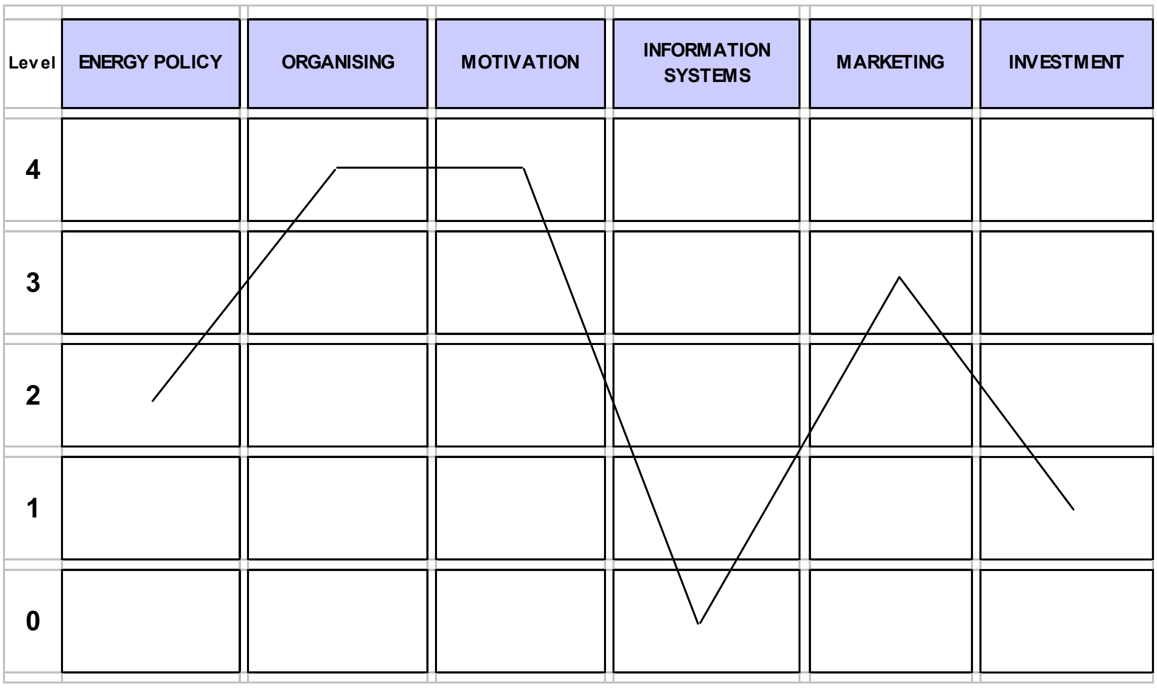


Figure 2.4: Unbalanced Energy Management Matrix

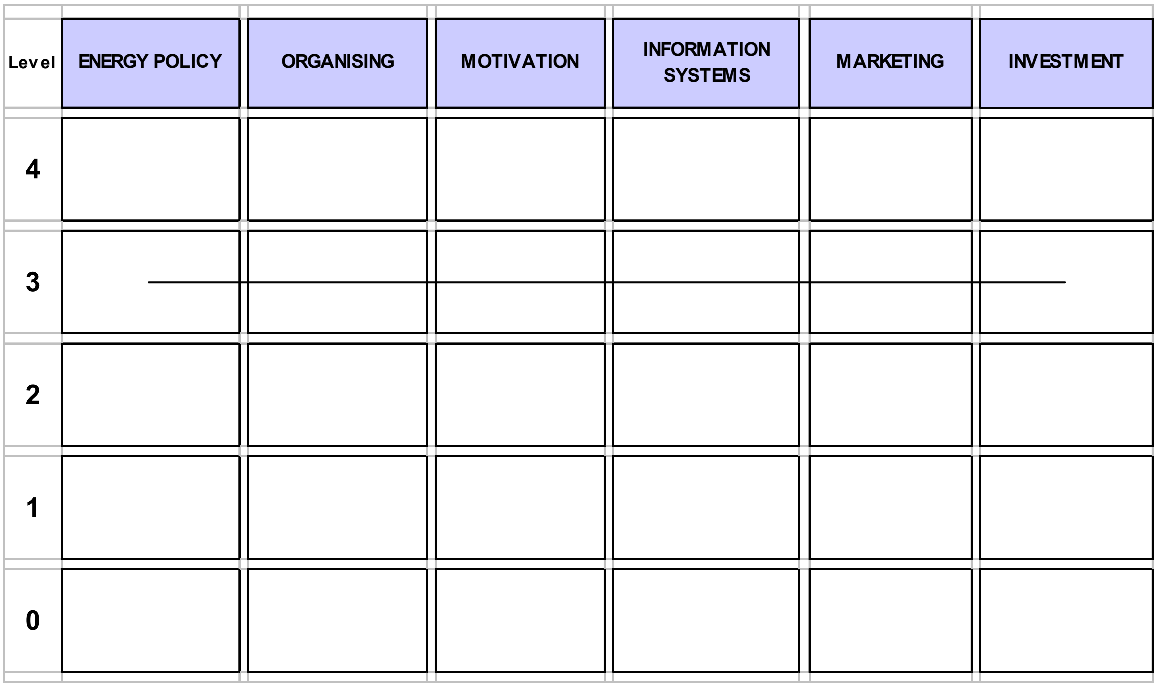


Figure 2.5: Balanced Energy Management Matrix

The six elements that must be assessed can assure the organisations benefits. These management issues are linked together, providing the approach that should be developed (Government of South Australia, 2005).

Energy policy

The policy should be evolved and strictly followed without any deviations. This describes the targets that should be met within a time scale. It also takes into account the future purchases and developments and sets the strategy for new and refurbished buildings.

Once the energy policy has been developed by the people engaged with the energy management of the organisation, it should be evaluated and reorganised yearly to encompass new elements.

Organisation

The energy management perception should be thoroughly considered in the organisation, providing sufficient resources for its completion. That is to say, the person responsible must have access to the financial department to inspect the invoices and the authority to negotiate with the utility companies, such as water and energy suppliers.

Motivation

The incentives provided to people to support this action is of great importance, thus keeping them well informed may achieve better results. A comprehensive leaflet published on a regular basis keeps people active and reinforces their interest. Moreover, this may change their attitude and make them behave competitively.

Information systems

The purchase of software is a wise decision as the volume of data that should be monitored is increasing. This also allows easy manipulation and better understanding of the situation as there are many buildings, different occupancy profiles and, possibly, different suppliers.

Marketing

The promotion of the action undertaken is a significant matter. It is also important to choose the correct way to support this action. The development of a website is a good approach, presenting information from the data metering, targets achieved and the future plans to radical change the organisation performance. The organisations environmental credentials should be used as a key element in its marketing.

Investment

Substantial savings can be achieved by energy efficient use and negotiations with the supply companies. These savings can provide a small percentage of the capital required to fund future projects for further economic benefits. Environmental investments should be allowed to have longer payback periods (DETR, 1997).

2.5 Carbon Trust - H.E.C.M. toolkit

The Department of Trade and Industry (DTI) established the Carbon Trust to communicate and assist in the implementation of the policies that should be developed by businesses to create a low carbon profile and to enable organisations to take advantage of the government funding and assistance available. As part of its task, Carbon Trust administers the support provided by the Energy Efficiency Best Practice Programme (EEBPP) (European Commission, 2002).

The Higher Education sector is estimated to have a potential for energy savings of over 20%. This percentage can be expressed as 3.3 million tonnes of CO_2 reduction annually. As the number of students involved in this sector rises, the interest of the organisations has increased accordingly.

The Carbon Trust has developed a flexible five step-process, as shown in Figure 2.8, which can be tailored and adopted by institutions according to their needs. Aiming to reinforce the awareness and to minimise the risks associated, while identifying the prospects involved in the near future, this procedure can be applied and redefined once it is implemented for further changes.

An organisations key stakeholders are directly influenced by the risks and opportunities related to carbon emissions. Their commitment is of high priority while they may also contribute to solutions. For the Higher Educational Institutions (HEIs), in the wider range of their stakeholders, the three key constituency groups, including students and operational and academic staff should be involved, as shown in Figures 2.6 and 2.7.

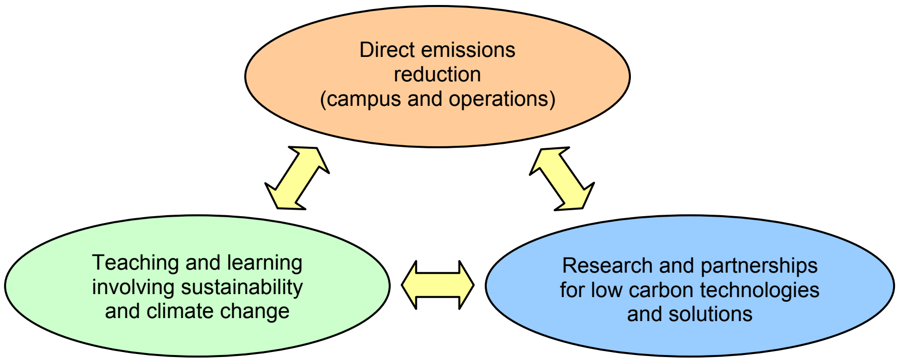


Figure 2.6: Sources presenting opportunities for carbon reduction

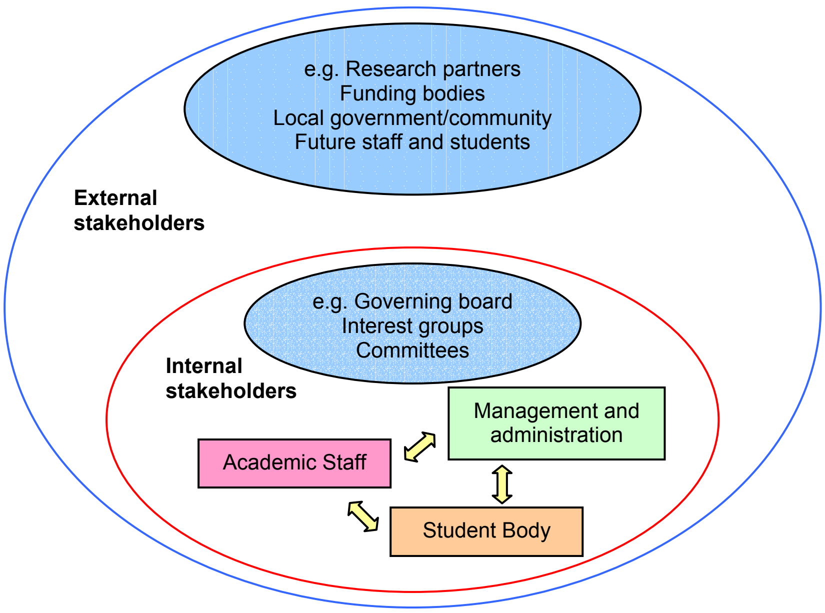


Figure 2.7: External and internal groups of stakeholders

The Higher Education Carbon Management (H.E.C.M.) Programme (Carbon Trust, 2005), developed also for University applications, is illustrated in Figure 2.8. The steps are stated in a chronological order, while activities of different steps can run simultaneously. Part of this programme includes the software H.E.C.M. toolkit, developed for the carbon footprint estimation.

2.6 Project objectives - Methodology

The objectives of this project can be described as outlined below:

- Use of the H.E.C.M. toolkit for the carbon footprint evaluation of the chosen site, so as to identify the software needs and to provide suggestions for its further effective use among the various buildings of the University of Strathclyde.
- Investigation of the carbon footprint alterations through sensitivity analyses on the transportation factor, concluding to the detail up to which the data should be gathered in the future.
- Graphical representation of the buildings' energy use using Geographical Information Systems (G.I.S.), so that their easier monitoring would save time for the appointed person.
- Identification of the efficiency of the meters' system for future investments.

The methodology followed for the carbon footprint evaluation was influenced by information related to building energy use provided by the Estates Management Department of the University of Strathclyde, and partly by a questionnaire developed to collect data related to the transportation and commuting of the people involved in the chosen site. The data was then inserted in the H.E.C.M. toolkit for the carbon dioxide emissions estimation.

2.6.1 H.E.C.M. toolkit description

The software comprises three working sheets in an Excel file. Except for those three sheets covering the emissions resulting from the building envelope as well the transport and commuting of the people using this building, the Excel file also provides a summary sheet. It must be kept in mind that in the graphs included in the next chapters of this report illustrating annual consumption, emission, or cost, an annual scale is used to represent the academic years (e.g. 2004 represents the academic year 2003 - 2004).

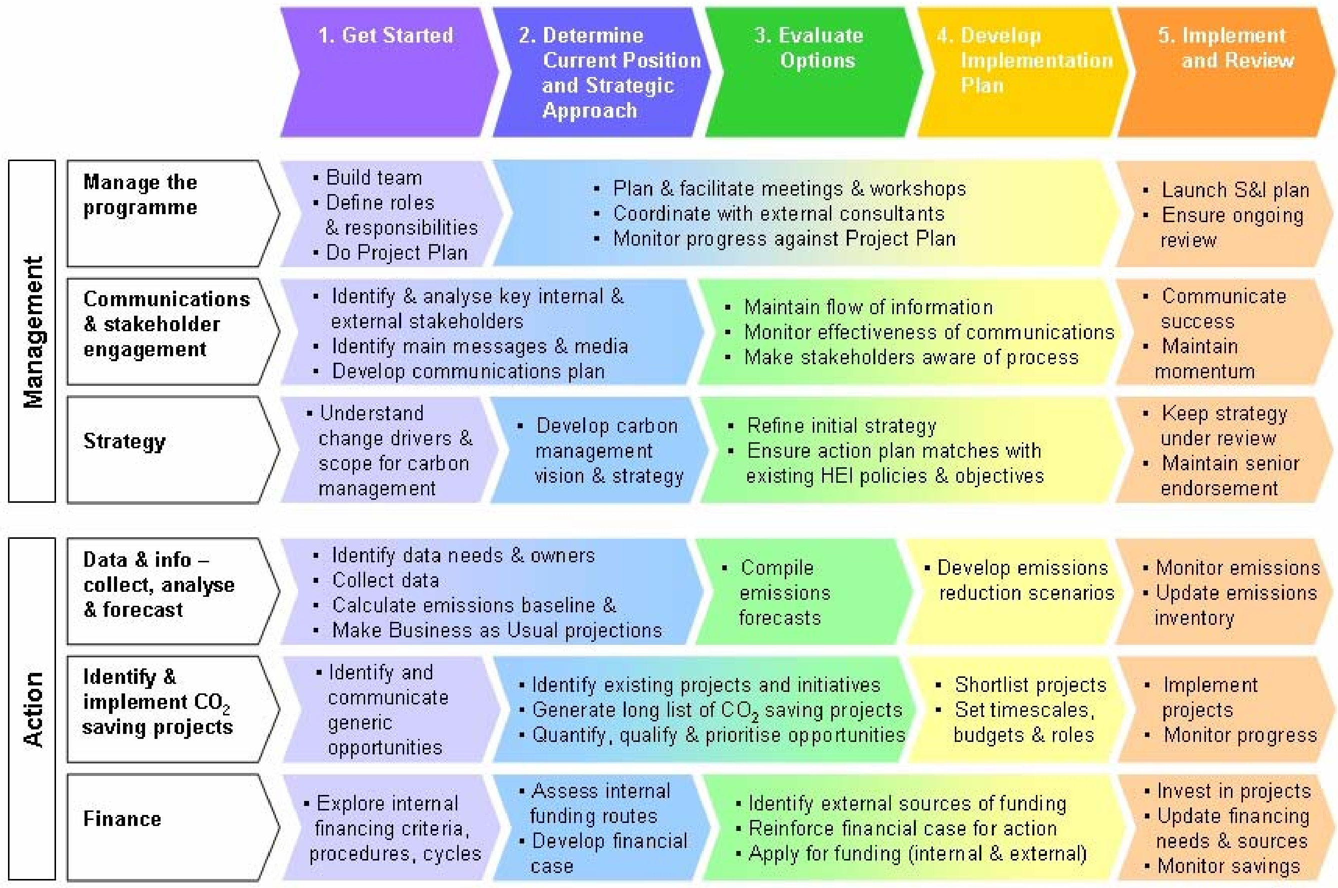


Figure 2.8: Five-step process developed by Carbon Trust (Carbon Trust, 2005)

3. Carbon footprint estimation

3.1 Choosing the appropriate site

Many factors had to be considered in advance for the site selection among the John Anderson Campus buildings of the University of Strathclyde. Due to the lack of data required as compulsory fields in the software, the selection became a critical issue. The sites excluded initially were those occupied by staff. This was influenced partly because of the staff absenteeism during summer as well as the difficulty involved with their transport and commute because of the spread information. Consequently, the available sites were the halls of residence. However, among the halls of residence, the sites excluded were the Patrick Thomas Court and the Andrew Ure Hall. In the former situation, where only electricity is provided, PowerCards are used. In Andrew Ure Hall both gas and electricity are available and the fact that both are paid using gas and power cards makes it impossible to record the data. Furthermore, as many halls of residence are vacated during the summer period the options were less. The selected site is the James Goold Hall of residence (Block A). This building is occupied by full-time postgraduate students having a contract of 50 weeks and subsequently, it would be feasible to obtain the transportation and commuting information of the residents. Block B of this hall of residence was excluded because it is not occupied by students for the summer period.

The detailed breakdown should be introduced covering the level of analysis of each factor separately influencing the carbon footprint of this site, shown in Table 3.1.

Factors	Level of analysis
Energy	• Emissions related to electricity and gas consumption
Transport	• Emissions related to student commuting (from and to university) • Emissions related to staff travel (short and long hauls) • Emissions related to students' educational journeys • Emissions related to suppliers and contractors
Waste	• Emissions related to landfilled waste
Plantation	• Amount of emissions sequestered

Table 3.1: Level of analysis of factors influencing carbon footprint

3.2 Gathering data

The data collection was conducted partly through the questionnaire available in Appendix I, and partly by the Estates Management Department while some data was provided by the software itself. Data collection took place to cover the software's needs for the James Goold Hall's carbon footprint estimation. The questionnaire, after approval by the Department of Mechanical Engineering Ethics Committee, was completed by conversation with the occupants. At the end of the survey, 55 questionnaires were collected from the James Goold Hall, Block A. Table 3.2 presents the information required and the sources used to obtain the data.

Aspects	Data	Sources
Building Data	Gas consumption annually (in kWh)	Estates Management
	Cost for gas (in p/kWh)	Estates Management
	Electricity consumption annually (in kWh)	Estates Management
	Cost for electricity (in p/kWh)	Estates Management
	Renewable sources contribution (in %)	Estates Management
	Gross internal area (in m^2)	Estates Management
	Electricity CO_2 factor (in kg/kWh)	Software
	Gas CO_2 factor (in kg/kWh)	Software
	Typical practice value for electricity benchmark	Estates Management
	Good practice value for electricity benchmark	Estates Management
	Typical practice value for gas benchmark	Estates Management
	Good practice value for gas benchmark	Estates Management
	Building type	Known
	Country degree days (the 20-year average heating)	Software
Transportation data	Trips conducted annually (departure and arrival destinations)	Questionnaire
	Type of ticket (one way or return) per trip	Questionnaire
	Mean of transportation per trip	Questionnaire
	Type of trip (personal or course related)	Questionnaire
	Potential alternative means of transport per trip	Questionnaire
Commuting data	Commuting/educational trips conducted annually (departure and arrival destinations)	Questionnaire
	Means of transportation per trip	Questionnaire
	Duration (in weeks)	Questionnaire
	Days per week	Questionnaire

Table 3.2: Information and sources used

3.3 Energy use in buildings

Gas and electricity consumption was provided in a monthly basis, for all the halls of residence by the Estates Management Department. However, the data related to the James Goold Hall (Block A and B) are graphically illustrated in Appendix II. The development of the charts is considered to be important in order to identify possible mistakes. Faulty values may be caused by:

- Meter errors
- Technician errors during meter reading
- Typing errors during data input in the database
- Author's errors during manipulation

Following the identification of the faulty data, the gas and electricity consumption data should be scaled considering only Block A of James Goold Hall. Calculation of the floor area was required. The total gross internal area for both buildings accounts for 3.595 m^2, however the main differences between the two are:

- Block A has 13 flats, one more flat than the other block in the basement, while on the last floor there is only one flat covering 1,5 times the typical floor area.
- Block B has 12 flats, one of which is used for the boiler plant Therefore, Block B is considered to comprise only 11 flats in the calculations.

So, each flat in both Blocks is 146,73 m^2, while the flat on the last floor at Block A is 220,1 m^2. Consequently, Block A accounts for 1980,91 m^2 and Block B for 1614,08 m^2, translated in 55,1% and 44,9% of the total respectively.

Using these percentages the monthly gas and electricity consumptions of the Block A was calculated. Where some of the initial data provided were found to be unrealistic corrections had to be considered.

Where the gas data had to be changed, a factor f_1 had to be introduced arising from the degree days of the month under change and the month previous to it. For example, if February data were under manipulation, factor f_1 would arise from the degree days of February and January.

As far as the changes in the electricity data are concerned, the introduction of a second factor f_2 was needed. This factor f_2 was calculated using the electricity consumptions of the corresponding period of time, the year before and after the year of the study. For example, if the data for the period January/February 2003 was manipulated, the factor f_2 would derive from the data of January/February 2002 and January/February 2004.

Two examples are presented below; one for gas and one for electricity consumption. Illustration of the needed changes is taking place. The gas consumption example refers to the year 2000 whereas the electricity consumption example refers to the year 2001. Analysis of the gas and electricity consumption took place for all the years between 1999 and 2005 (to May). All the outcomes of this analysis can be found in Appendix III of this report.

As far as the gas consumption is concerned, Table 3.3 illustrates all the needed alterations for the determination of the correct gas consumption for January 2000. The needed input was the degree days of the month December 1999 and January 2000 as well as the gas consumption for December 1999. The correction factor f_1 derived by dividing the degree days of January, for which faulty measurements were provided, with the degree days of December. The correct gas consumption for January was then calculated by multiplying the gas consumption of December with the correction factor.

Month - Year	Degree days	Consumption (in kWh)	Correction factor f_1	Resulted consumption
December -1999	372	70.119,86	0,887	70.119,86
January - 2000	330	47.451,42		62.203,1

Table 3.3: Initial and resulted gas consumption

Consequently, the James Goold Hall consumptions changed from Chart 3.1 to Chart 3.2.

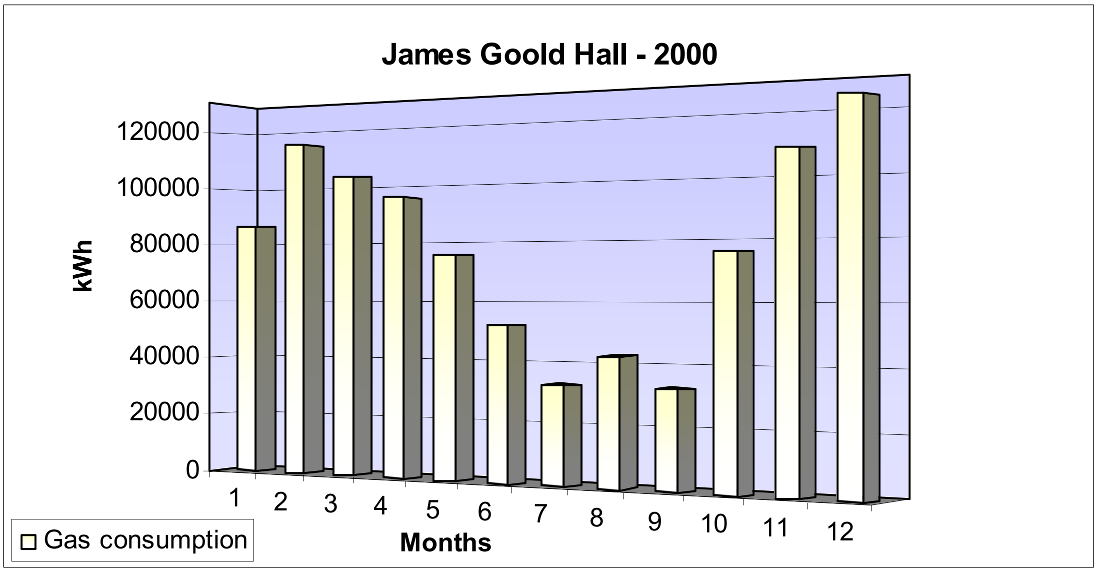


Chart 3.1: James Goold Hall initial consumption

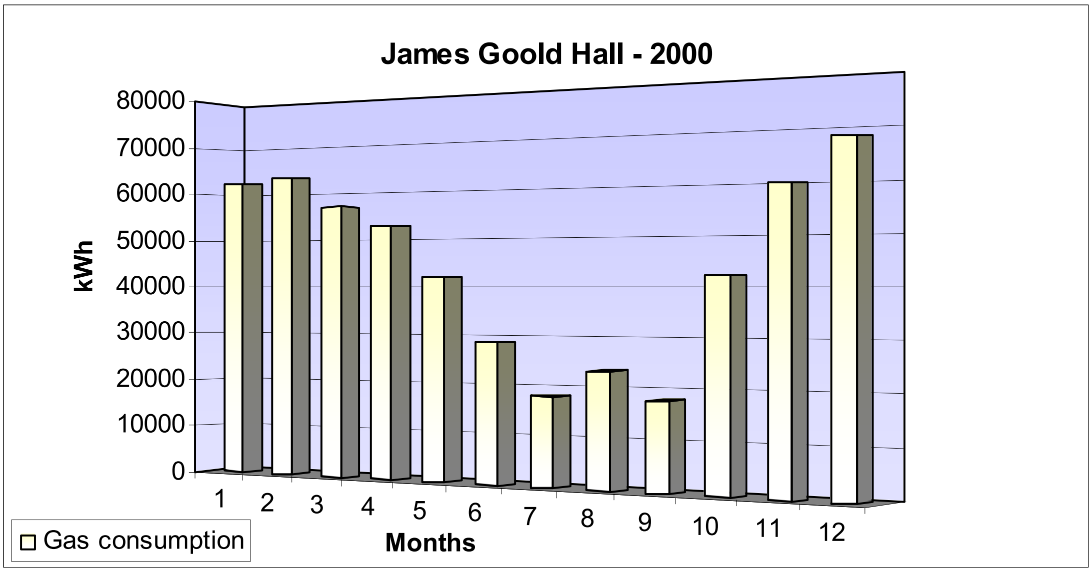


Chart 3.2: James Goold Hall altered consumption

For the year 2001, the electricity consumption was scaled related to the floor area of Block A and the July's, August's and September's consumption was adjusted according to the average factors for the corresponding readings of the 2000's and 2002's consumptions. The factor column results from the ratio of the corresponding months consumption, while the new correction factor f_2 represents the mean value of the two calculated factors of the corresponding months. The resulted consumption of July 2001 is calculated by multiplying the calculated correction factor f_2 with the consumption of the previous month (June 2001). Tabulated values are presented in Table 3.4.

Month - Year	Consumption (in kWh)	Factor	Correction factor f_2	Resulted consumption
June - 2000	9.121,25	1,13		
July - 2000	10.308,1	1,019		
August - 2000	10.511,97	0,78		
September - 2000	8.202,73	1,749		
October - 2000	14.354,65			
June - 2001	14.105,6	7,918	1,057	
July - 2001	111.695,414	0,867	1,021	14.910,93
August - 2001	96.948,45	-4,506	0,782	15.209,14
September - 2001	-436.937,49	-0,032	1,738	11.863,13
October - 2001	14.138,66			
June - 2002	11.411,76	0,984		
July - 2002	11.229,93	1,024		
August - 2002	11.503,77	0,785		
September - 2002	9.041,91	1,727		
October - 2002	15.616,44			

Table 3.4: Initial and resulted electricity consumptions

Subsequently, the James Goold Hall consumption for the year 2001 changed from Chart 3.3 to Chart 3.4, shown below.

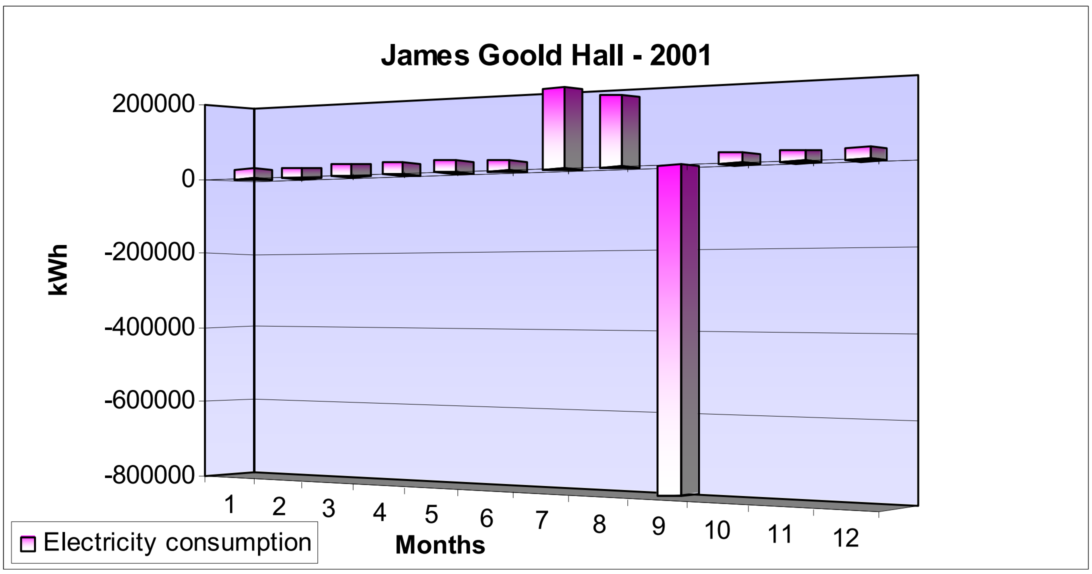


Chart 3.3: James Goold Hall initial consumptions

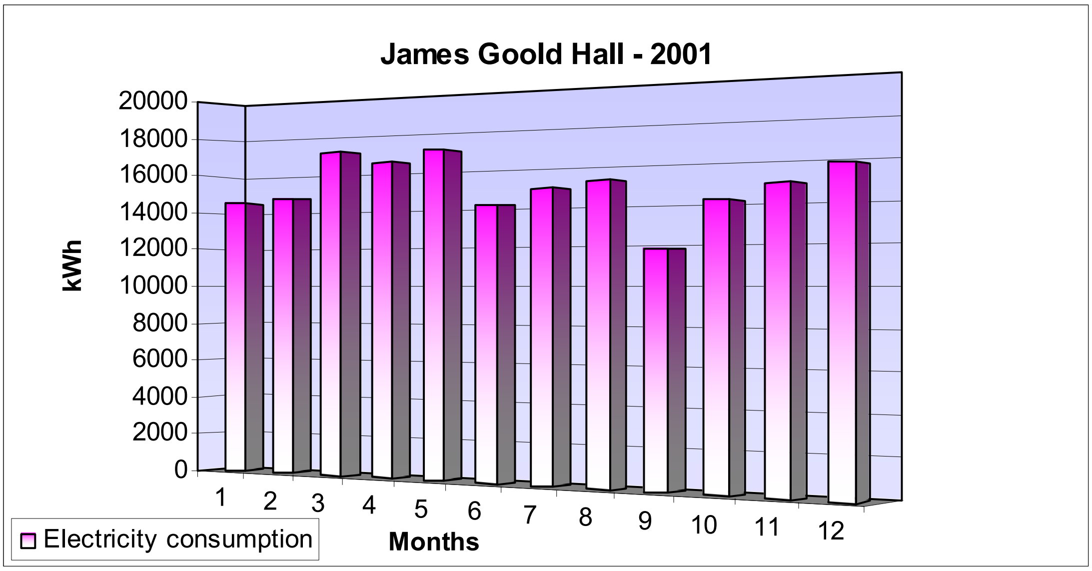


Chart 3.4: James Goold Hall altered consumptions

The resulting gas consumption for the period between 1999 - 2005 (until May) after the correction of the data is illustrated in Chart 3.5.

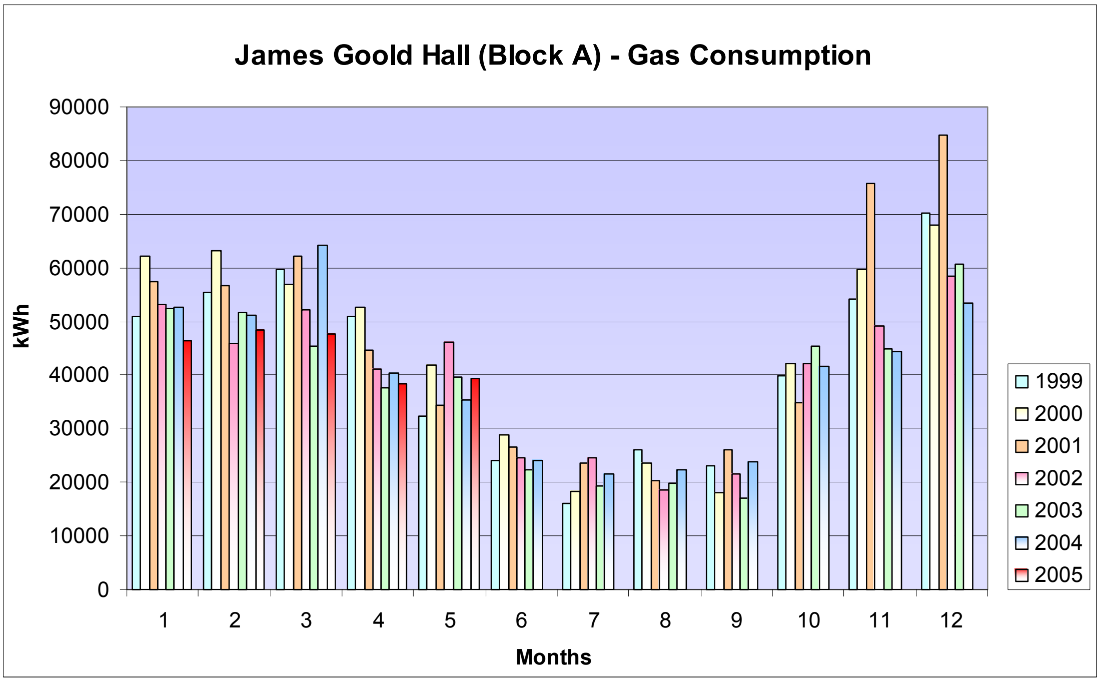


Chart 3.5: James Goold Hall altered gas consumptions

The resulting electricity consumption for the period between 1999 - 2005 (until May), after the correction of the data, is illustrated in Chart 3.6.

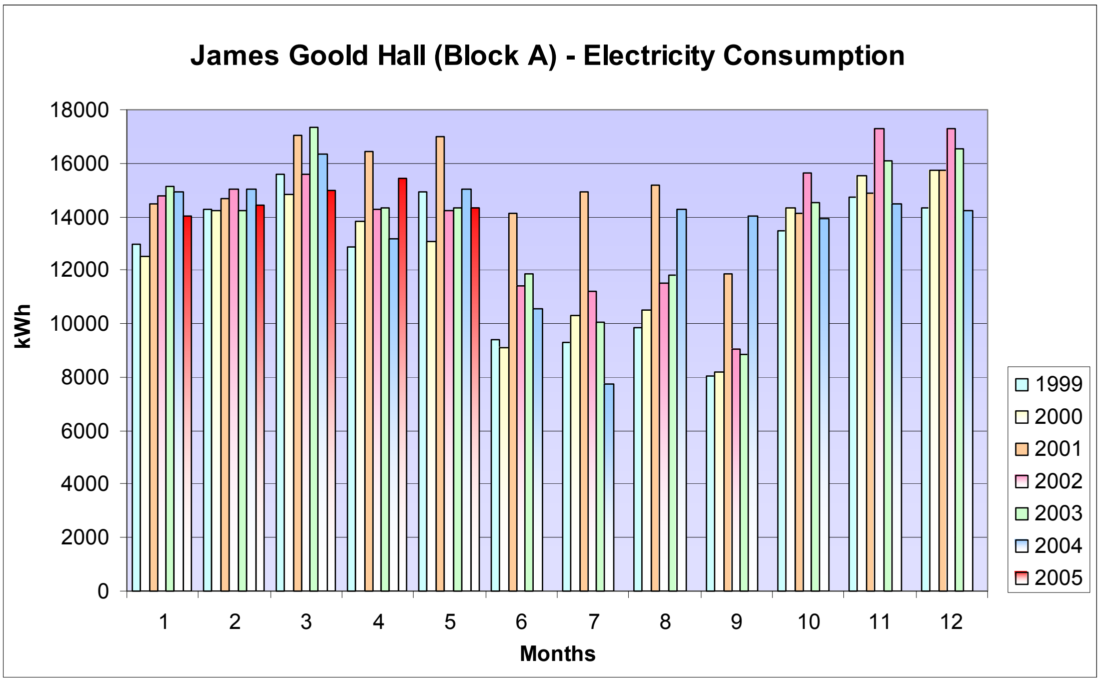


Chart 3.6: James Goold Hall altered electricity consumptions

A more detailed analysis for each hall of residence trend consumptions' profiles is provided in Appendix IV. The profiles of gas, electricity as well as total energy consumption (gas and electricity) were developed on an annual basis.

All these profiles for the annual gas and electricity consumption are illustrated in Chart 3.7 and 3.8 below. Comparisons between building consumptions can take place as well as evaluations of critical or outstanding performances can be conducted. Having identified all the differences, explanations can be given regarding excessive gas and electricity consumptions.

Analysis of the data shows differences in the building consumptions even if they are used for the same purposes. These differences are due to the date of construction and the relevant building regulations, their floor area and the occupants' behaviour.

As data for the year 2005 was available only until May 2005, a procedure had to be followed to estimate the energy needs (both electricity and gas), illustrated in Charts 3.7 and 3.8, for the buildings to fulfil the demands of the software for the calculation of the James Goold Hall carbon footprint for the academic year 2004 - 2005. The procedure followed for each building involved the following steps:

1. Determination of the total consumption of the year 2004 (Parameter A).

2. Determination of the consumption for the period January - May 2004 (Parameter B).
3. Determination of the consumption for the period January - May 2005 (Parameter C).
4. The consumption of each building for the academic year 2004 - 2005 resulted from the formula:

$$\frac{Parameter\ A \times Parameter\ C}{Parameter\ B}$$

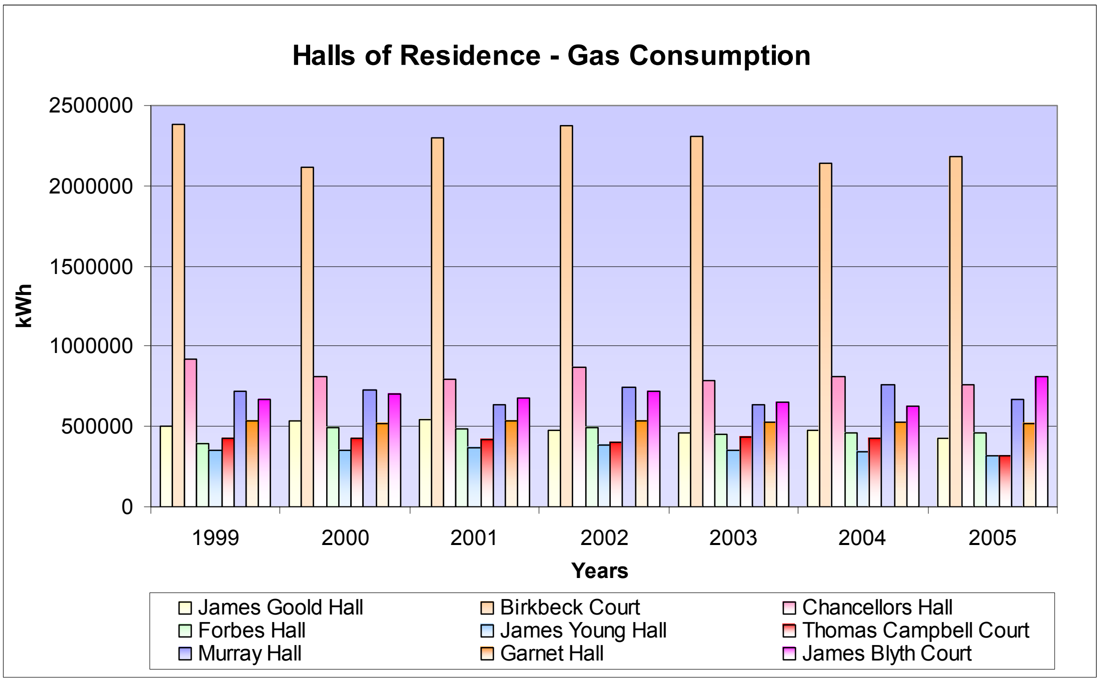


Chart 3.7: Annual gas consumption profiles

From the chart above comparing the halls of residence consumptions, Birkbeck Court is the biggest in floor space area and oldest hall of residence within the John Anderson's Campus, which can explain the significant amount of gas that is consumed. Additionally, this hall has an underground district heating scheme which is in a deteriorated condition with excessive heat losses. What is more, Chancellors Hall being the third biggest among the halls stands also for high gas consumption which can be explained by the floor area that it occupies.

Comparing Birkbeck Court's gas and electricity consumption, which follows, it can be observed that while a decline in the gas consumption occurs, starting in 2002, electricity consumption is increasing for the same period. This sudden increase in Birkbeck Court's electricity consumption, during 2002 to 2003, was caused by a failure of the underground district heating scheme, used to provide heating to the rest four buildings of the hall. As a result of student complains, electric heaters were distributed. The fault was recovered and the electricity consumption is expected to drop more than the 2004's level. However, a slight increase in electricity consumption had begun two years before the failure, which can be explained with the possible constant decrease in the scheme's efficiency, resulting in the use of electric heaters by students. However, high electricity consumption is also attributed to the fact that the laundry facilities are installed in this particular hall of residence.

The halls' of residence electricity consumption is shown below.

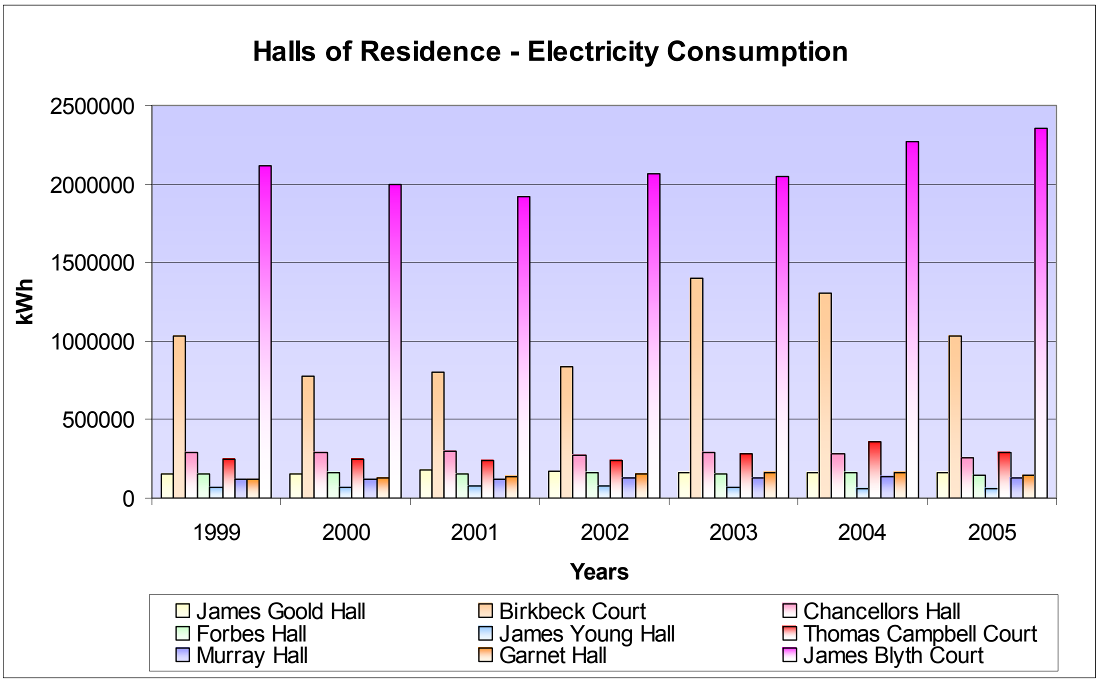


Chart 3.8: Annual electricity consumption profiles

It can be identified from Chart 3.8 that the two halls of residence, Thomas Campbell Court and James Blyth Court, compared to the rest have an exceptional performance. The gas in both cases is supplied only for hot water purposes. Thomas Campbell Court as well as James Blyth Court, both built in 1989, have passive solar facade systems. It is important to mention at this point that James Blyth Court occupies almost 3 times the floor area occupied by Thomas Campbell Court which stands for the second biggest among the rest of halls. Laundry facilities are also located in James Blyth Court, being a reason for its increased electricity consumption. Furthermore, a few months after the buildings' completion, complaints began about the ineffective performance of the systems.

Each bedroom had as a back-up a 200 W electric heater, while in the common area the heater was 750 W, operating remotely. However the residents had partial control. Some occupants, though, were operating the heaters more often than they should. Furthermore, additional heating, of 2 kW, was occasionally delivered since 1989 for the reported complains. In year 2003 - 2004, all the back-up heaters were replaced by 650 W ones, which constitutes the explanation for the increased electricity consumption. A project is to be undertaken by Mr Robert Shanks, Estates Management Department of the University of Strathclyde, concerning a feasibility study on a long term heating solution of the Thomas Campbell Court and James Blyth Hall.

Further comparison is made in Paragraph 3.4.1 on a kWh/m^2 basis.

3.4 Importing data in the H.E.C.M. toolkit

3.4.1. Building sheet

Having the information available comprising the building data, input to the software relevant sheet was the next step for the James Goold Hall's (Block A) carbon footprint evaluation of the academic year 2004 - 2005. Furthermore, the carbon footprint of the rest of the halls of residence was established.

In this sheet, the software inputs are as follows:

Electricity CO_2 factor (in kg/kWh)	0,43
Gas CO_2 factor (in kg/kWh)	0,19
Electricity cost (in p/kWh)	5,0
Gas cost (in p/kWh)	1,6
Typical practice value for electricity benchmark	54 kWh/m^2
Good practice value for electricity benchmark	45 kWh/m^2
Typical practice value for gas benchmark	240 kWh/m^2
Good practice value for gas benchmark	200 kWh/m^2
Building type	Residential
Gross internal area (in m^2)	Each buildings
Electricity consumption (annual values in kWh)	Each buildings
Percentage of renewable sources	10 %
Gas consumption (annual values in kWh)	Each buildings
Degree days (20-year average value for West Scotland)	2505

Table 3.5: Parameters set in the software

The buildings mentioned above comprise the James Goold Hall (Block A), Birkbeck Court, Chancellors Hall, Forbes Hall, James Young Hall, Thomas Campbell Court, Murray Hall, Garnet Hall and finally James Blyth Court.

The software provides the 20-year average heating degree days for the U.K. as specified for different regions. However, instead of using the data provided for West of Scotland, the actual monthly heating degree days for every year is added in this field to provide a more accurate output (Vesma, 2005).

The University of Strathclyde does not exploit the renewable sources on site. However, the utility company, supplying the University, obtains 10% electricity generated by renewable sources. This in turn is considered in the University carbon footprint having a zero emission factor.

Graphs are provided automatically by the software, once the data is input. A pie chart can be obtained for each year, illustrating the percentage of emission contributions of each building as shown in Chart 3.9. This graph shows that for year 2003, as it was expected, Birkbeck Court accounts for the highest percentage, 33%, followed by James Blyth Court having 31%, the Chancellors Hall with 9% and the Thomas Campbell up to 6%.

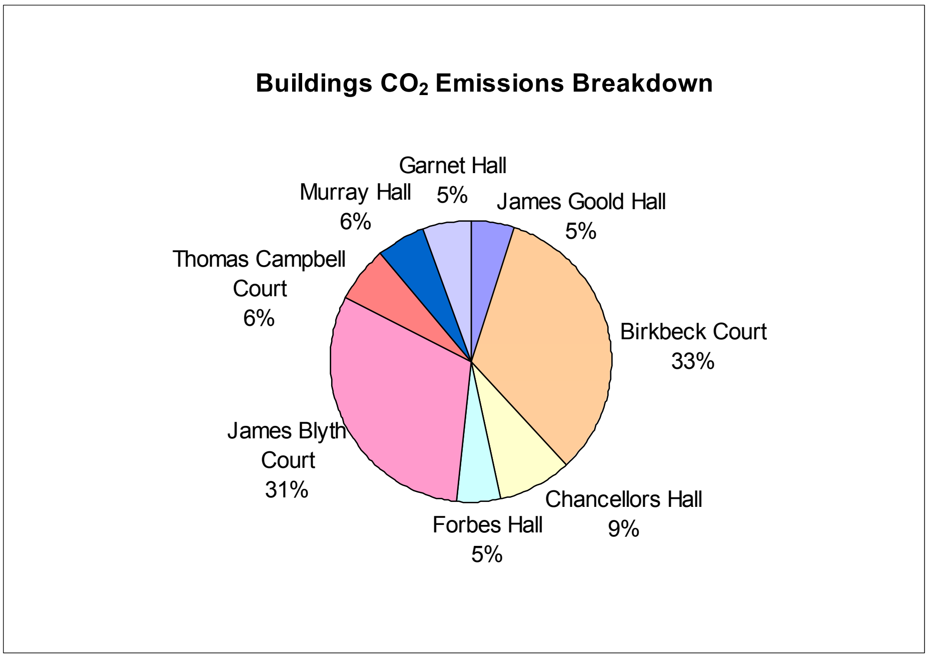


Chart 3.9: Percentage of emission contribution of each building

The graphical illustration of the halls of residence energy consumption and the associated CO_2 emissions are found in Appendix VI.

Chart 3.10 obtained from the software indicates the carbon dioxide emissions that the fossil fuels and the electricity contribute on a yearly basis for all the buildings. It can be identified from the chart that even if the electricity consumptions are less than the ones of the gas, its contribution of CO_2 emissions is higher.

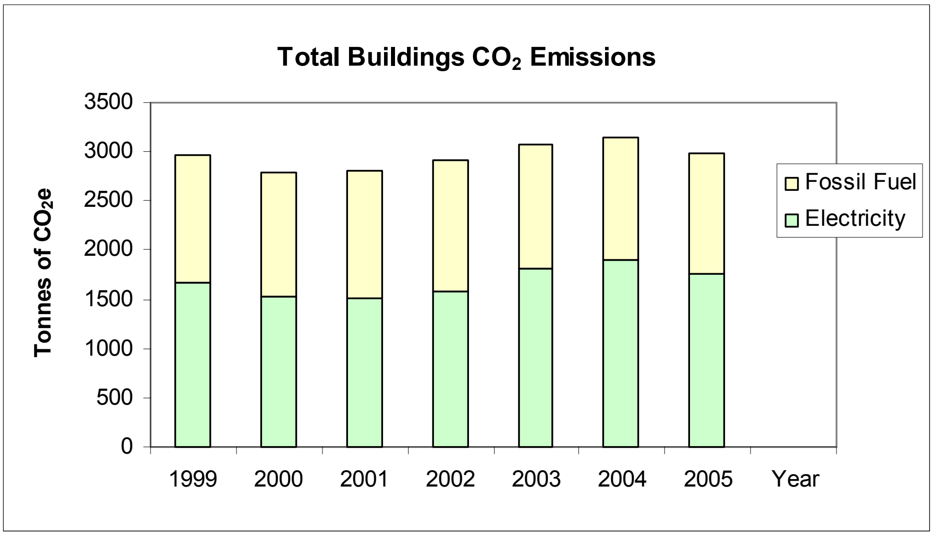


Chart 3.10: Annual CO_2 contribution

Chart 3.11 obtained from the software, regarding the building's envelope emissions, shows the actual buildings CO_2 emissions per student and the target reduction during the years. However, in this case, the scope was the evaluation and not the monitoring of continuous improvement, so a target value was not set. The number of students considered was 1366 (Student Accommodation at University of Strathclyde Handbook, 2004), excluding the residents from the Block B of James Goold Hall. The chart underlines the decrease between the year 1999 - 2000 up to 0,3 tonnes of CO_2, which is followed by a constant state for the next academic year, 2000 - 2001, and finally the linear increase as it reaches the 2,3 tonnes of CO_2 by the year 2003 - 2004.

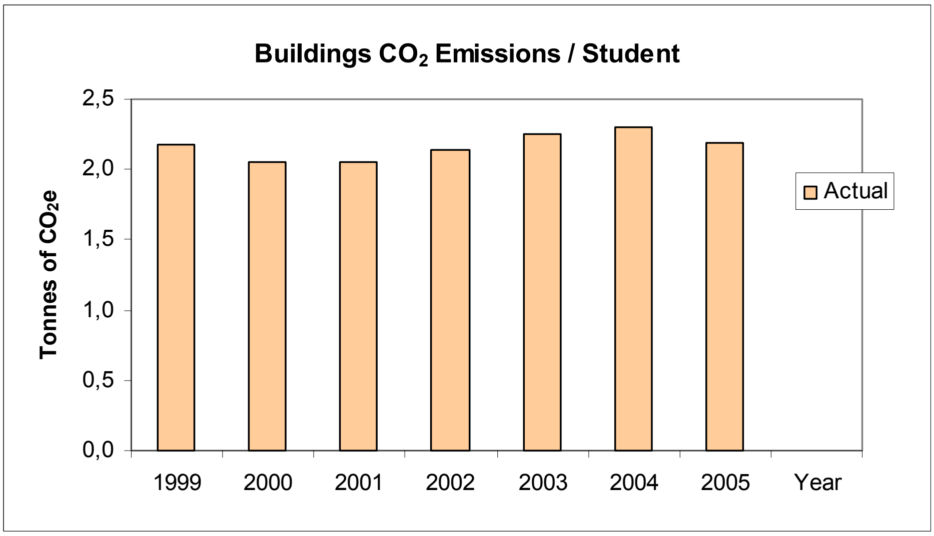


Chart 3.11: Actual buildings CO_2 emissions per student

As far as the gas benchmark is concerned (see Chart 3.12), the annual performance of the halls of residence is illustrated, compared to the residential sector's typical and good practice benchmarks. The red bars show values above typical practice, which is 240 kWh/m^2, while the yellow ones show values which are above good practice being 200 kWh/m^2.

On the two following charts, each column corresponds to a line reading on the legend i.e. or e.g. the first column corresponds to James Goold Hall, the second one to Birkbeck Court, etc.

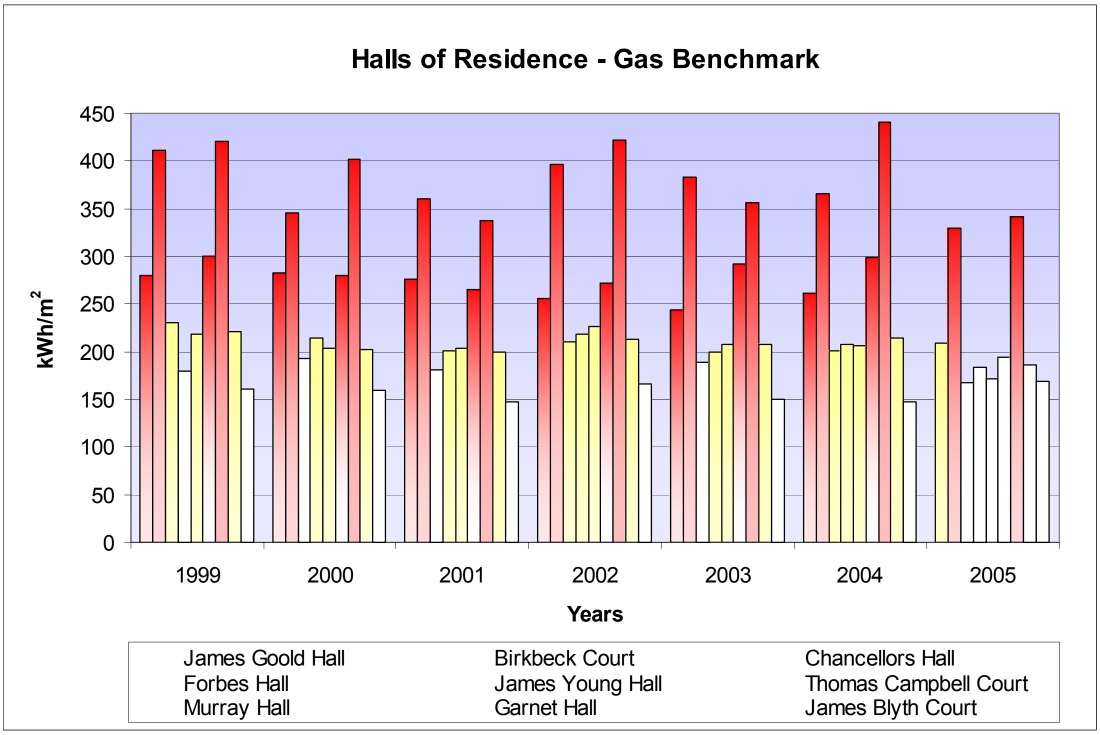


Chart 3.12: Annual halls of residence gas performances

Regarding the gas consumption, Chancellors Hall's performance shows the most frequent fluctuation with values between, below and above the typical ones, while James Blyth Court has a constant good performance for the time period examined. However, four halls of residence, James Goold Hall (Block A), Birkbeck Court, Thomas Campbell Court as well as Murray Hall, according to the chart above, show the worst performance, based on their floor area. These halls of residence, as well as the ones illustrated in yellow, are considered to have the potential for gas consumption reduction. For this reason, an example focused on James Goold Hall (Block A) is conducted, as this is the selected site to be analysed in depth. The cost savings associated with the CO_2 emissions are calculated and illustrated in Charts 3.14 and 3.15.

Considering the electricity benchmark, the red bars show values above the typical practice, which is 54 kWh/m^2, while the yellow ones show values which are above the good practice being 45 kWh/m^2.

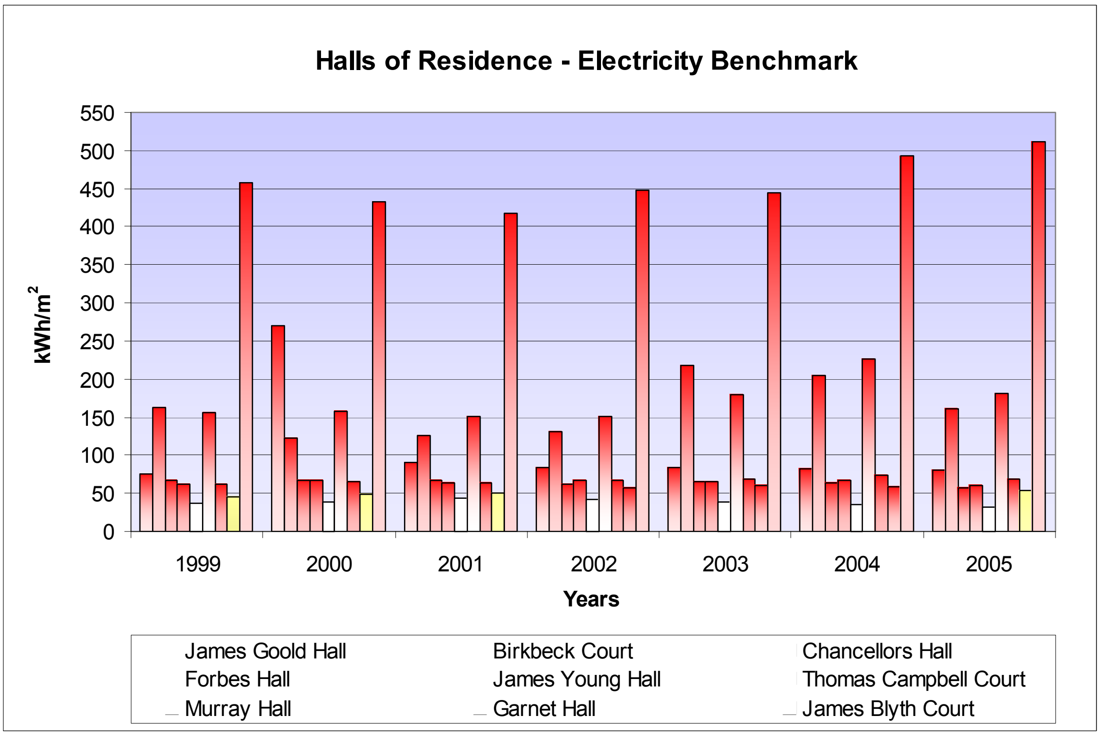


Chart 3.13: Annual halls of residence electricity performance

The electricity benchmarks show that the majority of the buildings consume more than they should. When comparing the gas with the electricity performance, it is obvious that the buildings show a better behaviour to the gas consumptions.

As the software requires the cost per kWh, the calculation of the cost associated with the gas and electricity consumption takes place and the potential cost savings for both cases is estimated. This evaluation is conducted through comparison in kWh per m^2 between the actual consumption per m^2 with the good practice benchmark. The benchmark values for both gas and electricity consumptions can be found in Table 3.5 above. Another reason for the analysis which follows was to identify whether the potential for future reduction is greater in gas or in electricity consumption. However, the overall quantification for all halls of residence can be found in Appendix VII.

Analysis of Chart 3.14 shows that the potential electricity consumption reduction can reach up to 48,27% whereas the potential gas consumption reduction could be up to 23,26%.

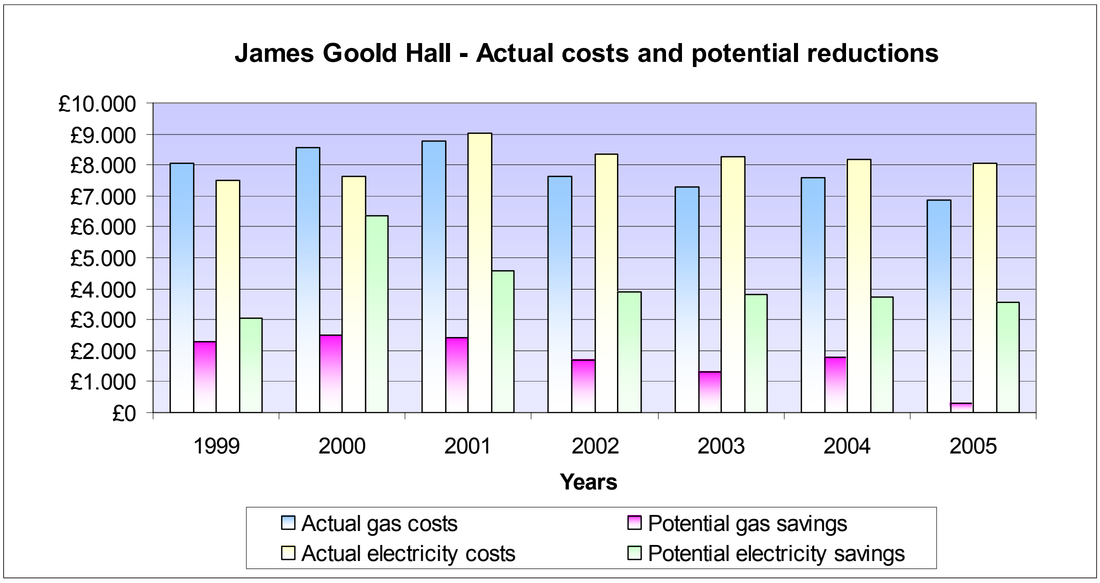


Chart 3.14: Actual associated costs and potential savings

Chart 3.15 arises by interpreting the cost analysis illustrated in Chart 3.14 in CO_2 emissions. Furthermore, in the actual CO_2 emissions associated with the electricity consumption, the 10% is considered to be carbon-free as this is supplied by renewable sources. Moreover, as mentioned above, these costs as well as carbon dioxide potential reductions are plotted against the good practice benchmark and are shown in Chart 3.15.

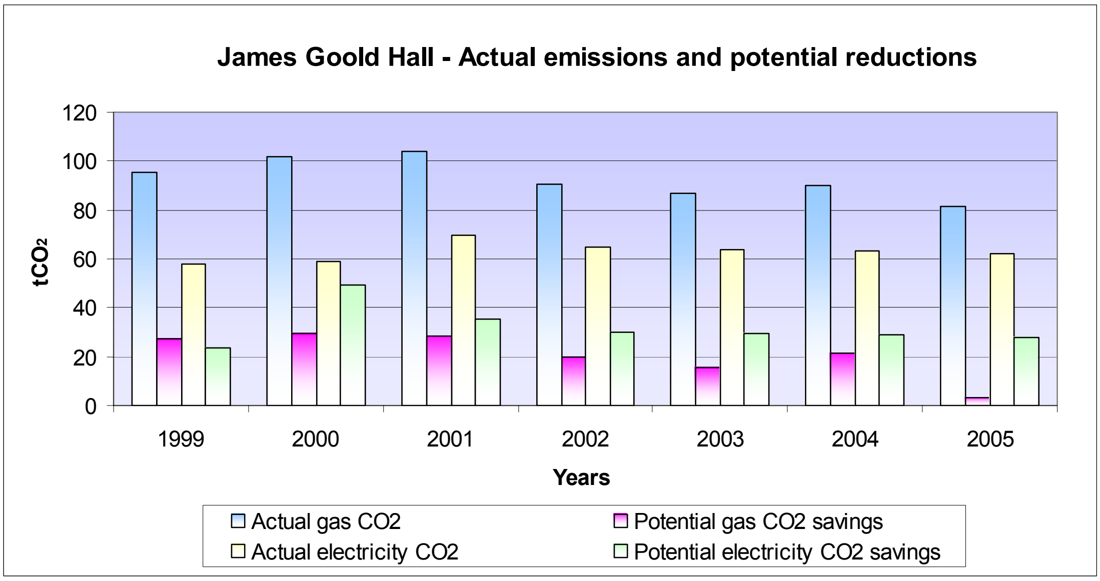


Chart 3.15: Actual associated CO_2 emissions and potential reductions

3.4.2 Transportation sheet

In this sheet, the fields consisted of:

Transport type	Air (long/short flight), Car (Diesel: large/small engine, LPG, Petrol: large/medium/small engine), Rail (or Diesel coach)
Cost/unit (in £/mile)	For all the means of transportation
Amount	Depending on the trip conducted (in miles)
Unit	Mile/Litre/Custom
CO_2 factors (in kg/km)	For all the means of transportation
Transportation group	Fleet/Business
Potential alternative transport type	Air (long/short flight), Car (Diesel: large/small engine, LPG, Petrol: large/medium/small engine, Rail (or Diesel coach)

Table 3.6: Parameters set in the software

The questionnaire was developed and tailored to cover the required sheets fields, for the James Goold Hall carbon footprint estimation, while a completed sample of it and explanations are provided with the use of the following example in Table 3.7.

Trips inside UK

Places visited		One way ticket	Return ticket	Means of transportation	Type of trip
From	To				
Glasgow	Edinburgh		3	Car	P*
Glasgow	London		2	Plane	P
Glasgow	Inverness	1		Bus	C*
Inverness	Glasgow	1		Train	C

** P - personal, C - course related*

Trips outside UK

Places visited		One way ticket	Return ticket	Means of transportation	Type of trip
From	To				
Glasgow	Athens	1		Plane	P
Glasgow	Barcelona		1	Plane	P
Glasgow	Berlin		1	Plane	P
Glasgow	Belfast		1	Car	C

Table 3.7: Example of the first completed part of the questionnaire

The trips were divided in two categories the local ones, comprising the trips within the UK, and the international ones. The students were also asked to include the trips that will be conducted until the end of September 2005.

The mileage between the departure and the arrival destination for the trips done using aeroplanes was estimated using the Expedia Travel website (Expedia, 2005). Moreover, for the car, bus, train trips and walk/bike journeys, the distances were interpreted in miles with the help of Maporama website (Maporama, 2005). In the former case, for the trip from Glasgow to London (by plane), the departure and arrival destinations were added in the relevant fields of the webpage and then the most economic trip was chosen (considering one way ticket), where all the distances were provided in miles and km, e.g. 344,87 miles or 555 km. However, consistency of the data was considered and thus all the distances were chosen to be used only in miles (1 mile = 1,6093 km). In the latter case, for the trip conducted from Glasgow to Edinburgh (by car), the distance was estimated by Maporama, where the departure and arrival destinations were added in the relevant fields, and the distance was displayed in km (the software takes always into account one way trips). The results were then interpreted in miles e.g. 30,69 miles. The same process was followed for the other means of transportation comprising the car and the bus. However, once again, these distances were also interpreted in miles.

This is because the basic formulae in the spreadsheets use miles and in the interest of reducing possible calculation errors, it was decided to use miles as a basis across the board.

However, even if the means of transportation were provided as options, the students did not know the exact type of fuel consumed by each means of transportation, and were completing only the basic type of transportation. As a result, according to the National Statistics' (DfT, 2004), the diesel to petrol car proportion is 1:4,32. Thus, for the 54 trips that took place by car, 12 of them were considered to use diesel (small engine) and the rest petrol cars (small engine), while for the alternative transport type option, 41 out of 177 were considered to use diesel.

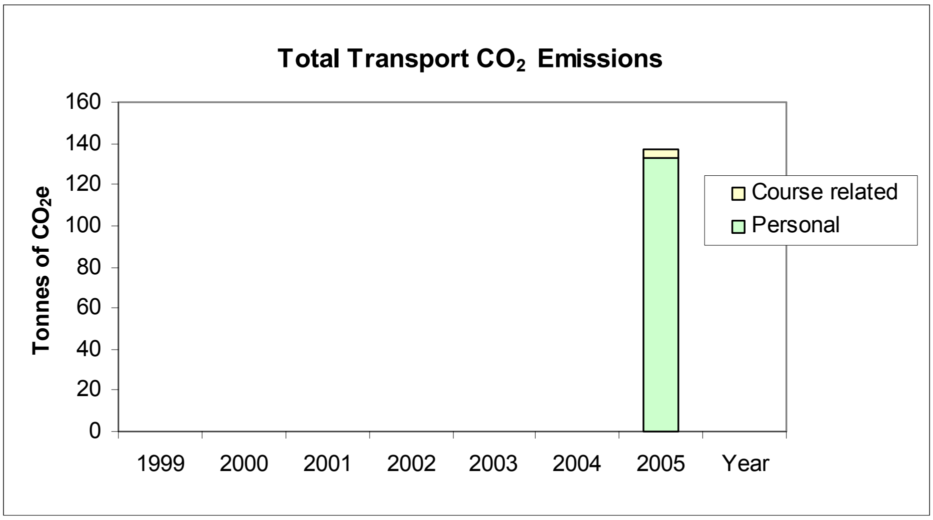
For the cost per unit estimation, one example of each category is carried out. The software separates the long from short flights underlying that the long ones are more than 500 km while the short ones less than 500 km. Consequently, the flight from Glasgow to London was considered a long flight (555 km, 344,87 miles), whereas the flight from London to Liverpool was considered to be a short one (270 km, 167,77 miles). By working out these two examples using Expedia, it was found that the long flights cost per unit is £0,13 per mile, having a single ticket value of £43,80. As far as the short flight is concerned, the cost is estimated to be £0,26 per mile, with single ticket value of £43,40. As far as the train and bus are concerned, the software does not separate them, not giving therefore the option of having different costs per unit. Therefore, an example conducted with the National Rail Enquiries website (National Rail Enquiries, 2005), departing from Glasgow and arriving at Leeds (323,6 km, 201,08 miles, single ticket), shows that the cost for this trip is £0,08 per mile. Moreover, the cost per unit for trips conducted by car was provided by the software.

The total amount of miles travelled was estimated using the number of trips conducted. That is to say, the Glasgow to London distance (by plane) considering one way ticket is 344,87 miles. Having conducted this trip 2 times return, as mentioned in the example, the total mileage is calculated to be 4 x 344,87 = 1.379,48 miles. The same procedure was followed for the rest of the means of transportation.

The CO_2 factors for all the types of transportation were provided by the software. However, these are in kg/km and during the calculation of the actual CO_2 emissions their conversion in kg/miles takes place.

As far as the transportation group fields are concerned, and as the questionnaire was initially tailored to cover the software's demands, these were altered in personal (P), or course (C) related trips.

The transportation sheet, providing the graphs and as data do not exist for previous years, showed:



Note: Data does not exist for previous academic years.

Chart 3.16: Associated CO_2 emissions resulting from personal and course related trips.

Chart 3.17 shows the percentage that each means of transportation was used during the academic year 2004 - 2005, while this chart is feasible to be obtained for any year.

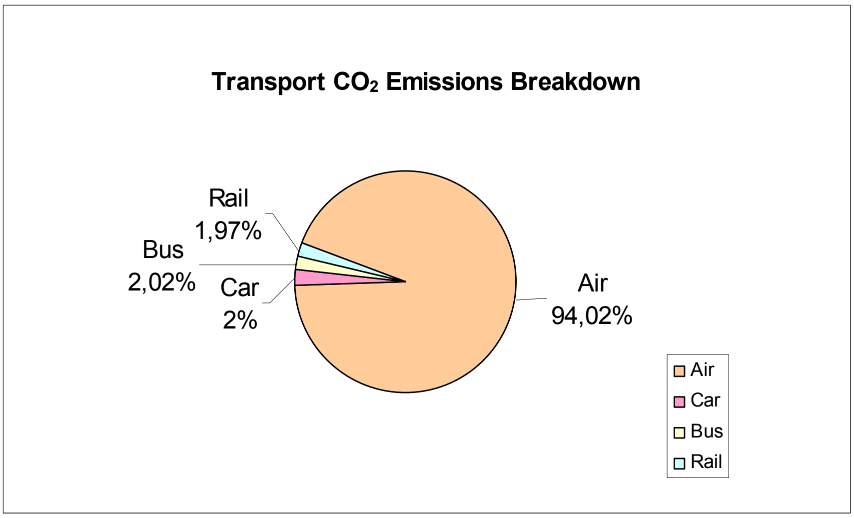
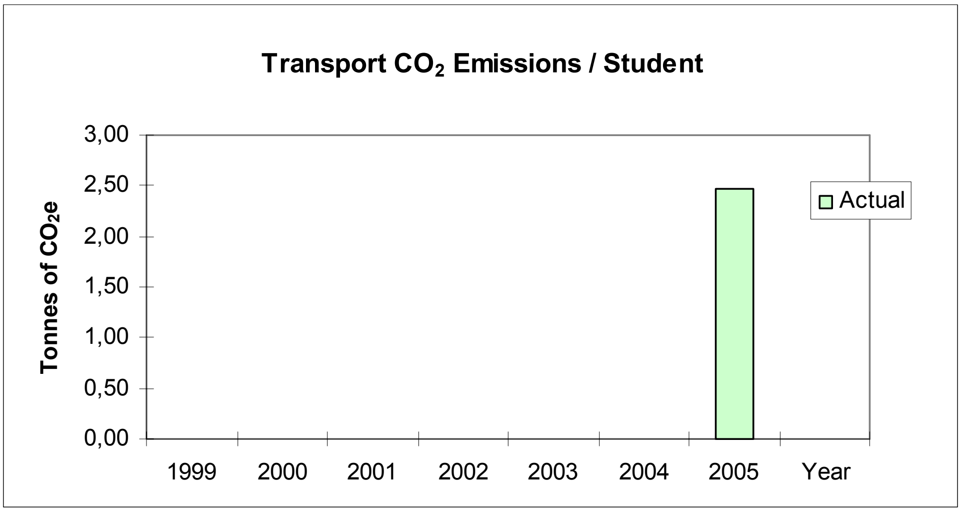


Chart 3.17: Percentage of use of each mean of transportation

Chart 3.18 from the transportation sheet shows the CO_2 emissions per student and the target reduction. However, data exists only for the year 2005 and the target value was not set. The number of students considered in the transport sheet was 55, as this was the number of the questionnaires gathered.



Note: Data does not exist for previous academic years.

Chart 3.18: Associated CO_2 emissions per student

Nevertheless, further analysis was conducted. Chart 3.19 below shows the reasons for the trips conducted the academic year 2004 - 2005 by the residents of the James Goold Hall (Block A).

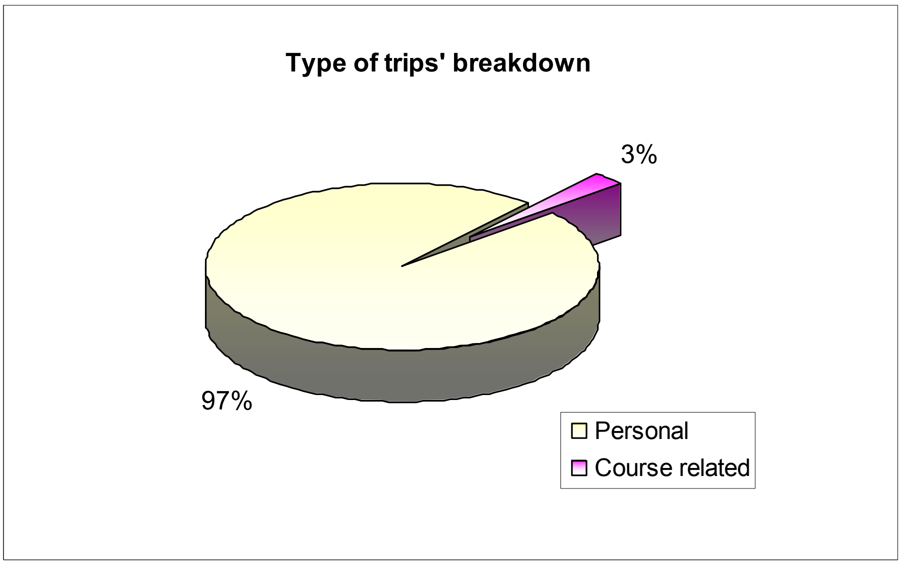


Chart 3.19: Breakdown of trips type for the academic year 2004 - 2005

As the University comprises a high percentage of international students, the pie chart following shows that while the air travel accounts for 94,02% (as shown in Chart 3.20) among the rest of the means of transportation, the long flights account for 99% of the total. An important point is that 89% of James Goold Hall are international students. This percentage may differ from hall to hall, thus, when comparing carbon footprints and taking into account transportation this should be considered. During this thesis it was impossible to ascertain the percentage of international students for each hall due to the Data Protection Act constraints.

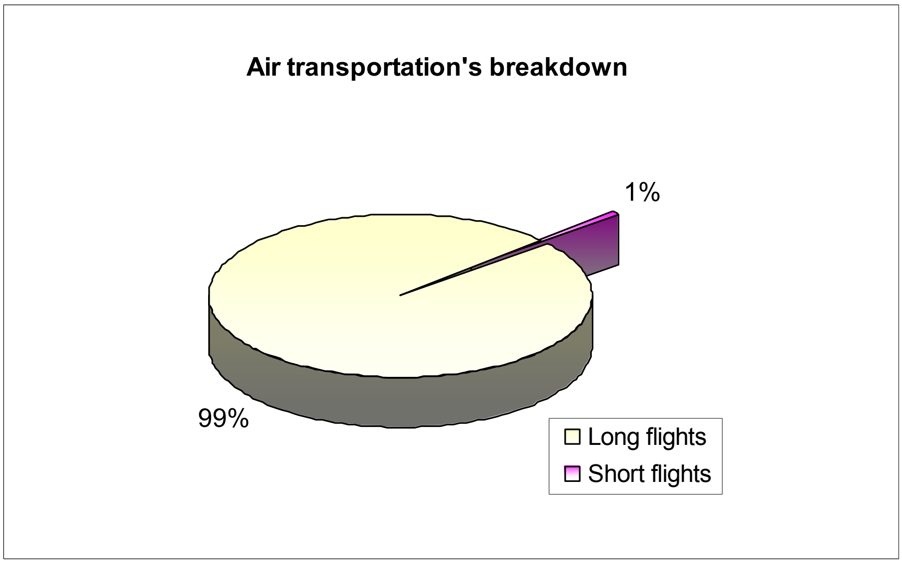


Chart 3.20: Breakdown of air transportation for the academic year 2004 - 2005

3.4.3 Commuting sheet

In this sheet, the fields consist of:

Transport category	Bus (Diesel), Car (Diesel: large/small engine, LPG, Petrol: large/medium/small engine), Motorbike, Rail, Walk/Bike
CO_2 factors (in kg/km)	For all the transportation categories
Number of passengers per car	If used

Table 3.8: Parameters set in the software

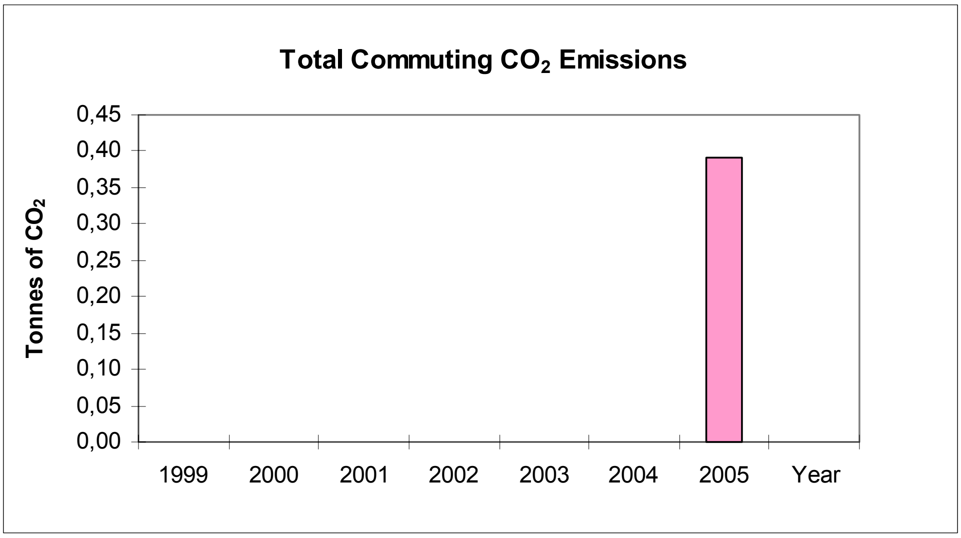
The second part of the questionnaire was developed to gather data for the commuting sheet. A worked example is provided below to describe the process.

Places visited		Means of transportation	Distance in miles	Duration in weeks	Days per week
From	To				
James Goold Hall	University	Walk	0,0932	42	5
James Goold Hall	SECC	Rail	2,11	1	5
James Goold Hall	Southern General Hospital	Bus	5,9	1	4

Table 3.9: Example of the second completed part of the questionnaire

Once again, the commuting distances' were estimated using the Maporama website, following the same process as in the transport sheet. An average value was considered for the commuting from the James Goold Hall to the University, including not only the commuting for attending classes but also the daily commuting from the hall to the library, while the duration in weeks taken into consideration the academic year 2004 - 2005. As the students stay on campus, their commuting is insignificant because it is conducted either by foot or bike, having a zero carbon dioxide factor. However, this was not omitted due to the requirement of a detailed output. The graphs provided from the software have as follows.

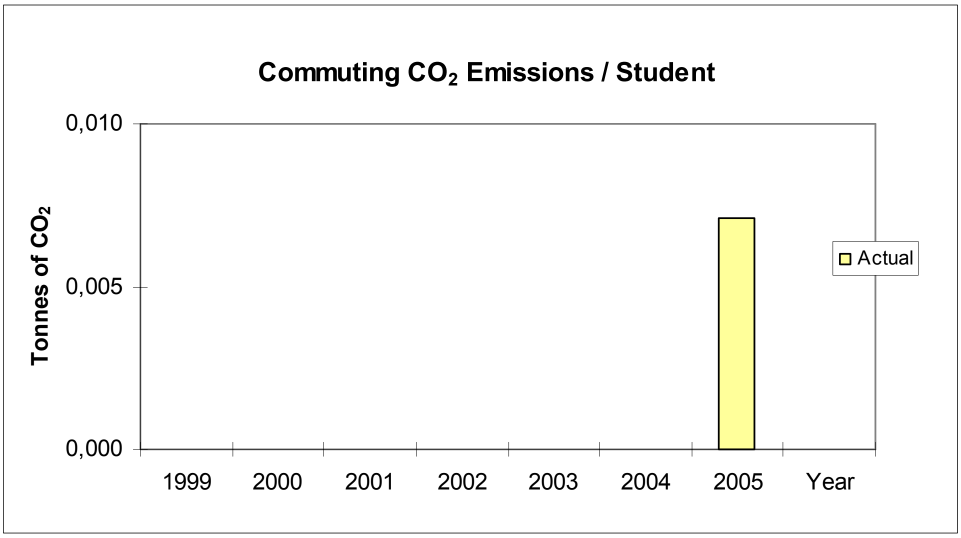
For the academic year 2004 - 2005, the students' commuting is estimated associated with the resulting CO_2 emissions in Chart 3.21.



Note: Data does not exist for previous academic years.

Chart 3.21: Associated CO_2 emissions resulting from commuting

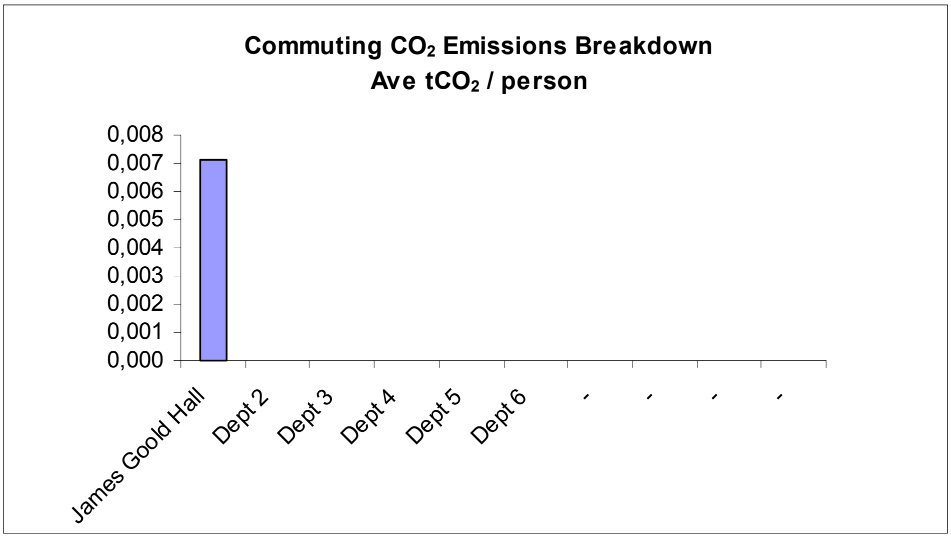
Chart 3.22 can also provide the target values however, in this case, these were not used. The number of students taken into consideration was 55, related to the questionnaires gathered.



Note: Data does not exist for previous academic years.

Chart 3.22: Associated CO_2 emissions per student for the academic year 2004 - 2005

The emissions per person, illustrated in Chart 3.23, can assist in setting each building's targets for future carbon dioxide reduction.



Note: Data does not exist for other departments.

Chart 3.23: Estimated average tCO_2 per person per University building

3.4.4 Summary sheet

Finally, the software summary sheet provides two graphs, one of which illustrates the total CO_2 emissions per academic year for all the buildings under survey. However, this could not be obtained in its entirety, as the transportation and commuting estimation were conducted only for the site chosen and for the academic year 2004 - 2005.

The second graph is provided combining all the emissions resulting from the building, the transport and the commuting which represents the carbon dioxide emissions per student and the target values for the carbon dioxide reduction. Once more, as target values have not been set this chart could not be obtained.

In conclusion, by assessing all the sources emitting carbon dioxide, the establishment of the carbon footprint of the Block A of the hall for the year 2004 - 2005 has as follows.

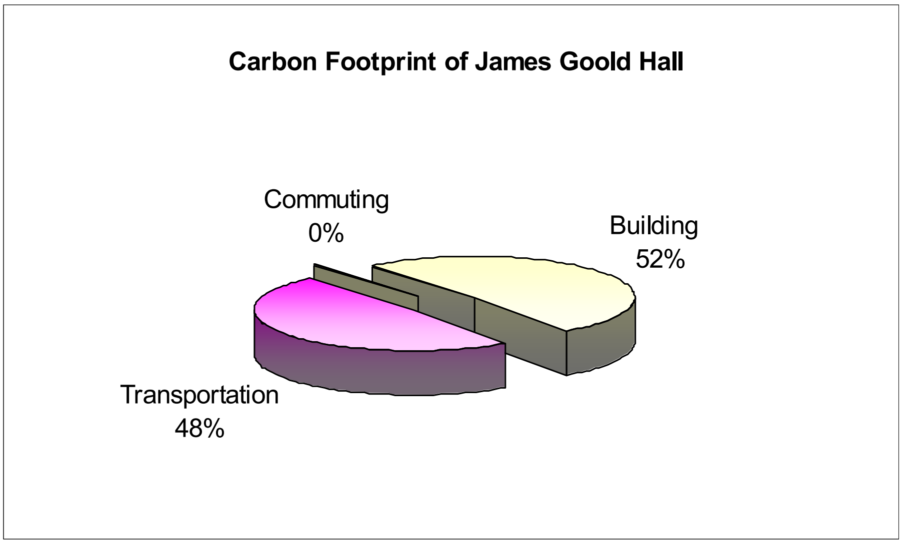


Chart 3.24: James Goold Hall carbon footprint for the academic year 2004 - 2005

Considering the contribution per student on the carbon footprint, it was found that each person has been responsible for 5,07 tonnes of CO_2 for the academic year 2004 - 2005, corresponding to 2,61 tCO_2 resulting from buildings, 2,46 tCO_2 from transportation and 0,00711 tCO_2 from commuting.

As the contribution to the carbon footprint of the hall of the emissions due to transportation, corresponds to 135 tonnes of CO_2 emissions, is approximately as high as the buildings one, corresponding to 144 tonnes of CO_2 emissions, a sensitivity analysis was conducted, which follows.

The last section of the questionnaire was developed to estimate the environmental awareness of the students analysed in the Paragraph 3.6 of this report.

3.5 Sensitivity analysis

By conducting a sensitivity analysis on the carbon footprint of the James Goold Hall (Block A), it becomes easy to identify how selected variables influence it (Lightfoot and Tsenddavaa, 1997). The trips conducted were divided in two categories, considering the national and international ones. As mentioned earlier, the transportation emissions are responsible for 48% of the total James Goold Hall carbon footprint. Chart 3.25 below illustrates the contribution of the national and international journeys on this percentage.

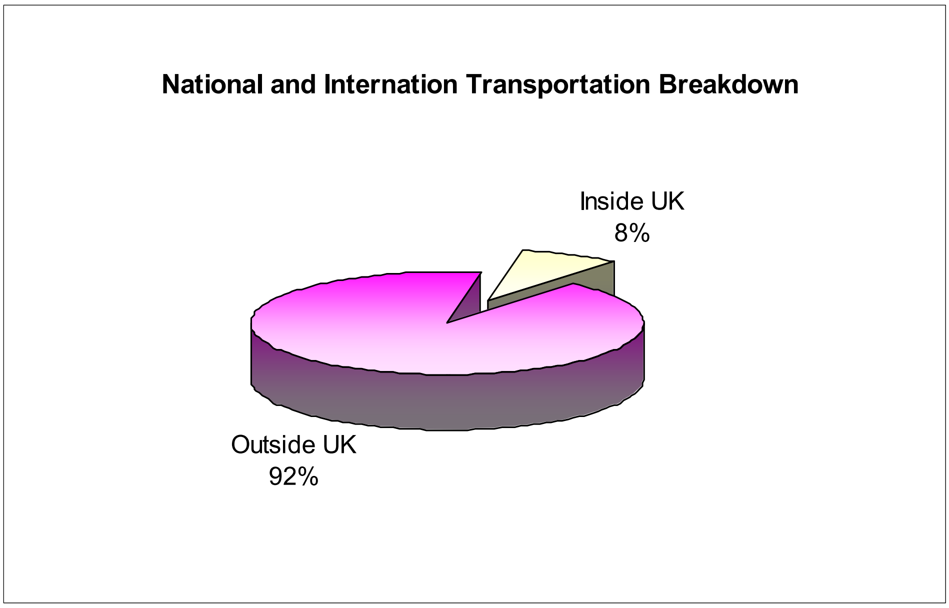


Chart 3.25: Breakdown contribution of trips on carbon footprint

Comparison took place between the carbon footprint calculated for the actual means of transportation used and the resultant carbon footprints arising from the assumptions that all the journeys were fully conducted by either buses/trains, diesel cars or petrol cars.

3.5.1 Case I

If the actual means of transportation of the national trips were fully replaced by buses or trains, there would be cost savings of 33,69% whereas as far as the CO_2 emissions is concerned, reduction would reach 27,25%, as shown in Chart 3.26.

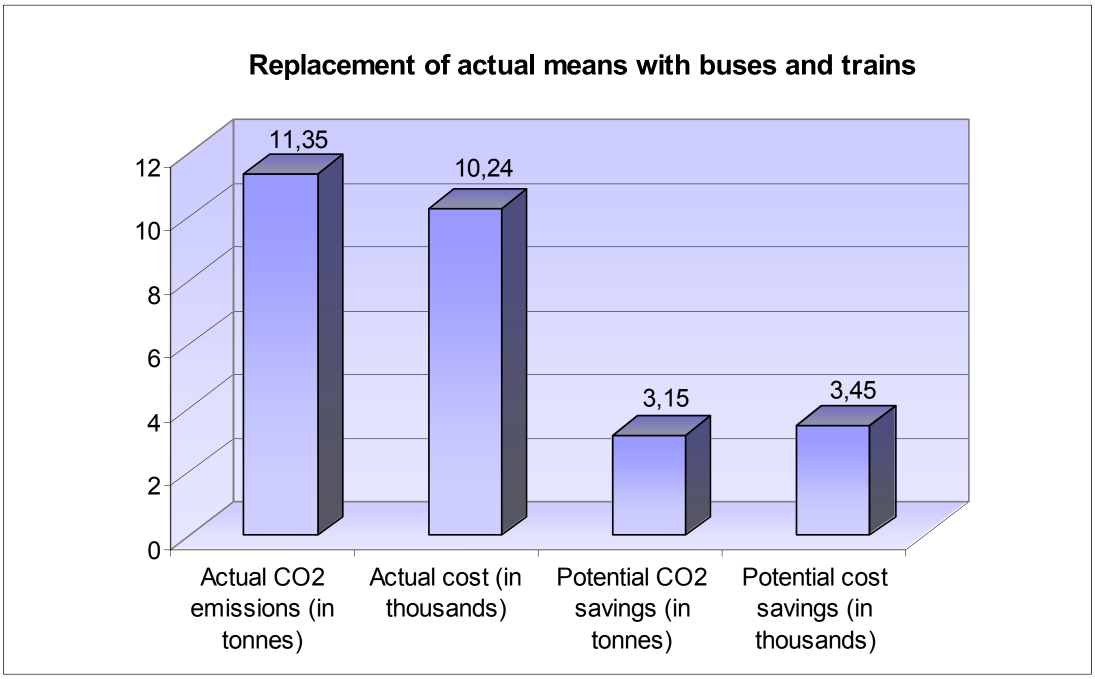


Chart 3.26: Replacement of the actual means of transportation used by buses/trains for the national trips

However, the initial carbon footprint would not change.

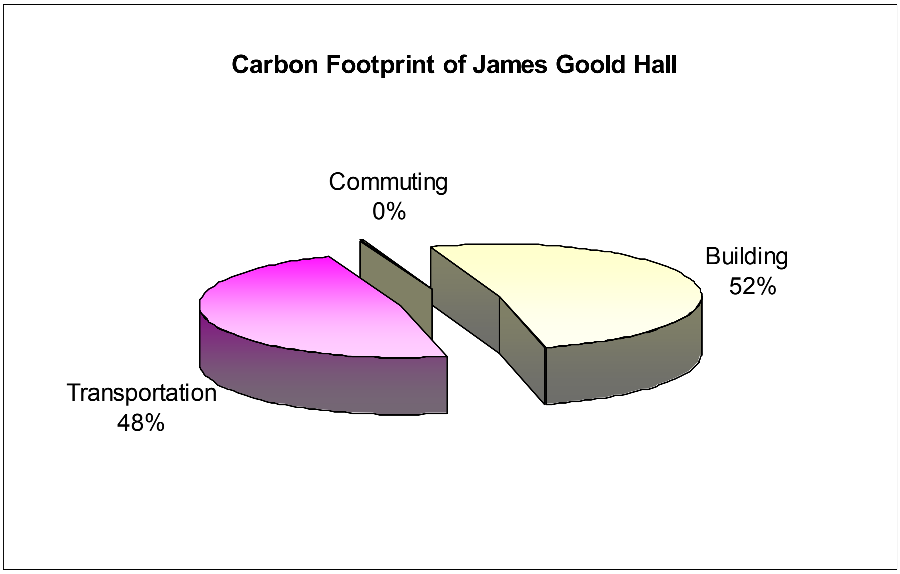


Chart 3.27: Resulting carbon footprint

3.5.2 Case II

The second scenario considers the possibility that the actual means of transportation of the national trips, were fully replaced by diesel cars. This assumption would raise the costs approximately 150% while the CO_2 emissions would increase by 45%, as shown in Chart 3.28.

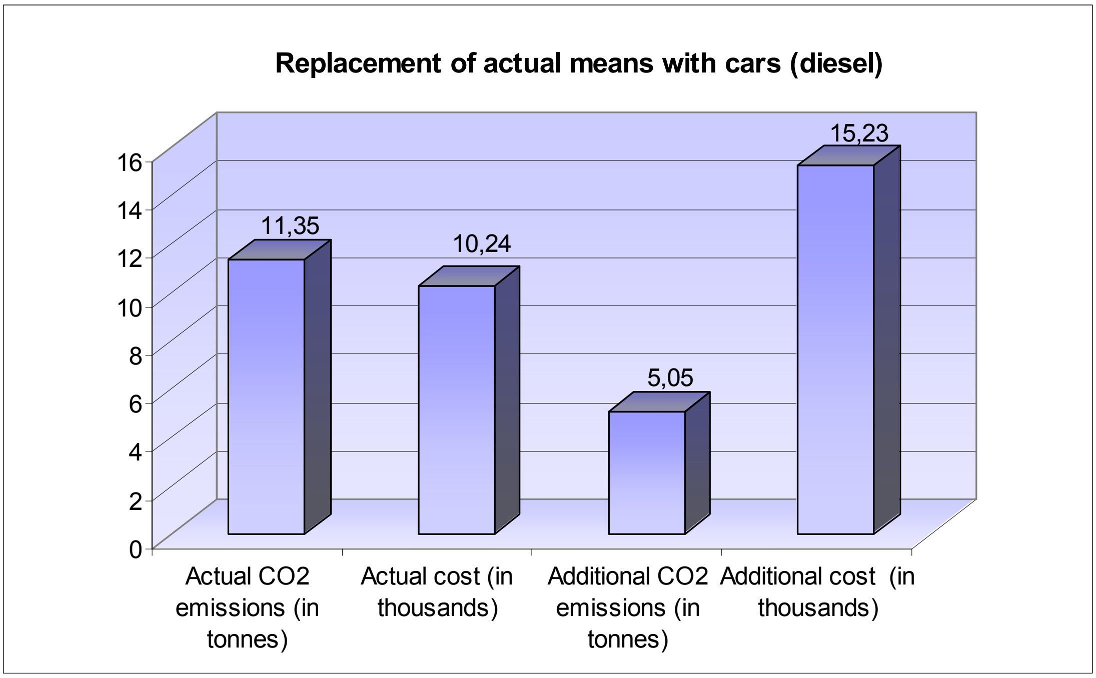


Chart 3.28: Replacement of the actual means of transportation used by diesel cars for the national trips

The resulting carbon footprint would be as illustrated in Chart 3.29.

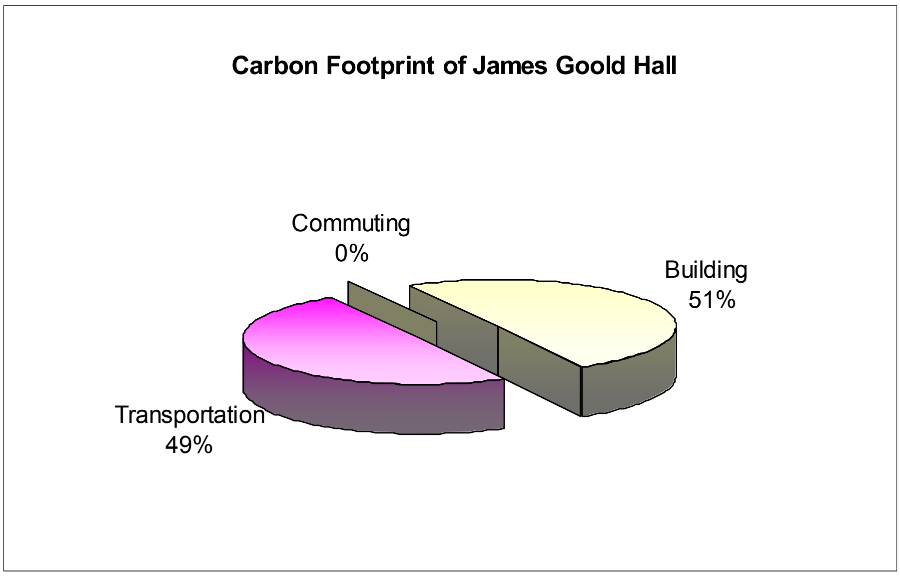


Chart 3.29: Resulting carbon footprint

3.5.3 Case III

The third case assumes that all the national trips took place by petrol cars. Results show that in this case CO_2 emissions would increase by 200% whereas only a 1,48% cost increase is noticed, as shown in Chart 3.30.

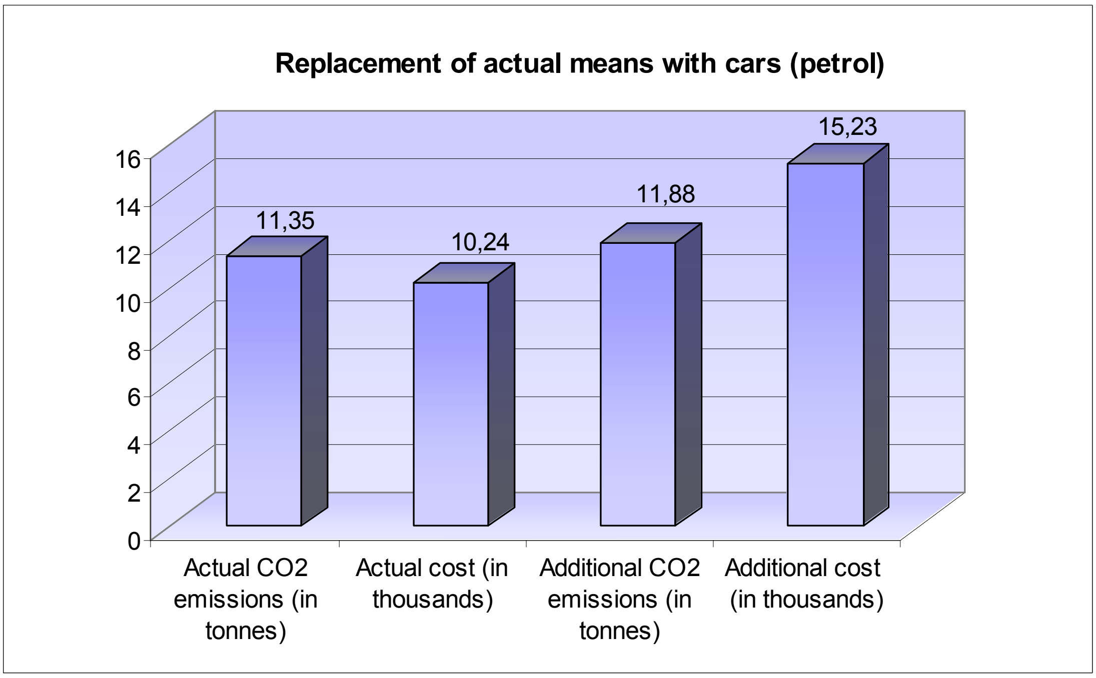


Chart 3.30: Replacement of the actual means of transportation used by petrol cars for the national trips

The subsequent carbon footprint would undertake a change as shown in Chart 3.31.

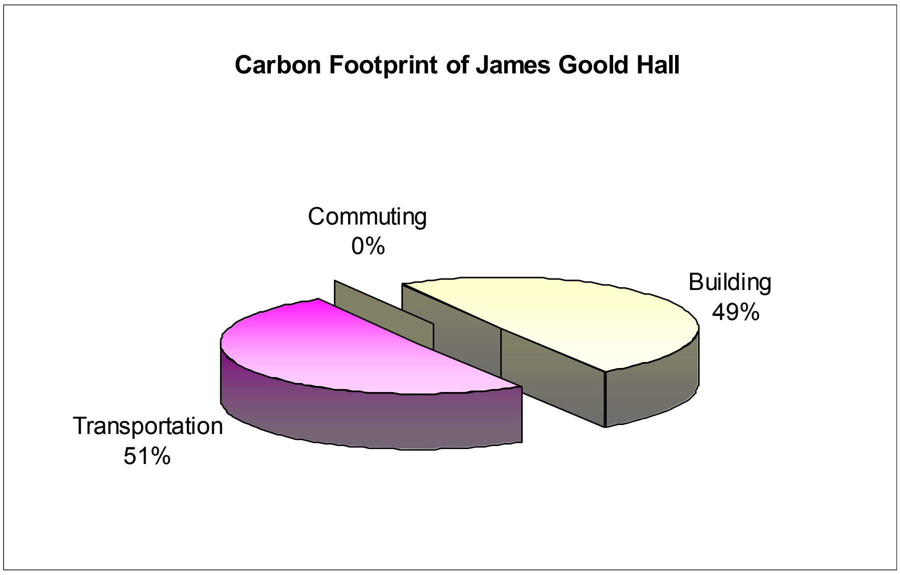


Chart 3.31: Resulting carbon footprint

By comparing the three scenarios above, it was found that the carbon footprint of the James Goold Hall (Block A), as far as this academic year is concerned, is sensitive to the third case's parameters regarding the CO_2 emissions and the costs. This can be realised due to the biggest difference that the carbon footprint showed in this case among the rest of the scenarios studied. Furthermore, a positive output could result only by the first scenario's assumption, that is to say, the trips fully conducted by buses/trains as this can decrease both the costs and the CO_2 emissions. This can be explained due to the lowest CO_2 factor and cost per mile that the bus/train option has, comparing to the rest means of transportation examined. However, the overall James Goold Hall carbon footprint would remain the same.

Following the investigation of the three scenarios examined earlier, the final part of this sensitivity analysis examines the correlation of the mileage reduction with the estimated carbon footprint arising from the transportation parameter.

The first alteration to the carbon footprint was observed when trips up to 43.902 miles were ignored, representing the 5,6% of the total miles conducted and 7,7 tonnes of CO_2. The resulting carbon footprint is shown in Chart 3.32 below. As it can be observed when reducing mileage by 5,6% the contribution of the transportation to the carbon footprint drops from 48% to 47%.

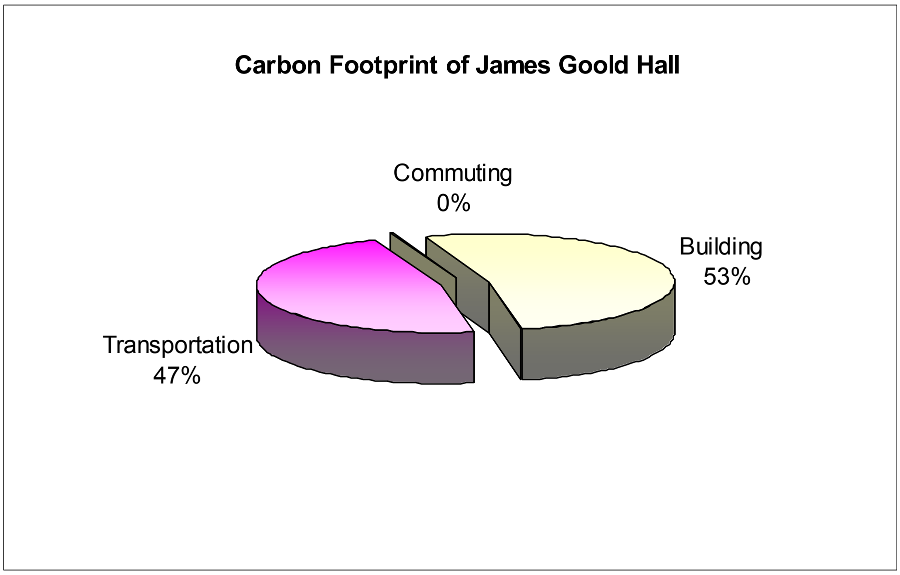


Chart 3.32: Resulting carbon footprint

When reducing the total mileage by 61.883,7 miles (corresponding to 7,9% of the total miles conducted) another 1% reduction in the transportation contribution determined as illustrated in Chart 3.33. This reduction corresponds to a 10,9 tonnes of CO_2 emissions reduction.

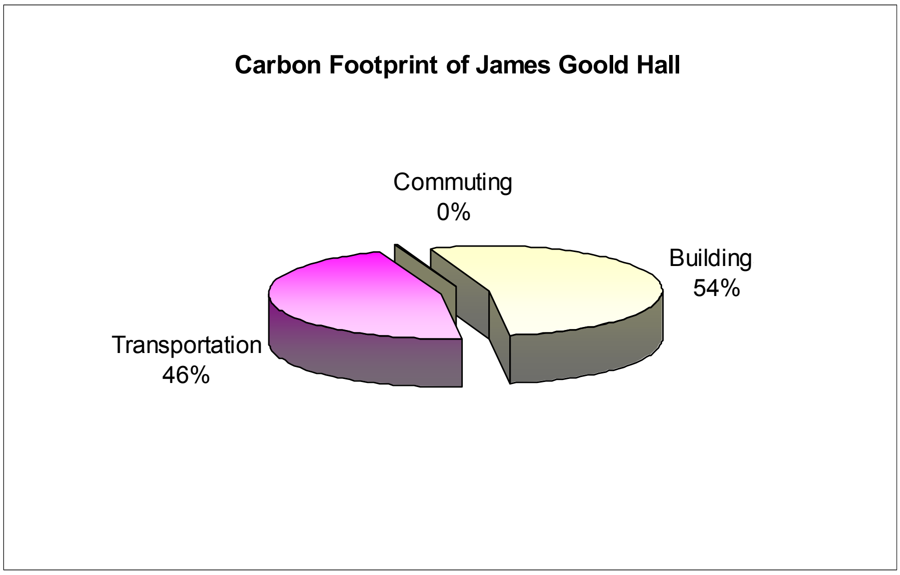


Chart 3.33: Resulting carbon footprint

A further reduction of 1% of the transportation contribution in the total carbon footprint estimation arises from a mileage reduction of 88.819,8, illustrated in Chart 3.34, representing the 11,3% of the total mileage. 15,6 tonnes of CO_2 emissions are calculated to be avoided by this assumption.

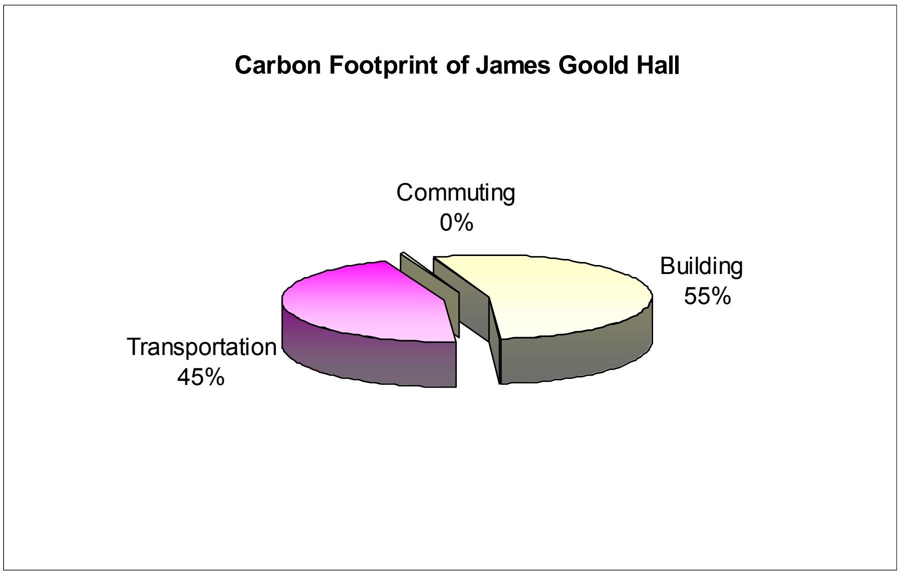


Chart 3.34: Resulting carbon footprint

Furthermore, when the 20% of the total miles travelled were ignored, that is to say 156.921,1 miles, corresponding to 27,3 tonnes of CO_2, the consequential carbon footprint is illustrated in Chart 3.35.

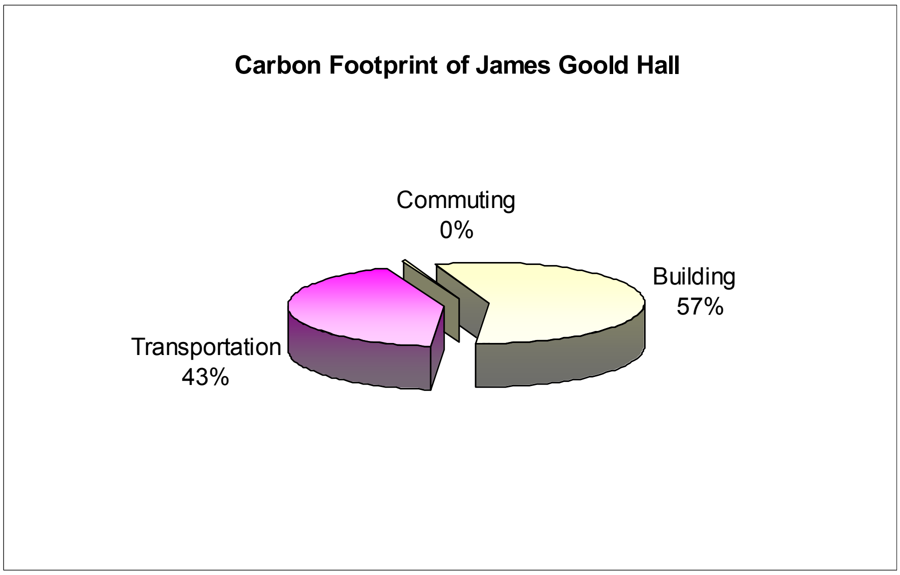


Chart 3.35: Resulting carbon footprint

Considering the examination of the above scenarios, it can be realised that there is no need for a detailed analysis on the trips conducted during the academic years. False trip description or even faulty estimation of the journey mileage will not result in a dramatic reduction or increase of the transportation contribution to the total carbon footprint.

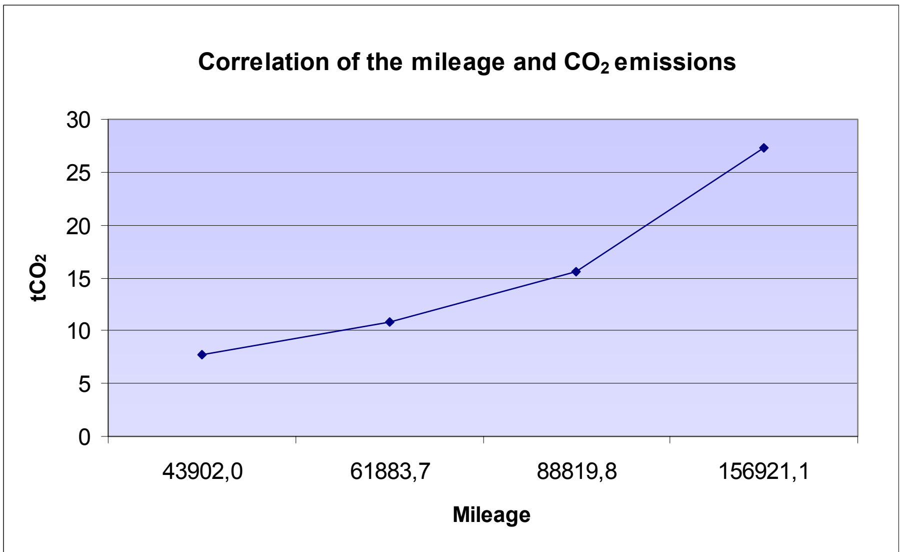


Chart 3.36: Correlation between the mileage and the CO_2 emissions

3.6 Remaining halls of residence carbon footprints

As far as the rest halls of residence carbon footprint are concerned, the software has provided the CO_2 emissions released by the buildings energy consumption. However, the transportation and the commuting of the residences were estimated taking into account the tonnes of CO_2/student value which was a factor resulting from the James Goold Hall transportation contribution as, according to the sensitivity analysis conducted, the transportation contribution would result in a low deviation. That is to say, for the transportation the factor corresponds to 2,46 tonnes of CO_2 per student and for the commuting one 0,00711 tonnes of CO_2. The carbon footprints are illustrated below.

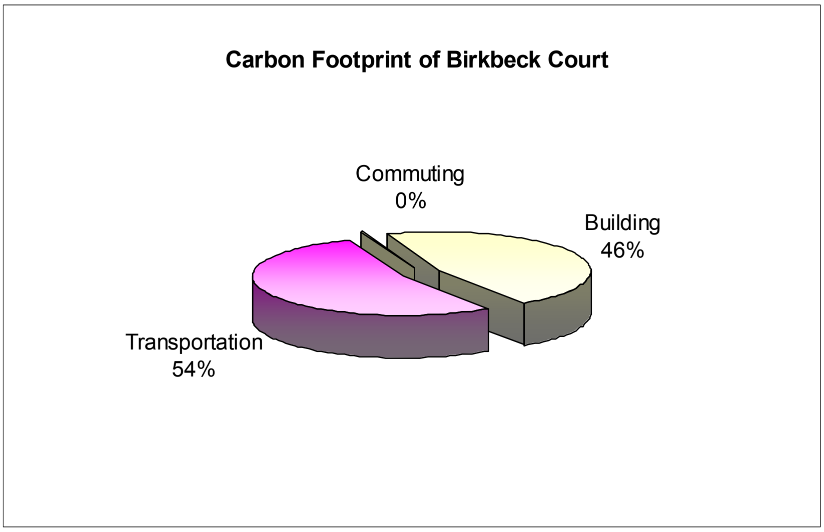


Chart 3.37: Birkbeck Court carbon footprint

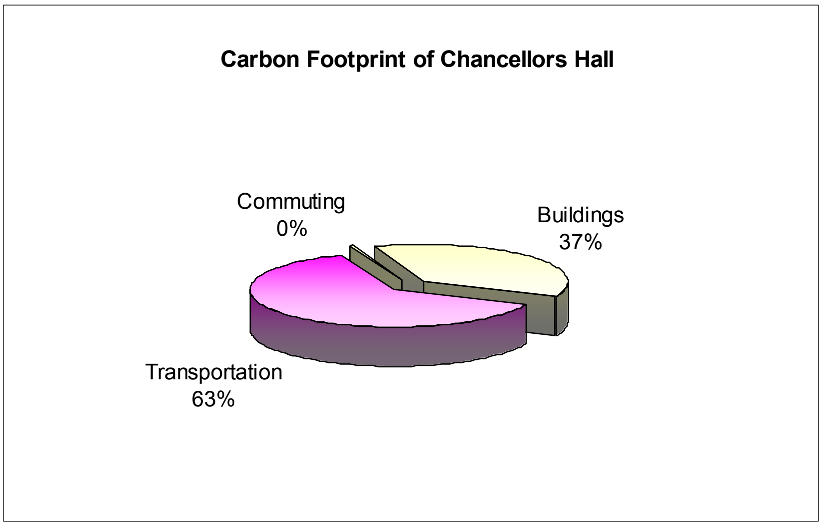


Chart 3.38: Chancellor Hall carbon footprint

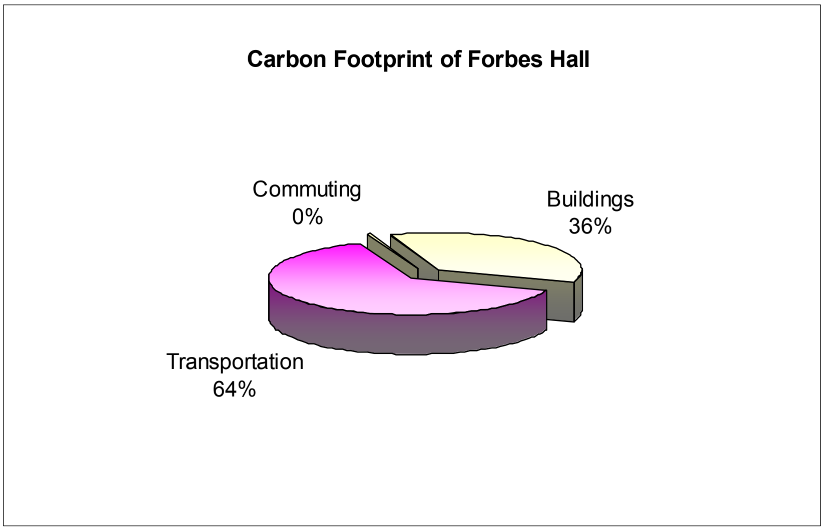


Chart 3.39: Forbes Hall carbon footprint

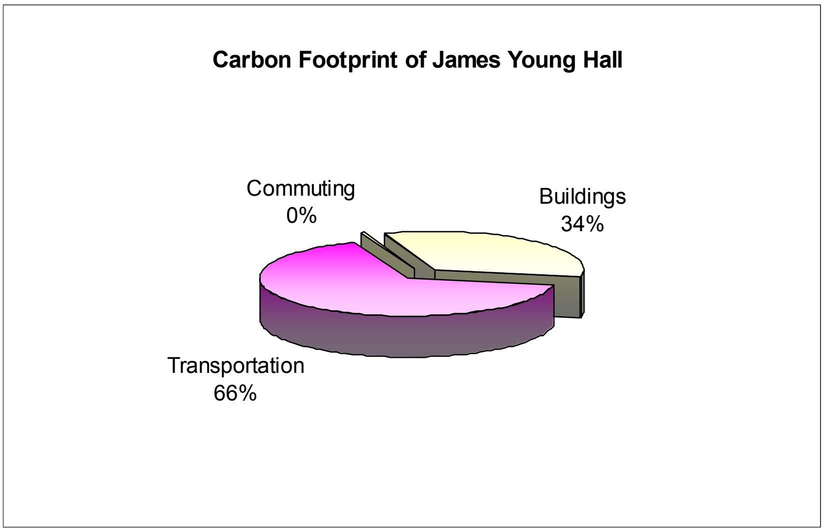


Chart 3.40: James Young Hall carbon footprint

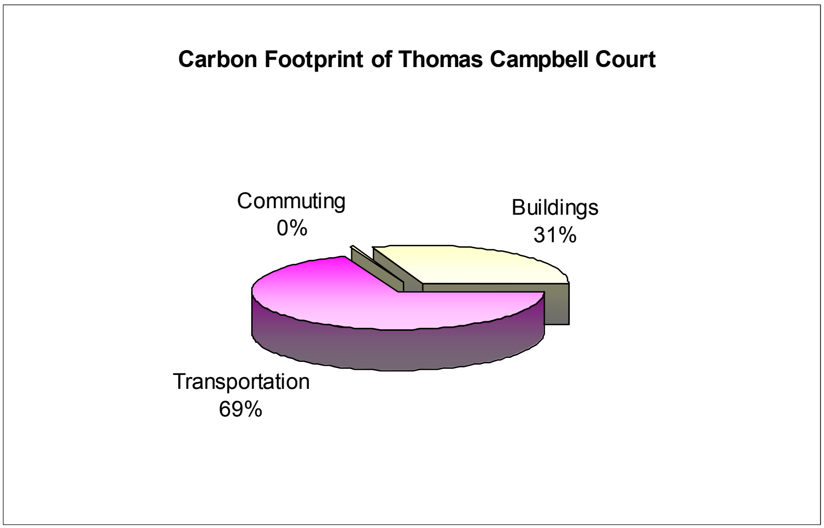


Chart 3.41: Thomas Campbell Court carbon footprint

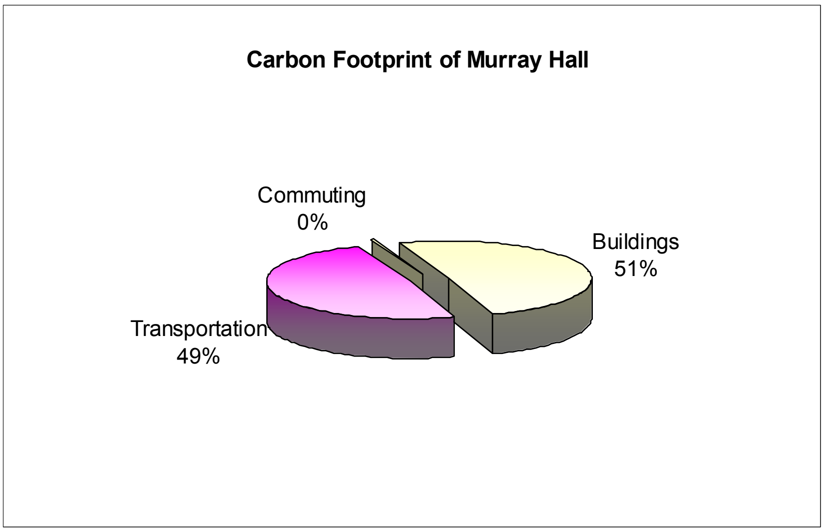


Chart 3.42: Murray Hall carbon footprint

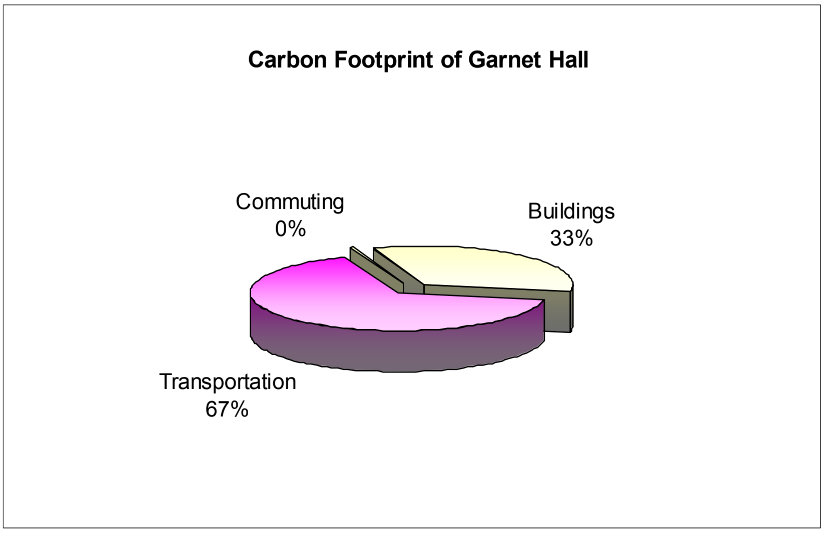


Chart 3.43: Garnet Hall carbon footprint

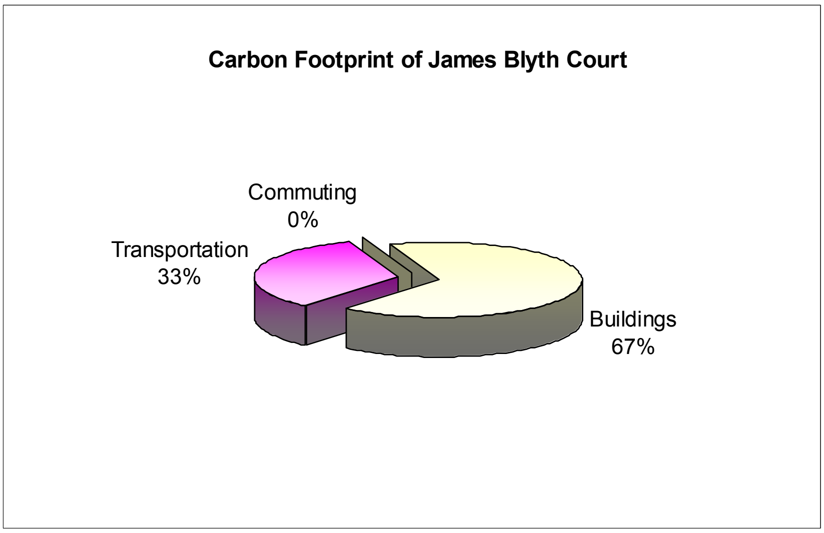


Chart 3.44: James Blyth Court carbon footprint

3.7 Environmental awareness estimation

The third part of the questionnaire included a set of questions trying to focus on peoples knowledge and interest to improve their lifestyle and support the activities related to environmental issues. The questions can be found in the Appendix I and the results are as follows.

The first question identifies the level to which students are informed or express an interest about recycling (see Chart 3.45), asking whether the occupants know the location of the recycling bins around the University.

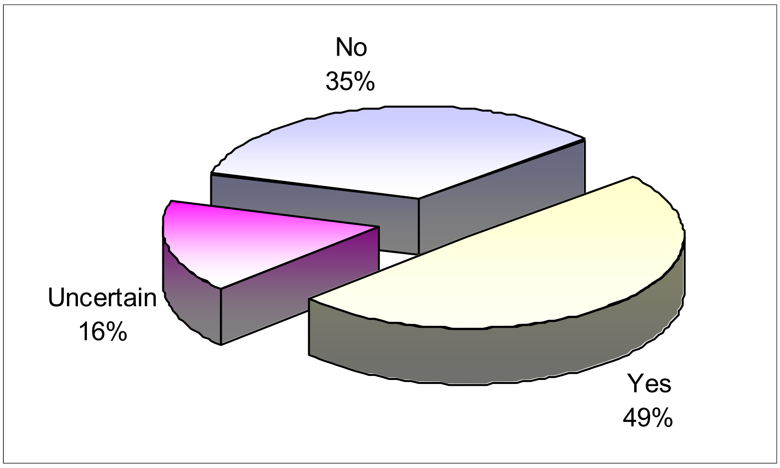


Chart 3.45: Student interest evaluation about the recycling bins location

The second question examines the degree at which students adopt sustainable ways in their lifestyle, requiring whether the students support the recycling.

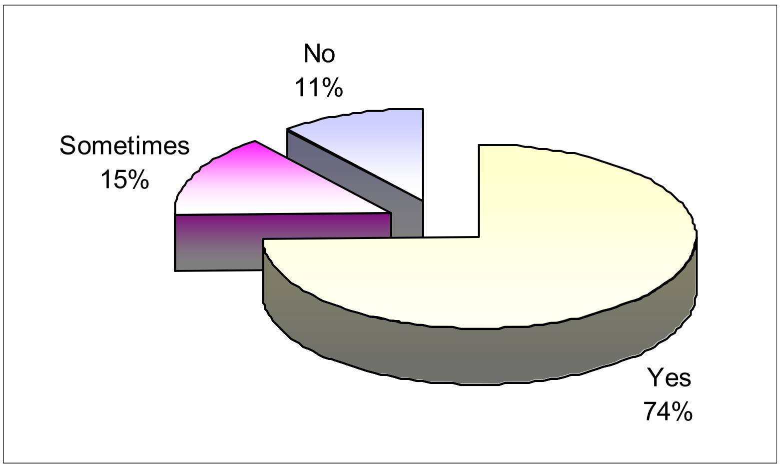


Chart 3.46: Estimation of recycling supported by students

The third question set estimates the depth of students' knowledge, while requires whether the residents use local products. Many students although supporting the local products, were found to be unaware of the local products benefits and their relation with the carbon dioxide emissions. The results are illustrating in Chart 3.47.

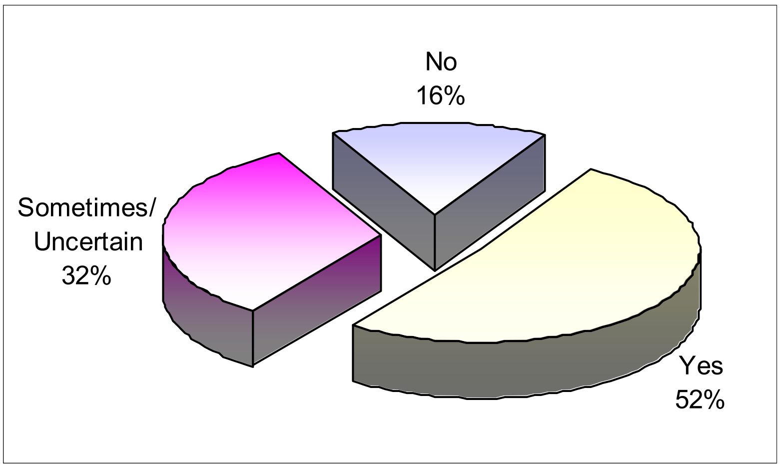


Chart 3.47: Assessment of local products used by the residents

The next question focuses on students willingness, to be involved in events relevant to the environment, while it can also represent the percentage of voluntary help in future activities, conducted by the University.

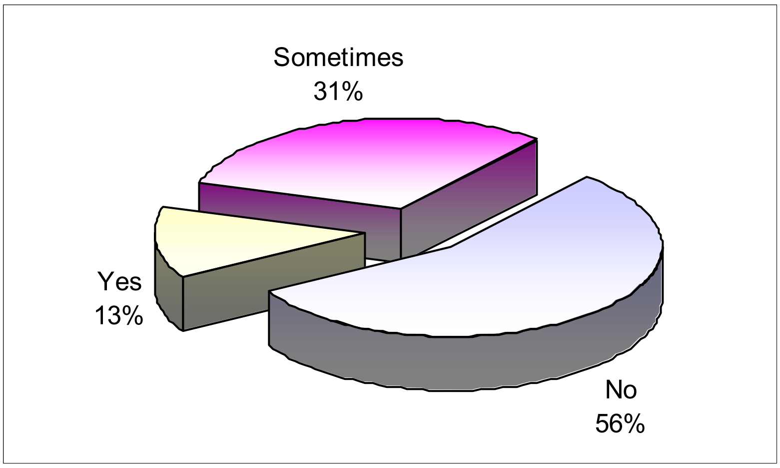


Chart 3.48: Evaluation of students willingness to be involved in environmental events

The following two questions discover whether signs, posters and leaflets are delivered and campaigns take place in an appropriate manner.

The occupants initially were asked whether they have noticed any environmental signs in the halls of residence. The results are shown in Chart 3.49.

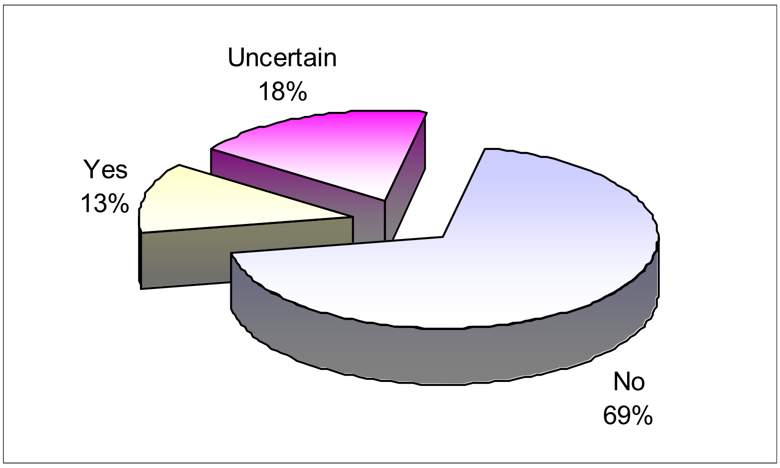


Chart 3.49: Estimation of environmental signs notification by the students in the hall of residence

This question set was related to campaigns and leaflets associated with energy efficient use and whether the students have noticed them.

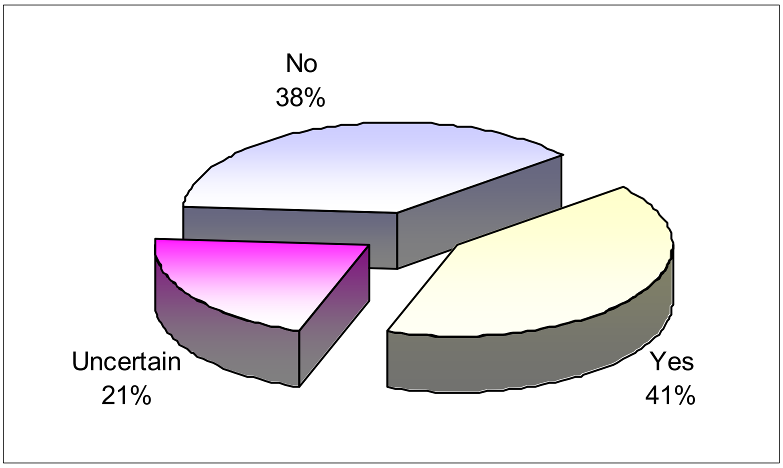


Chart 3.50: Estimation of energy efficient use leaflets notification by the students in the hall of residence

Chart 3.51 illustrates the results arising from the occupants' answers when asked whether they were informed about the ways related to energy savings achievements.

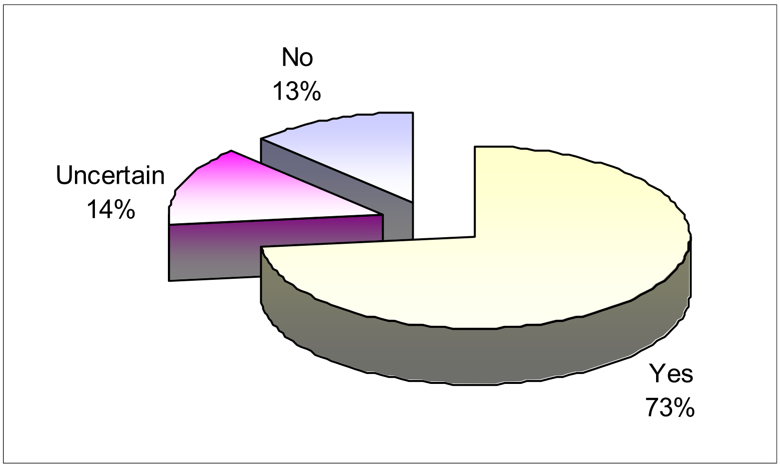


Chart 3.51: Assessment of student awareness about energy efficient ways

Questions 10 and 11 were examples of energy efficient use. However, the results showed that even if the residents are aware of the ways achieving energy savings, they do not adopt them. Furthermore, many residents admitted that they would be more conscious if either they were at home or they received invoices.

The residents were firstly asked whether they turned off the heating while they were away.

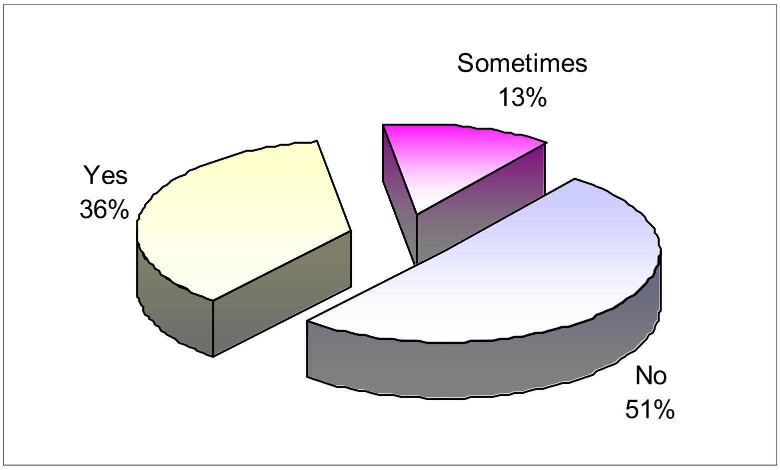


Chart 3.52: Evaluation of students' consciousness turning the heating off

The question followed inquired whether they switch off the unnecessary lighting. Chart 3.53 illustrates the results.

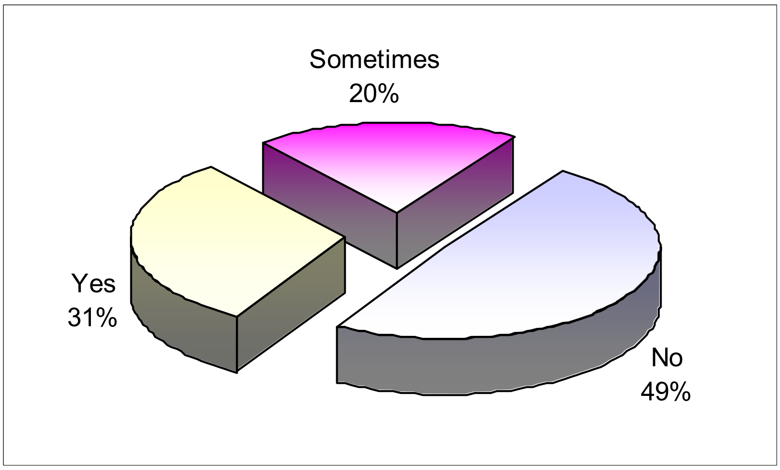


Chart 3.53: Estimation of students consciousness switching the unnecessary lighting

The last question considers the frequent use of the public means of transportation. Further conversation resulted in the fact that some students wondered about the correlation of the public transportation use and the carbon footprint.

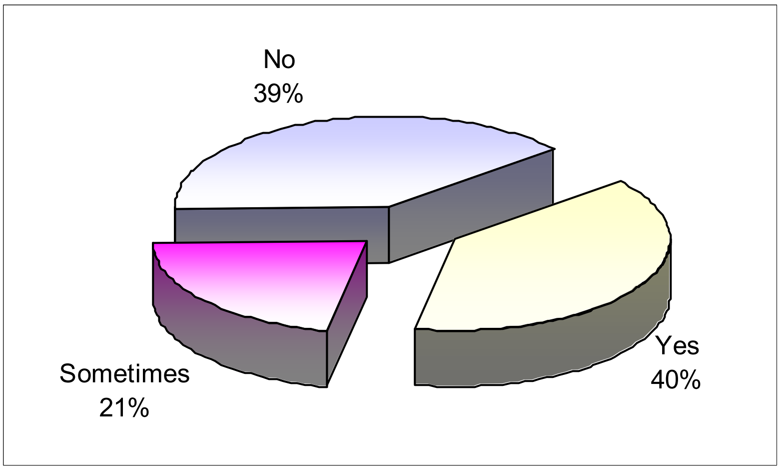


Chart 3.54: Assessment of residents percentage using the public transportation

3.8 The University of Strathclyde Energy Management Matrix

The energy management matrix profile of the University of Strathclyde was developed as part of the research for the overall performance assessment of the institution, as shown in Figure 3.1. An interview was conducted with Mr Ross Simpson, Estates Department of the University of Strathclyde, whose help was valuable for this evaluation. Great improvement can be noticed since the year 2003, however the energy management matrix of the University can be characterised as “unbalanced”.

Level	ENERGY POLICY	ORGANISING	MOTIVATION	INFORMATION SYSTEMS	MARKETING	INVESTMENT
4	Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy.	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption.	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it.	Positive discrimination in favour of "green" schemes with detailed investment appraisal of all new-build and refurbishment opportunities.
3	Formal energy policy, but no active commitment from top management.	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board.	Energy committee used as main channel together with direct contact with major users.	M & T reports for individual premises based on sub-metering, but savings not reported effectively to users.	Program of staff awareness and regular publicity campaigns.	Same payback criteria employed as for all other investment.
2	Unadopted energy policy set by energy manager or senior departmental manager.	Energy manager in post, reporting to ad-hoc committee, but line management and authority are unclear.	Contact with major users through ad-hoc committee chaired by senior departmental manager.	Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting.	Some ad-hoc awareness training.	Investment using short term payback criteria only.
1	An unwritten set of guidelines.	Energy management the part time responsibility of someone with only limited authority or influence.	Informal contacts between engineer and a few users.	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department.	Informal contacts used to promote energy efficiency.	Only low cost measures taken.
0	No explicit policy.	No energy management or any formal delegation of responsibility for energy consumption.	No contact with users.	No information system. No accounting for energy consumption.	No promotion of energy efficiency.	No investment in increasing energy efficiency in premises.

2005 Profile (solid line)
2003 Profile (dashed line)

Figure 3.1: Energy Management Matrix for the University of Strathclyde

4. Geographical Information Systems (G.I.S.)

4.1 Display of buildings energy use and CO_2 emissions

A G.I.S. is used to display, analyse and manipulate data geographically (Androulakis, 2000). An attempt is therefore made to graphically represent the processed energy use data of the halls of residence. Additionally, the procedure was expanded to present also the CO_2 emissions released by each hall, identifying the major contributors in the University's carbon footprint with time. This aims to make easier the monitoring of the halls' of residence energy consumption by identifying excessive and unrealistic behaviour to the responsible person such as the energy/environmental manager.

The John Anderson Campus map was provided by the Estates Management Department and is shown in a 1:2500 scale. The software used for the energy map development was the ArcView (Version 3.1).

The digitising of the map was the first step. Initially, sixteen new themes were added illustrating all the buildings of the halls of residence, using different colours. Grouping of the buildings belonging to the same hall of residence followed, resulting in common coloured representation, in order to provide the same information. Birkbeck Court consists of five buildings, all represented by one colour and having the same characteristics. The layout of the campus is shown in Figure 4.1 below.

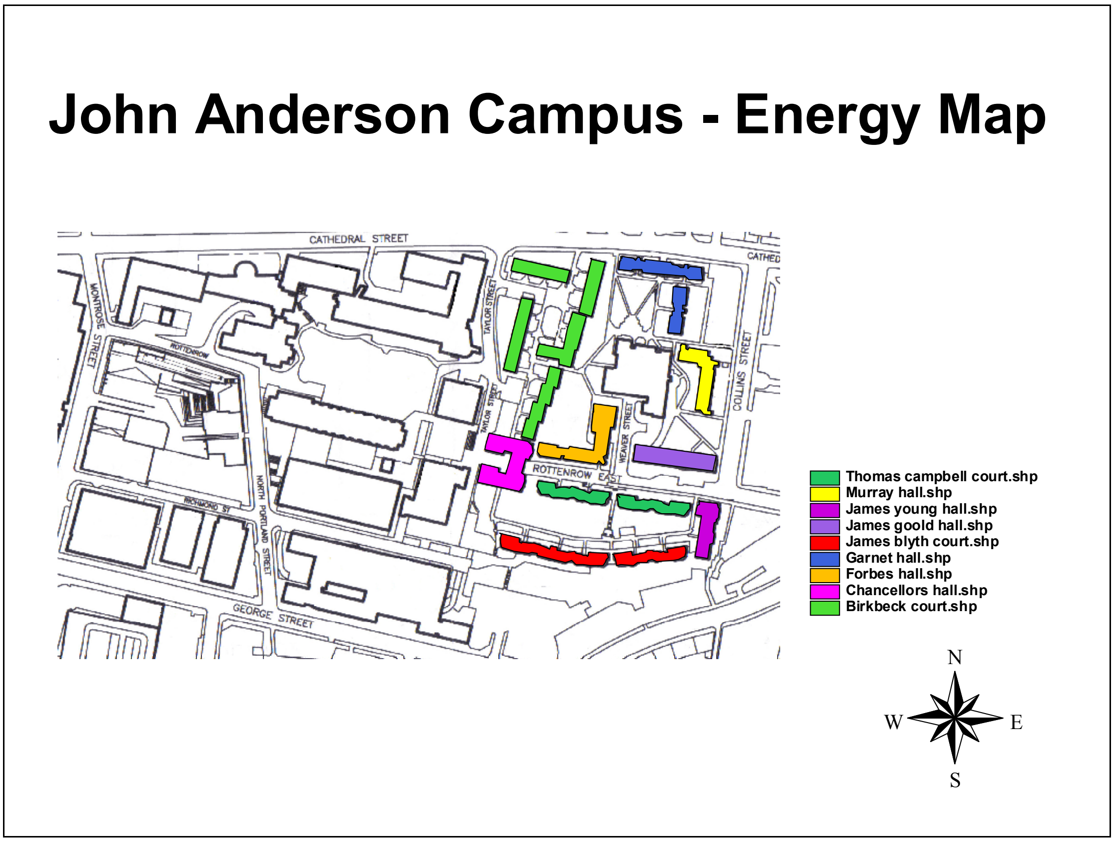


Figure 4.1: University of Strathclyde halls of residence

The halls' energy consumption as illustrated below was inserted as an image with the help of the "hot-link" option in ArcView software.

An example of the James Goold Hall follows, showing its energy consumption, Figure 4.2, and the resulting associated CO_2 emissions, Figure 4.3, while the data for the remaining halls can be found in Appendix VIII.

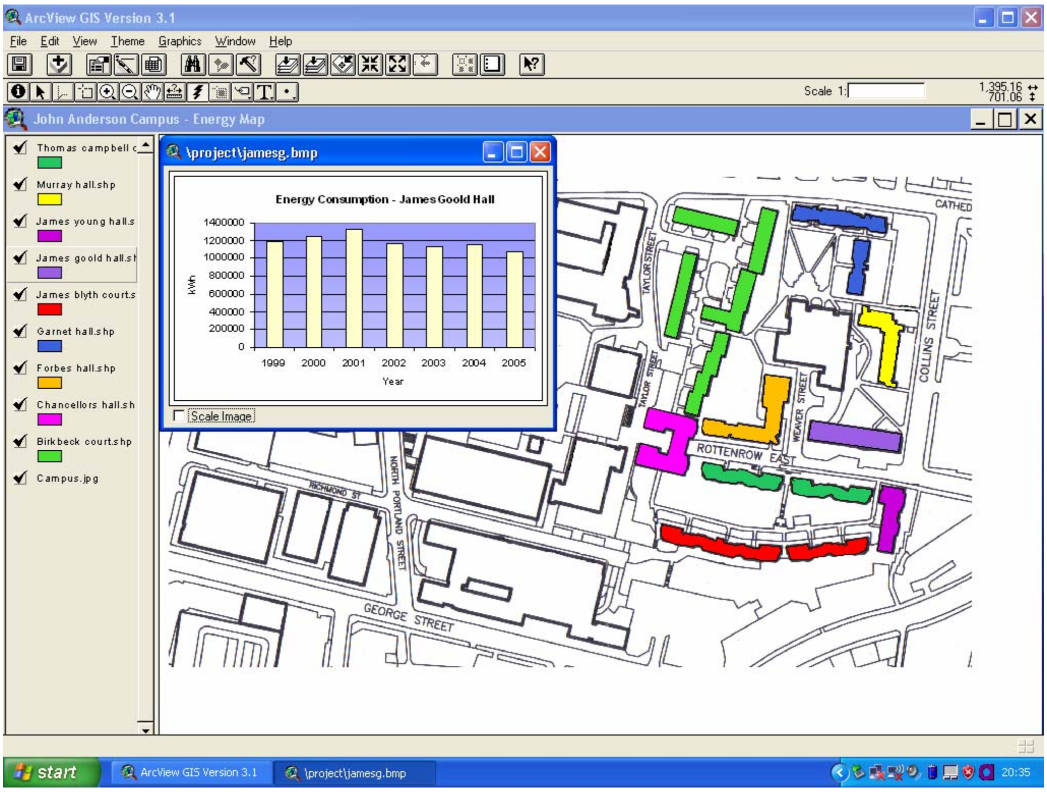


Figure 4.2: James Goold Hall's energy consumption

The same procedure was followed for the development of the halls' of residence CO_2 emission representations.

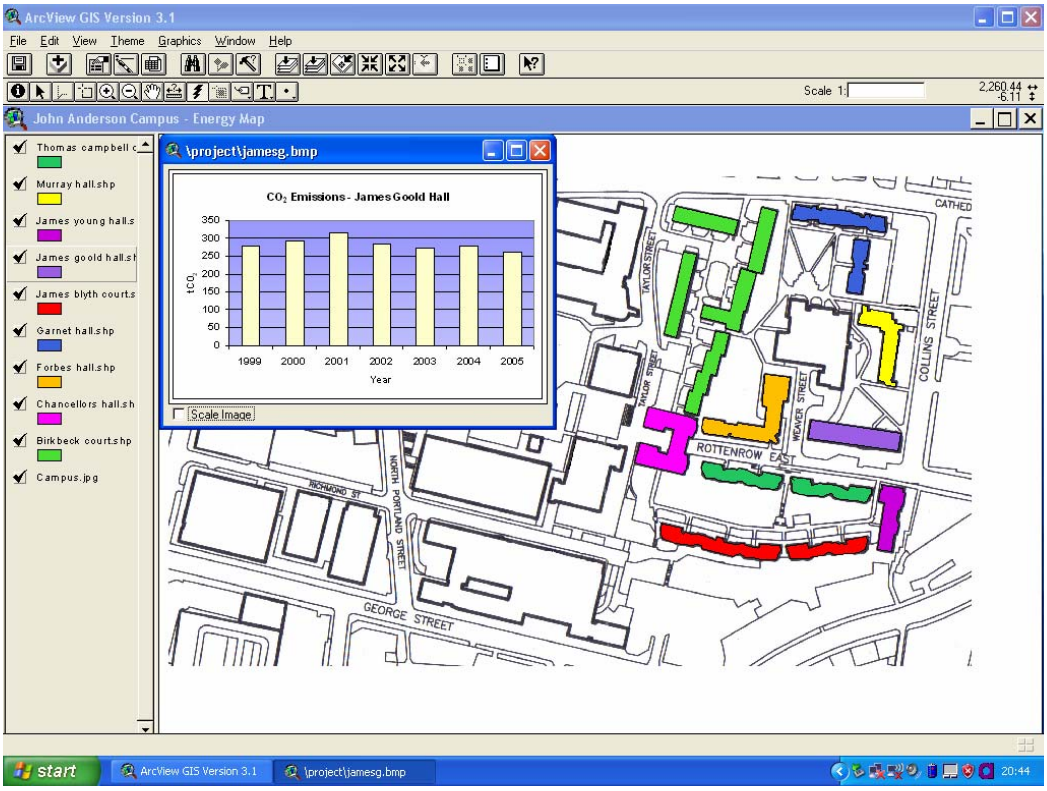


Figure 4.3: James Goold Hall's CO_2 emissions

5. Survey on campus meters

5.1 Main meters versus sub-meters

The initial idea was to identify any faults occurring among the electricity meters and sub-meters. The quality of data should be secured in advance to provide a correct result and consequently decisions. This could be done by comparing the main meters records with the sum of the sub-meters' one. Data was provided by the Estates Management Department of the University of Strathclyde and the period under study was considered between the years 1999 - 2004. However, it was beyond the scope of this project to examine all the sub-meters in depth.

The John Anderson campus has two main points where electricity is supplied, in Sir William Duncan and in Graham Hills buildings. However, in the former case, the two meters next to the main one were initially considered to be sub-meters. The drawings of the electricity meters showed that the three meters were in place, while the records showed that the main meter stopped to be monitored as soon as the two sub-meters started. After a walk about the building, it was identified that the main meter had been removed and replaced by the other two. However, the three meters were in place when the drawings were conducted, despite the fact that they were not monitored. Thus, the two initial sub-meters are now considered to be the main metering points. Consequently, for this case, it was unfeasible for the survey to continue. In the latter case, the main meter supplies seven buildings plus the pathway lighting, giving a total of nineteen sub-meters. Moreover, when the graphical representation of the comparison was attempted, it was realised that the dates of the meter reading did not concur, as full annual records for all the meters were not available. However, the only year for which full records of the meters were available was the year 1999, the chart of which can be found in Appendix IX.

Records for the main meter in Graham Hills Building exist up to 2004, when it is suspected that this period of time the main meter was replaced from another two (main and check meters) by Scottish Power. However, the only records that exist after the year 2004 are the ones that are provided by the utility company's invoices, as the University does not monitor them. Consequently, this data was used for the purpose of this study.

As data was missing, in order for the survey to be continued, changes were considered. These changes aimed to fill in the gaps from the monthly data that was missing. However, the process required the introduction of a correction factor, f_3. This factor was the result of the consumption ratio of the corresponding period of time (the month under change and its previous one) taking into account the year before the year of study. For example, if data for February 2000 was missing, the f_3 would result by dividing the January's 1999 consumption by February's 1999. Afterwards, this factor would be multiplied with the January's 2000 consumption. This would be considered as the February 2000 consumption. That is to say, the change was assumed to be linear between the month under study and its previous one (the year under study) with the corresponding period of time from the year before the year of study.

The bar charts, up to 2004, can be found in Appendix IX, while their summary is provided in Table 5.1.

Year	Main meter (in kWh)	Sub-meters total (in kWh)	Difference (in kWh)
1999	2.949.100	2.433.427	515.673
2000	3.003.800	2.469.675	534.125
2001	3.016.300	2.403.889	612.411
2002	3.165.900	2.509.556	656.344
2003	3.076.613	2.509.053	567.560
2004	3.236.221	2.640.140	596.081

Table 5.1: Summary of meter data

If the system presented no losses, the readings of the main meter should be the same with the total readings of the sub-meters for the corresponding period of time. The meters should be monitored and service should be provided to ensure maximum efficiency and minimum losses.

The results show that the difference between the readings of the main and the sub-meters increases year after year. As far as the values arising for the year 2003 and 2004 are concerned, the fact that readings for one meter of James Blyth Court are missing, explains the reduction in the difference value.

6. Conclusions

The establishment of a carbon footprint is of great importance to the management not only of the environmental pollution but also of the cost that results from the excessive pollutants. Many factors should be considered in advance so that the result is feasibly applicable.

6.1 Criticism of the H.E.C.M. toolkit

The software is a useful tool to estimate the carbon footprint of the various University buildings. However, the comments below may help towards its wider expansion.

Building

- The sheet is easy to use and covers all the aspects.

Transport

- A detailed leaflet should accompany this software providing the distances of all the countries and cities. Moreover, this should include the cost per unit, either calculated per miles or per km travelled by the customer with all the means of transport for the year that the software is developed. Obviously, this cannot happen for the following years since the fuel prices change so do the tickets for the types of transport. But a section for fuel price input can be provided to accommodate this. However, the software does cover some examples of distances while the costs per unit are provided for cars.
- The field which requires the actual and the potential means of transportation is too specific. The person who is interviewed cannot reply to such a question in detail. Consequently, due to this lack of knowledge the field, cost per unit, is difficult to be estimated. Therefore, these fields could be more general providing an average figure of CO_2 emissions and cost per unit.
- The software, in order to have the options clarified, should give initially the opportunity for the operator of the software to choose which units will be used, as it does in the commuting sheet. As in the beginning, the clarification of the type of data imported is required (such as the set of the cost per unit has one type of data to consider), consistency must be kept through the records. If more than one table was available to provide the information, then the mixing of the data type would be feasible but the complexity of the software would rise significantly.

- The field which requires the alternative transportation type does not provide the option of "none". However one has to either leave the field blank or add the same means of transport where no savings or additional costs occur.
- There is no option of adding more than one potential alternative transport means.

Commuting

- Once more, consistency must be kept with the input of the data. Specifications could be made from the beginning whether the imported data will be in miles or in km, while modifications of some data units cause automatic changes in the entire sheet.
- The software does not take into account the number of people doing the same commuting which is very possible for students living on campus, thus the sum of the same data is one option. It requires, however, the number of students but this field is not taken into consideration.
- Having as the first means the walk/bike option, in the following field of the transportation means CO_2 factor it adds as a default value 0,10. The same happens even if one has the walk/bike as a second or third means of transport. Consequently, the correction of the formula was required.
- As far as the motorbike is concerned, this is recognised as type of car for the calculation of its CO_2 factor, however the calculations taken place are correct.

Generally, it is found that most of the cells round up automatically which does not cause any problem but is not very useful as a very detailed result is required.

6.2 Recommendations

More graphs should be provided by the software, as the graphical representation obviously provides more help to the translation of the results, such as each buildings graphical representation of its associated emissions related to the three examined aspects: the building itself, the transport and commuting of the people involved with it. This would help further to the set of priorities identifying the critical factors. Furthermore, this can expanded for each year to monitor whether the significance of the factors is changed.

The software lacks any information about the waste transportation and the amount of materials landfilled and recycled. However, a rough estimation conducted showed that the waste transportation emissions is insignificant and can be ignored. The waste of the University of Strathclyde is gathered by the City Council and the materials are landfilled at Polmadie M.R.F., at Polmadie road being 2,98 miles away. Consequently,

2 (return way) x 2,98 (miles) x 0,92 (lorry diesel rigid CO_2 factor)
= 5,483/1000=0,005483 tonnes of CO_2

However, the percentage for the recycled materials cannot be assessed because the bins concentrate the waste from all the residences, as there are no available bins for each individual building. As a consequence, an accurate waste decomposition analysis was not feasible.

The results of the whole project should be delivered to all staff and students with feasible recommendations. The interest of the residents was obvious when the survey was conducted.

Additionally, prospective students should also be informed as soon as they arrive. A questionnaire should be included in the welcome pack required to be submitted to the office being responsible for the various halls of residence. However, the deadline should be set to around the end of the winter so that most of the trips could have been conducted and any future ones are planned.

As the contribution per student on the James Goold Hall carbon footprint has been estimated to be 5,07 tonnes of CO_2, this can be considered as a small percentage. However, a small reduction in per capita emissions can result in a large contribution on the overall carbon footprint. This can be achieved through:

- A checklist on each room door reminding the students to turn the heating and lights off while they are away.
- A responsible person informed by students for their expected days of absence (preferably for periods of over one week) from the hall of residence so that the isolation of the room from electricity and gas is possible.
- A central Building Management System (B.M.S.) providing monitoring on a daily basis.

However, the investment on a B.M.S. can be costly, and further work in the form of a detailed feasibility study is needed to accurately quantify the savings for the calculation of payback period for such an installation. Investment on the B.M.S. may be further justified through the reduction in gas and electricity bills that will surely ensue from the increase in control of heating and lighting systems.

6.3 Future work

A full feasibility study is required for the implementation of an integrated B.M.S. which is critical to the carbon footprint reduction as, the sensitivity analysis indicated that changes in student transportation and commuting could not affect the carbon footprint to a large degree.

As far as the G.I.S. program developed is concerned, this work can be further expanded to provide information on the remaining University's buildings. Additionally, the same procedure can be undertaken using languages used in website development, so that it can be uploaded onto the University's website. Further improvements can involve the link of the G.I.S. map to the ENTRAK database in order provide direct real-time information. The programme developed was provided to the University of Strathclyde for this purpose. A more detailed analysis can comprise the illustration of the monthly data from the halls of residence. Additionally, the software can be tailored to provide the normalisation of the gas consumption against the degree days. Finally, the annual energy profiles displayed for each hall would provide useful information.

Moreover, the metering system needs to be examined in detail for its effectiveness. Investments should be made, as the investigation undertaken shows that a fault exists somewhere in the system. Additionally, this could provide further accurate data in advance, minimising the required time spent by the responsible department for this purpose.

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Appendix I - Questionnaire
INVESTIGATION INTO THE CARBON FOOTPRINT OF THE UNIVERSITY OF STRATHCLYDE

PARTICIPANT INFORMATION LEAFLET

Aim of investigation

The Estates Management Department of the University are involved in a project to estimate and develop an environmental management system (E.M.S.) which will assist them in improving the energy and environmental aspects of the University's operation and ensuring their compliance with new legislation. Using some specialist software, it is intended that the carbon dioxide emissions associated with the function of the University will be established.

As a part of the analysis, this questionnaire has been tailored to gather data about the occupant's transport over the course of the year from September 2004, in order that the associated carbon dioxide emissions of some of the halls of residence can be estimated and supplied as inputs to the software package. Furthermore, this questionnaire is designed to estimate the residents' level of awareness about environmental issues. This is of a great importance as people are not aware of the activities polluting the environment. Consequently, this evaluation will show the strengths and weaknesses of our University which have to be addressed.

What do we want you to do?

If you are agreeable to participate in this research, you are asked to complete the consent form supplied. You will then be asked a few questions on your use of transport and your energy awareness.

Privacy and Confidentiality

The interviews will be conducted individually by research student Georgia Bezyrtzi. All the information you supply will be treated anonymously.

Outcomes of this research

This research will form part of Georgia Bezyrtzi's MSc dissertation (which will be available in pdf format via the University website) and will be input to the overall assessment of the University's Carbon Footprint, which is being undertaken by the Estates Department of the University.

Contact in case of questions: Georgia Bezyrtzi, E-mail: georgia.bezyrtzi@strath.ac.uk

INVESTIGATION INTO THE CARBON FOOTPRINT OF THE UNIVERSITY OF STRATHCLYDE

PARTICIPANT CONSENT FORM

I have read and understood fully the information given to me and I am both willing and able to answer questions related to my transport and energy use.

I understand that my participation is voluntary and that I may withdraw at any time without giving a reason.

I understand that any information I do give will be treated confidentially and will be anonymous.

Signed by ....

Date..

Questionnaire

My name is Georgia Bezyrtzi and I am a student of the University of Strathclyde. As part of my final thesis of the MSc that I attend, I have to evaluate the carbon dioxide emissions of your hall of residence. This anonymous questionnaire is to identify the emissions related to the residents' transport and their level of environmental awareness. I would be very grateful if you could fill it in.

Transportation

1. Please specify any trip you undertook (and you are planning to do) from September 2004 until September 2005.

Note 1: Include trips for educational purposes, exclude **local trips** conducted regularly.

Note 2: In the columns one way and return ticket, specify the number of trips that have taken and will take place during the period of time mentioned above.

Note 3: Means of transportation considered: plane, car (Diesel: large/small, LPG, Petrol: large/medium/small), rail (or Diesel coach). If you do not know the exact type of fuel, write only the basic mean of transportation.

Note 4: Type of trips: **P** for personal and **C** for course related trips.

Trips inside UK

Places visited		One way ticket	Return ticket	Means of transportation	Type of trip
From	To				

Trips outside UK

Places visited		One way ticket	Return ticket	Means of transportation	Type of trip
From	To				

Please proceed to the next page.

Commuting

2. Please specify whether you had to attend classes **on a regular basis** where you had to use public transportation.

Note 1: Refer to more than one means of transport (if necessary).

Note 2: Means of transportation considered: bus (Diesel), car (Diesel: large/small, LPG, Petrol: large/medium/small), motorbike, rail, walk/bike. If you do not know the exact type of fuel, write only the basic mean of transportation.

Note 3: If car, then specify the exact number of passengers.

Places visited		Means of transportation	Distance in miles	Duration in weeks	Days per week
From	To				

Level of awareness

This is a general estimation of consciousness about environmental issues in lifestyle.

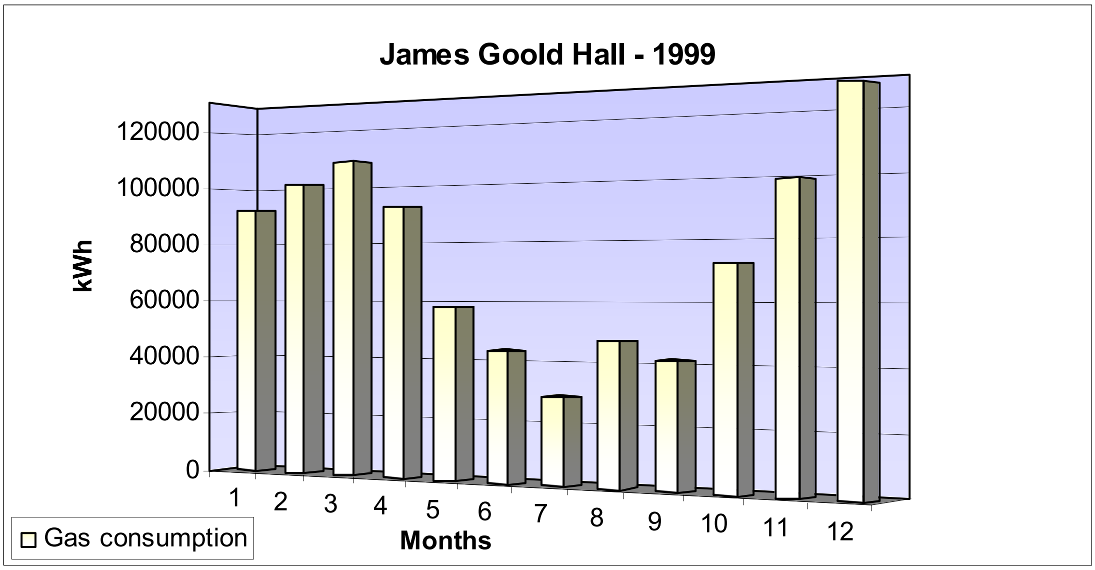
Please tick the appropriate box.

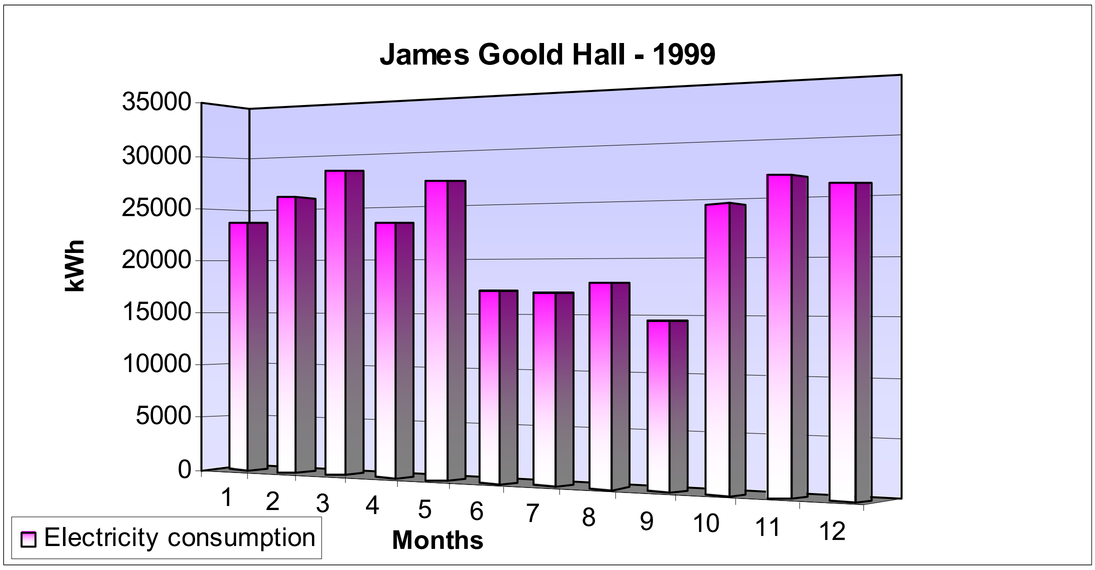
		Yes	Sometimes/ Uncertain	No
3.	Do you know if there are any recycling bins around University?	☐	☐	☐
4.	Do you support the recycling of the materials?	☐	☐	☐
5.	Do you buy local products?	☐	☐	☐
6.	Do you volunteer in any environmental event?	☐	☐	☐
7.	Have you noticed any environmental signs/posters in the residences?	☐	☐	☐
8.	Have you seen any campaigns/leaflets related to energy efficient use?	☐	☐	☐
9.	Do you know how energy savings can be achieved?	☐	☐	☐
10.	Do you turn the heating off while you are away?	☐	☐	☐
11.	Do you switch off the unnecessary lighting?	☐	☐	☐
12.	Do you regularly use public transportation?	☐	☐	☐

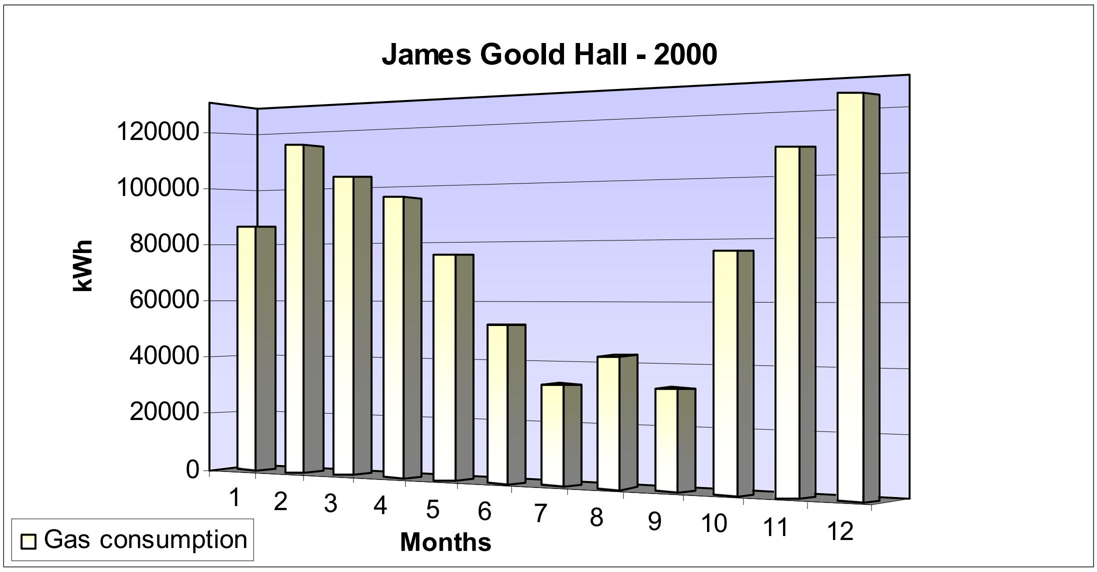
After completing the questionnaire, please leave it in the common room where the access is easy. Thank you very much for the support.

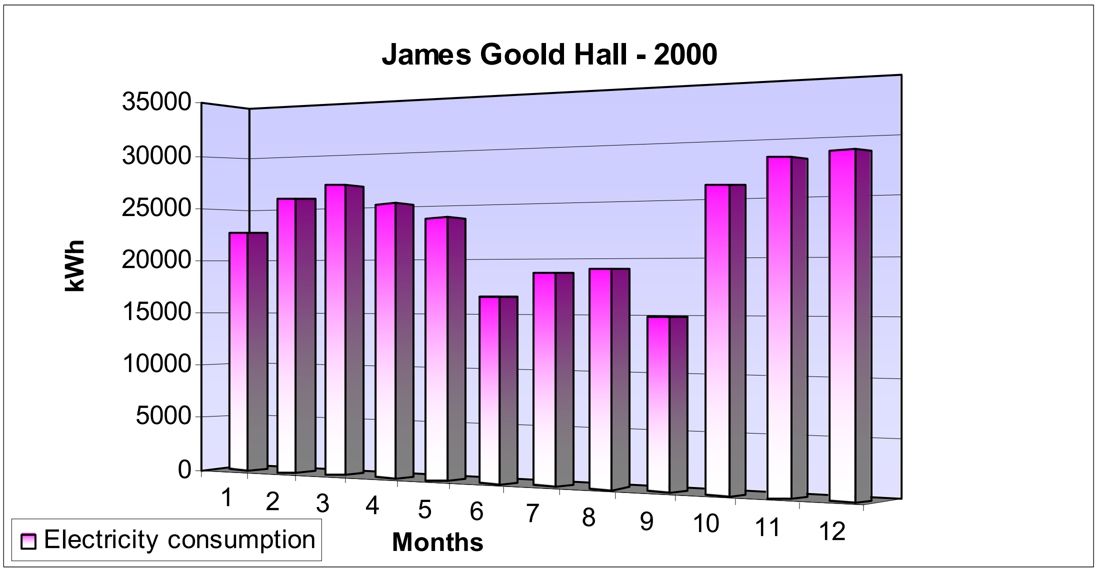
Appendix II - Original energy use data of James Goold Hall

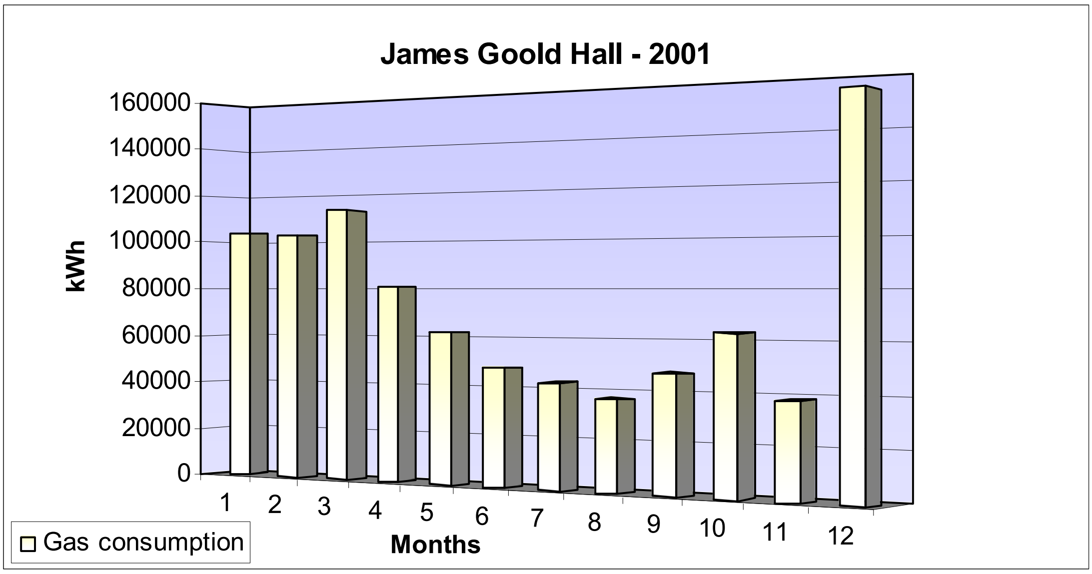
The graphical representation of the data provided by the Estates Management Department on a yearly basis follows; concerning the James Goold Hall of the residences to identify mistaken values.

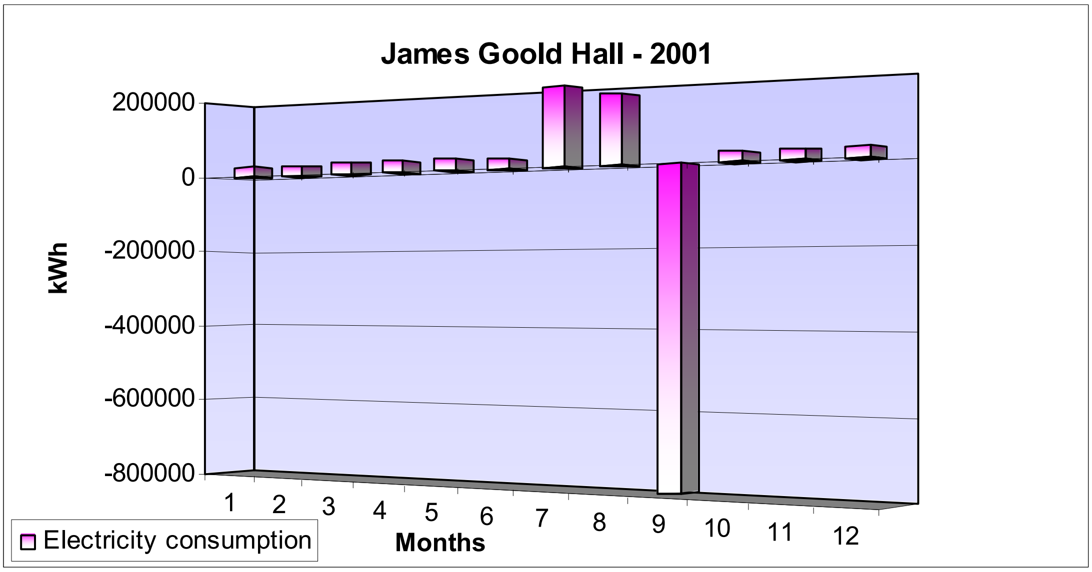


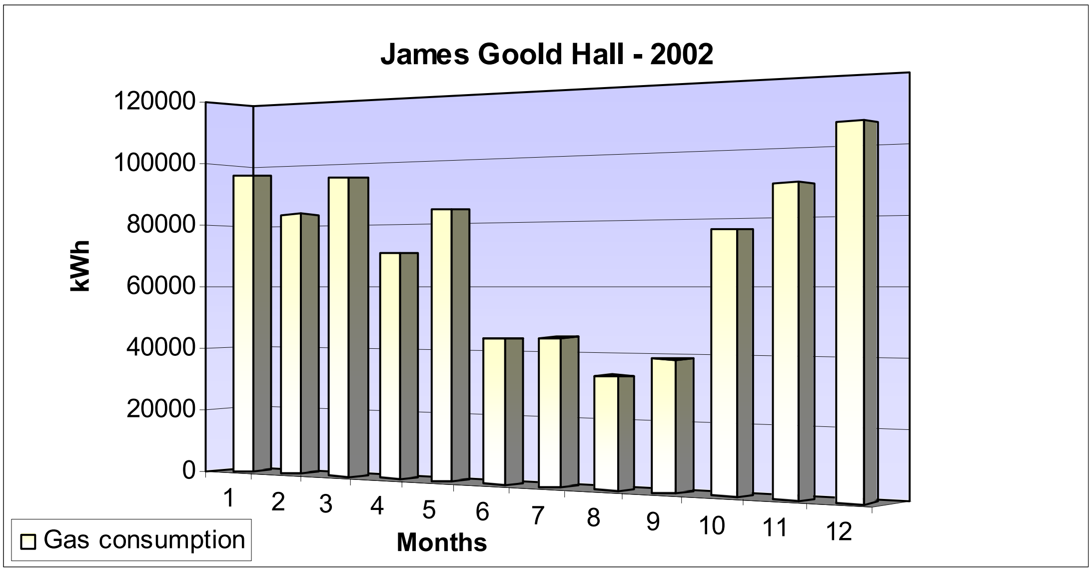


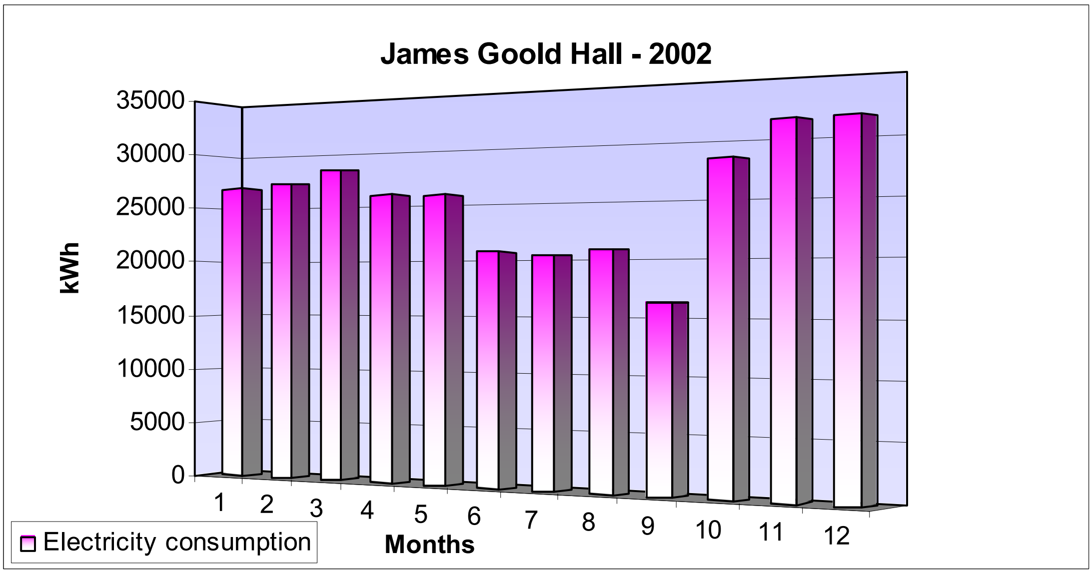

James Goold Hall - 2000
120000
100000
80000
60000
40000
20000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Gas consumption

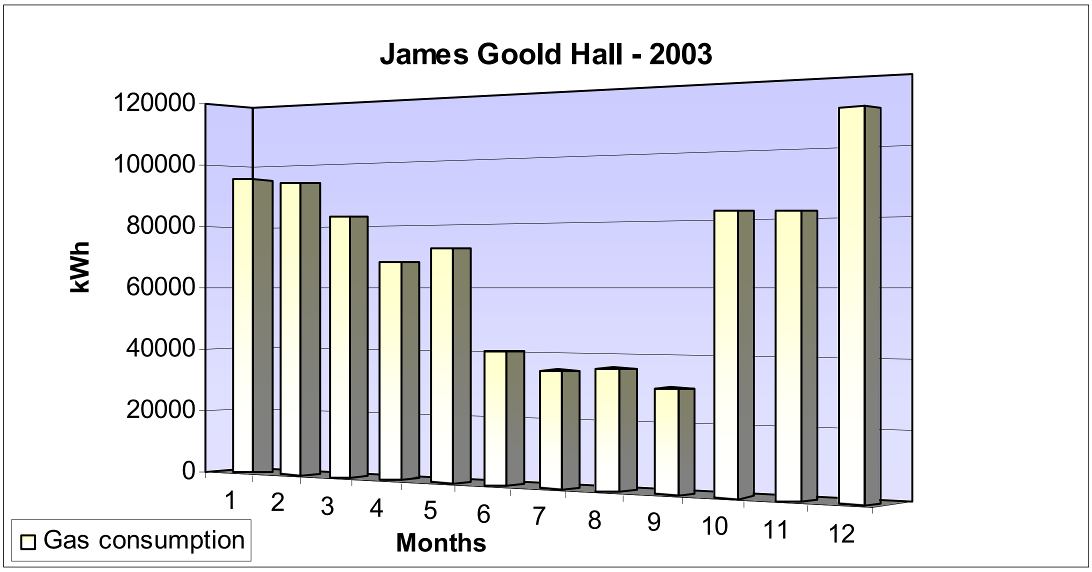

James Goold Hall - 2000
35000
30000
25000
20000
15000
10000
5000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Electricity consumption

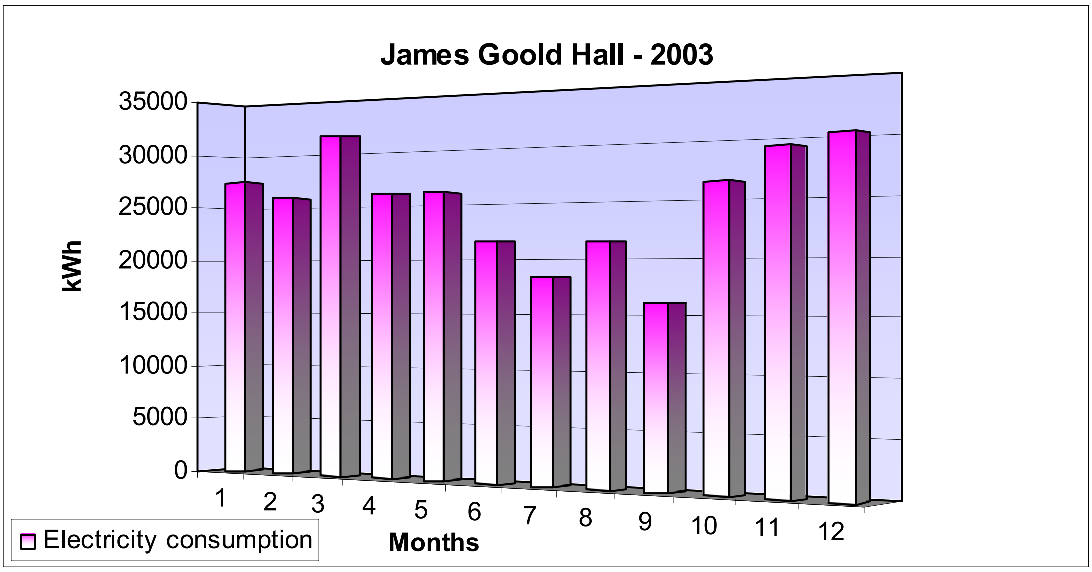

James Goold Hall - 2001
160000
140000
120000
100000
80000
60000
40000
20000
0
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Gas consumption

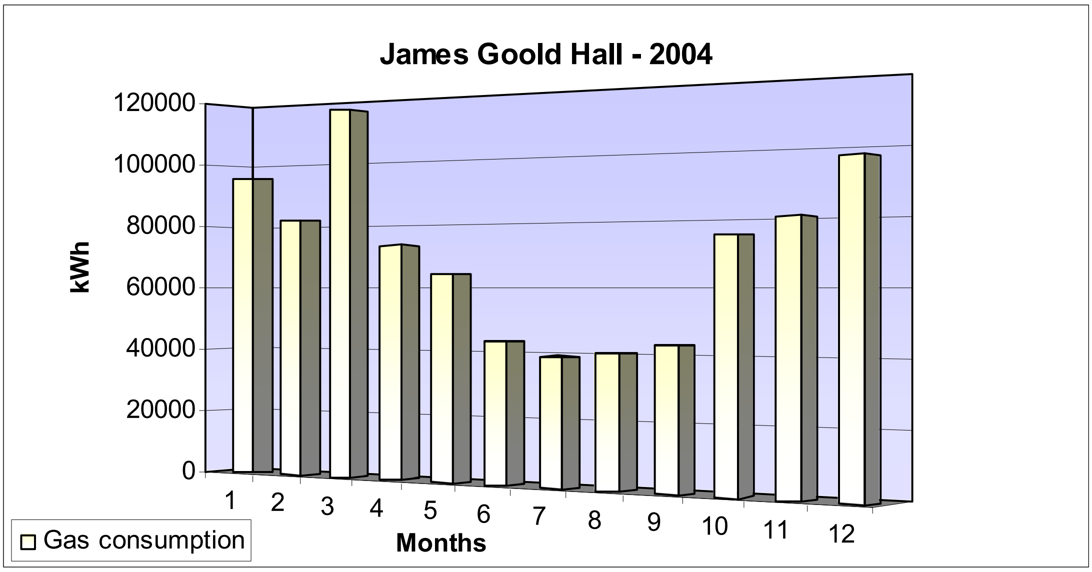

James Goold Hall - 2001
200000
0
-200000
-400000
-600000
-800000
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Electricity consumption

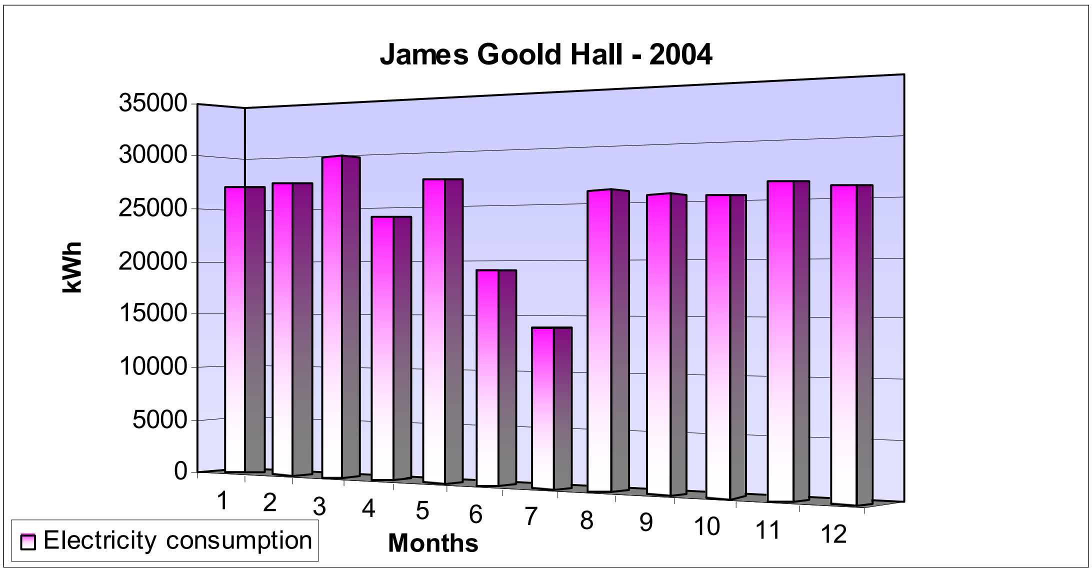

James Goold Hall - 2002
120000
100000
80000
60000
40000
20000
0
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Gas consumption

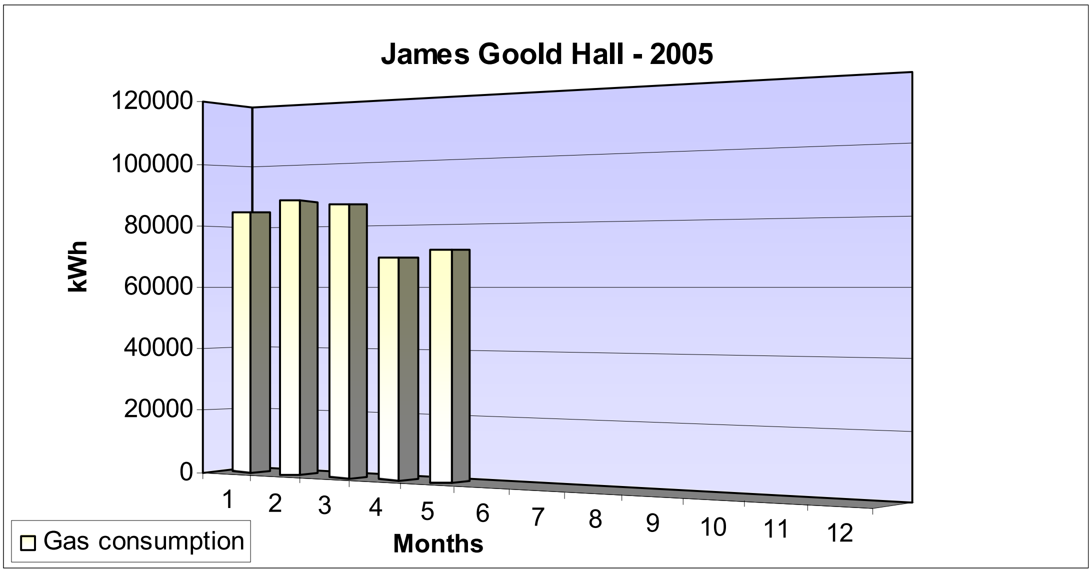

James Goold Hall - 2002
35000
30000
25000
20000
15000
10000
5000
0
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Electricity consumption

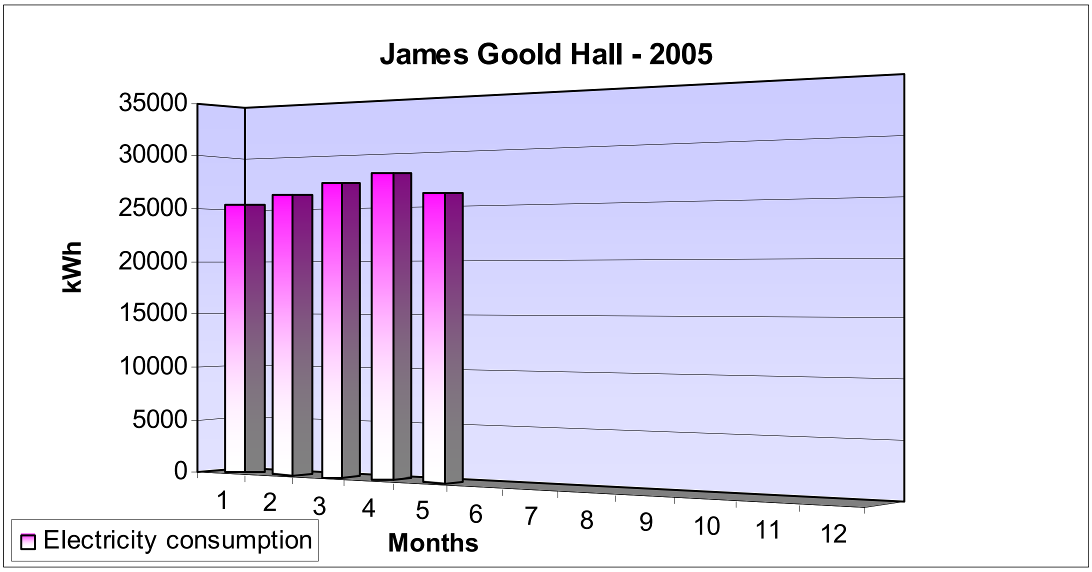

James Goold Hall - 2003
120000
100000
80000
60000
40000
20000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Gas consumption


James Goold Hall - 2003
35000
30000
25000
20000
15000
10000
5000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Electricity consumption


James Goold Hall - 2004
120000
100000
80000
60000
40000
20000
0
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Gas consumption

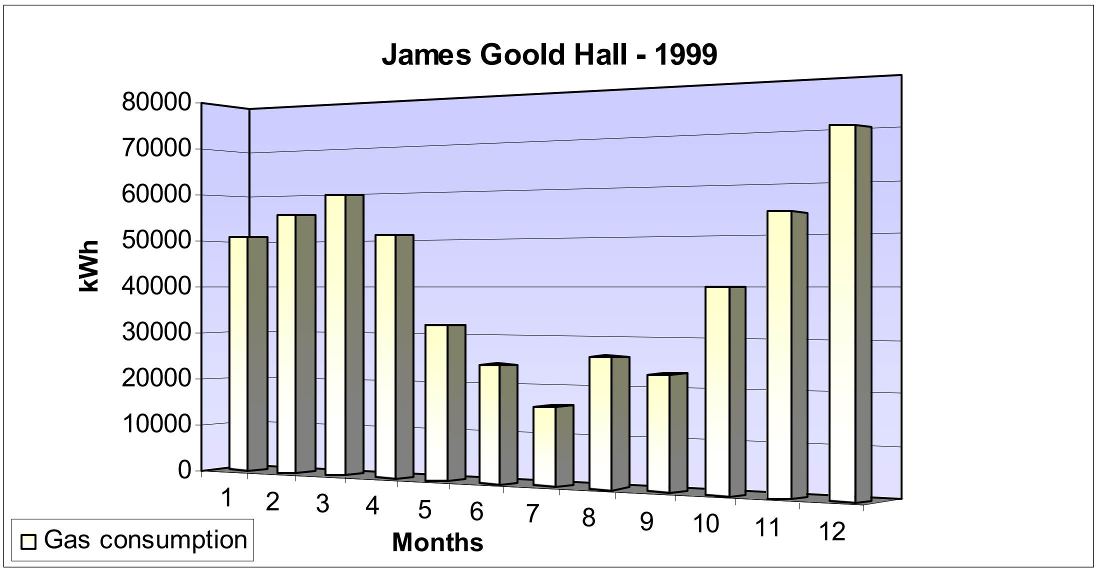

James Goold Hall - 2004
35000
30000
25000
20000
15000
10000
5000
0
kWh
1
2
3
4
5
6
7
8
9
10
11
12
Months
Electricity consumption

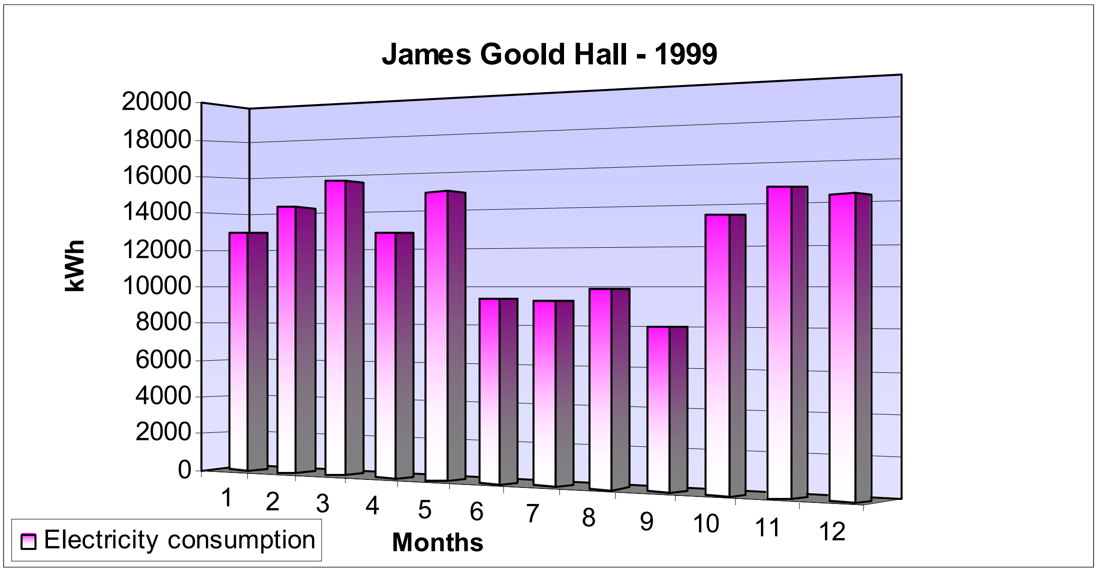

James Goold Hall - 2005
120000
100000
80000
60000
40000
20000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Gas consumption


James Goold Hall - 2005
35000
30000
25000
20000
15000
10000
5000
0
kWh
1 2 3 4 5 6 7 8 9 10 11 12
Months
Electricity consumption

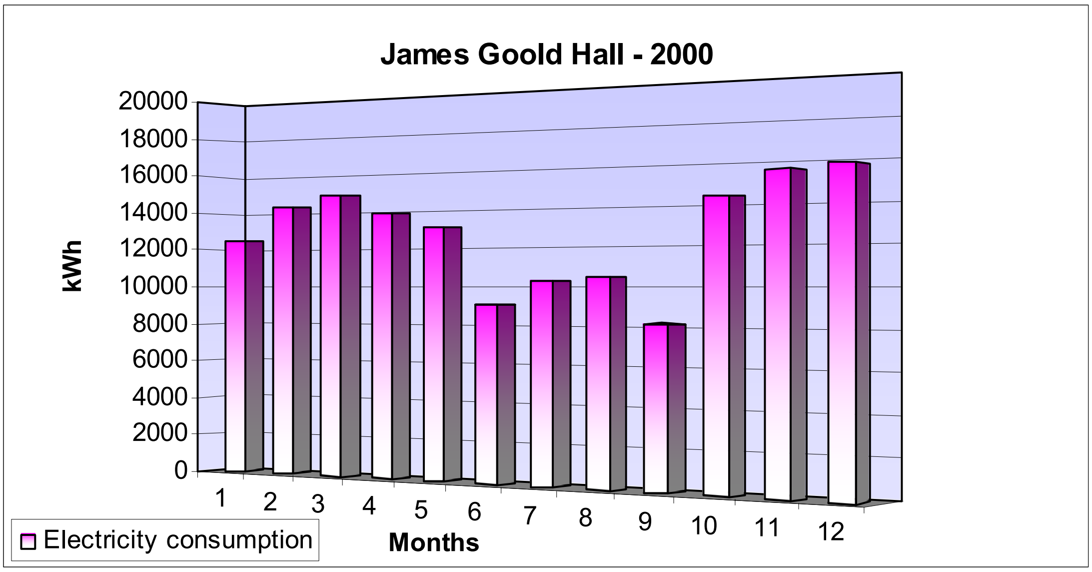
Appendix III - Altered energy use data of James Goold Hall

For 1999, the changes were made in the proportional gas and electricity consumption related to the Block A floor area.



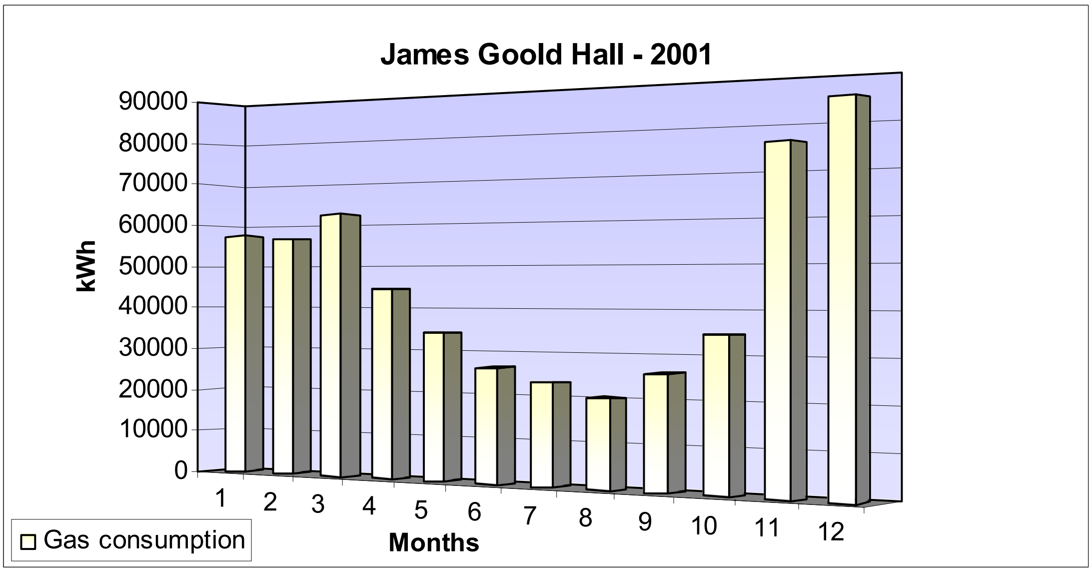


For 2000, the electricity consumption was scaled related to the floor area of Block A.



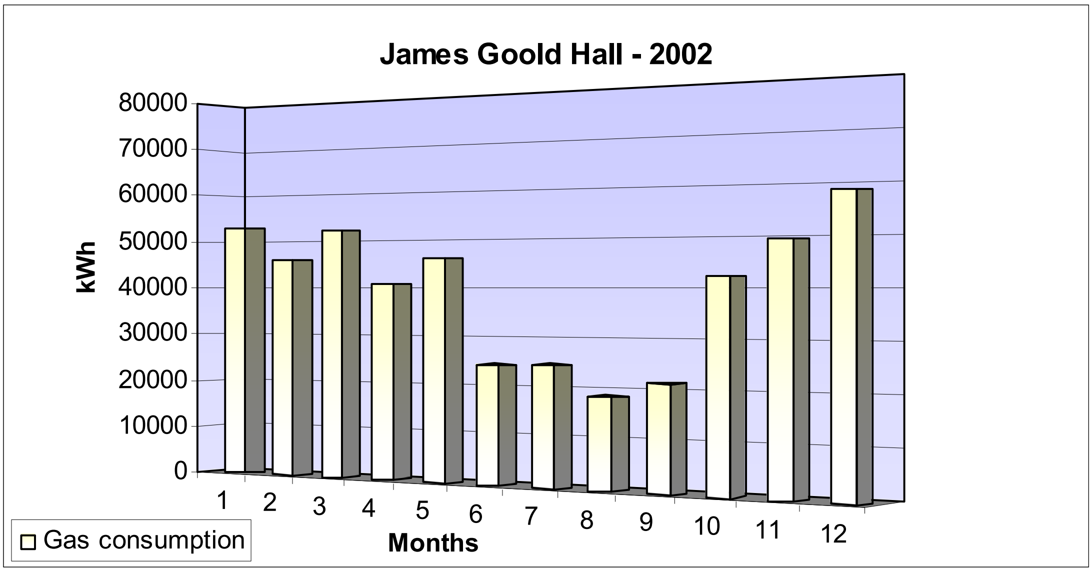
For 2001, the gas consumption was scaled in relation to the floor area of Block A and the November's consumption adjusted according to the degree days' change as follows:

Month - Year	Degree days	Consumption (in kWh)	Correction factor f_1	Resulted consumption
October - 2001	109	34.818,01	2,174	34.818,01
November - 2001	237	21.109,43		75.705,22

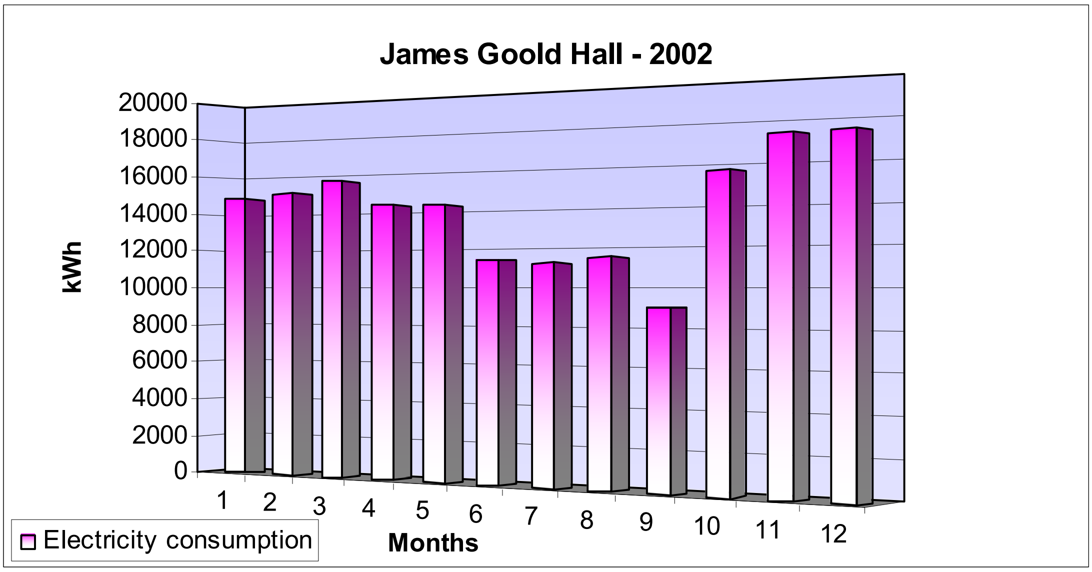


For 2002, the gas consumption was scaled in relation to the floor area of Block A and the April's consumption adjusted according to the degree days' change as follows:

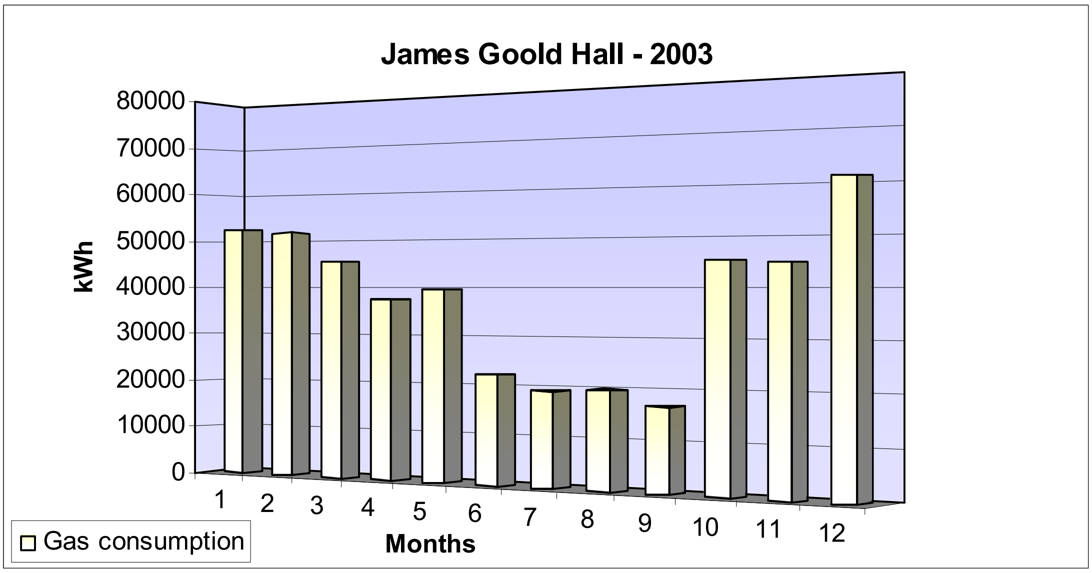
Month - Year	Degree days	Consumption (in kWh)	Correction factor f_1	Resulted consumption
March -2002	272	52.110,54	0,787	52.110,54
April - 2002	214	38.885,79		40.998,73

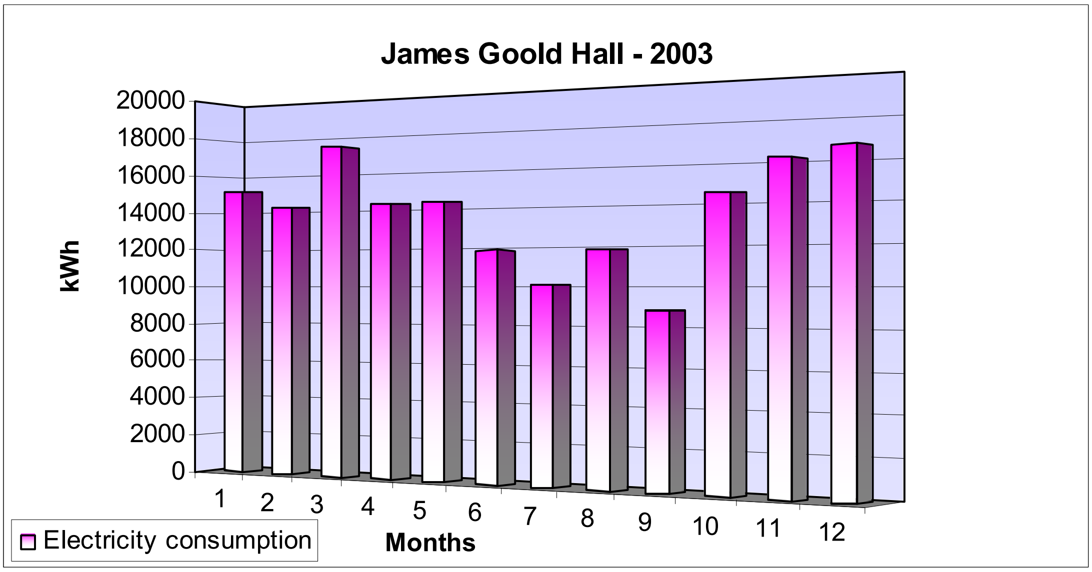


The electricity consumption was scaled related to the floor area of Block A.



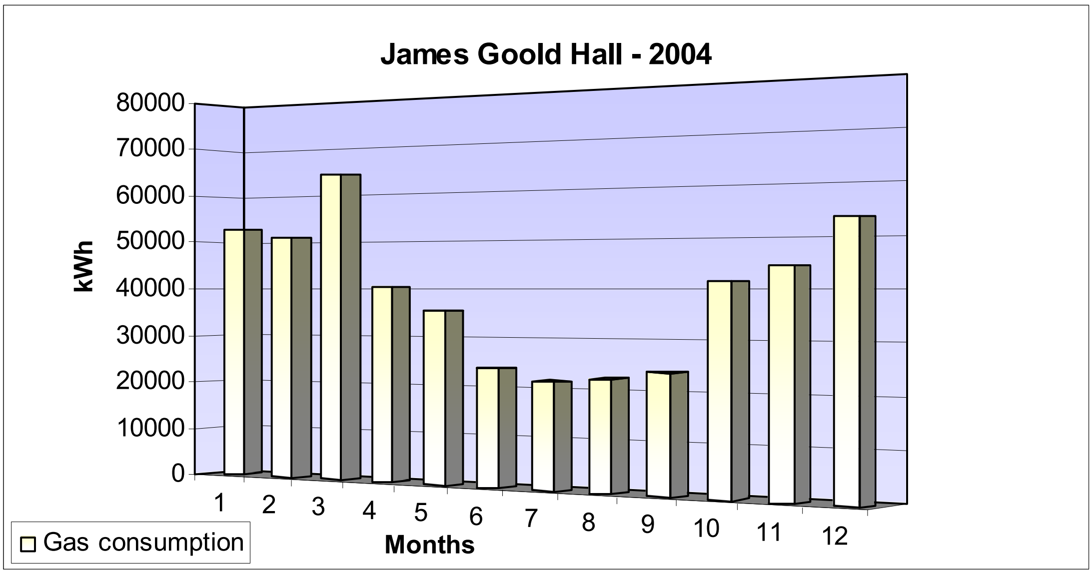
For 2003, the changes were made to the proportional gas and electricity consumption related to the Block A floor area.



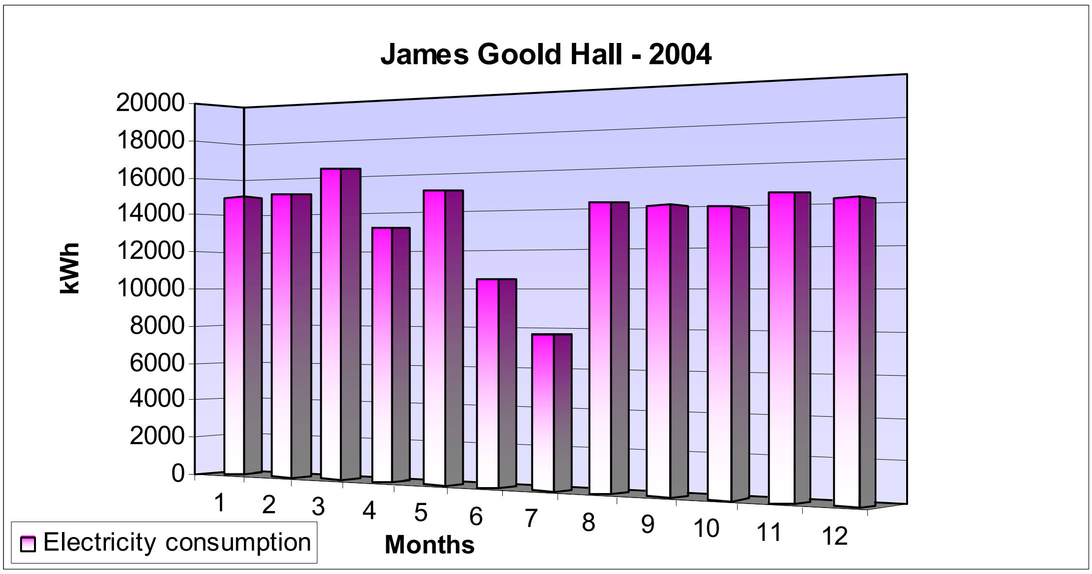


For 2004, the gas consumption was scaled in relation to the floor area of Block A and the February's consumption adjusted according to the degree days' change as follows:

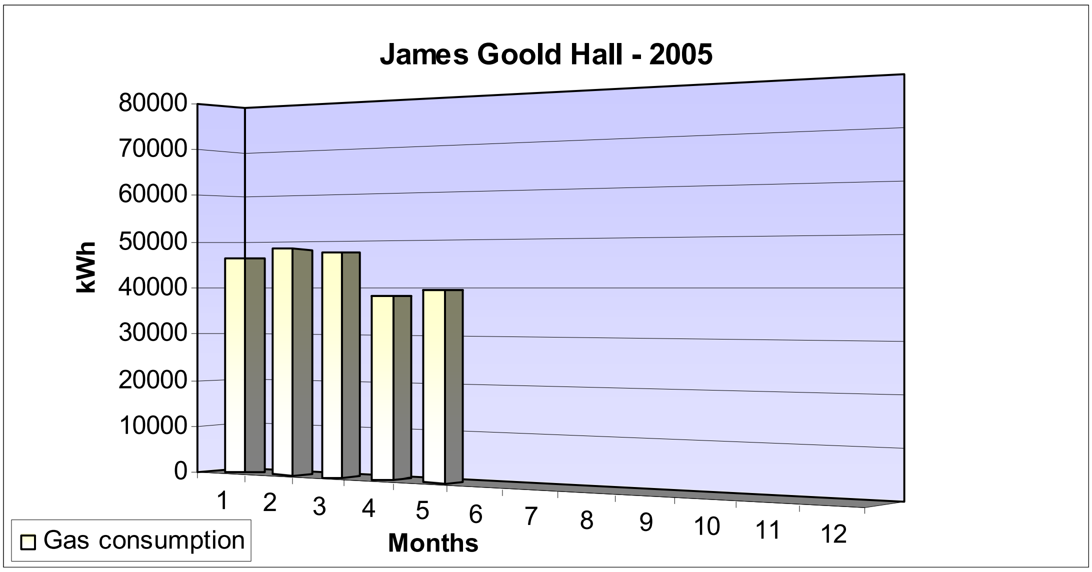
Month - Year	Degree days	Consumption (in kWh)	Correction factor f_1	Resulted consumption
January - 2004	322	52.683,97	0,968	52.683,97
February - 2004	312	44.870,97		51.047,82

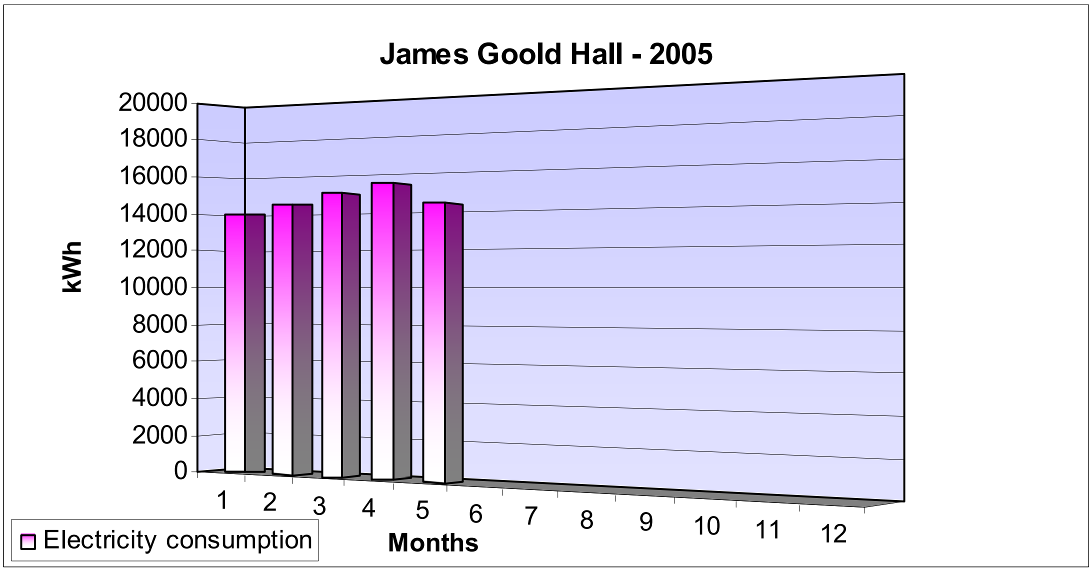


The electricity consumption was scaled related to the floor area of Block A.



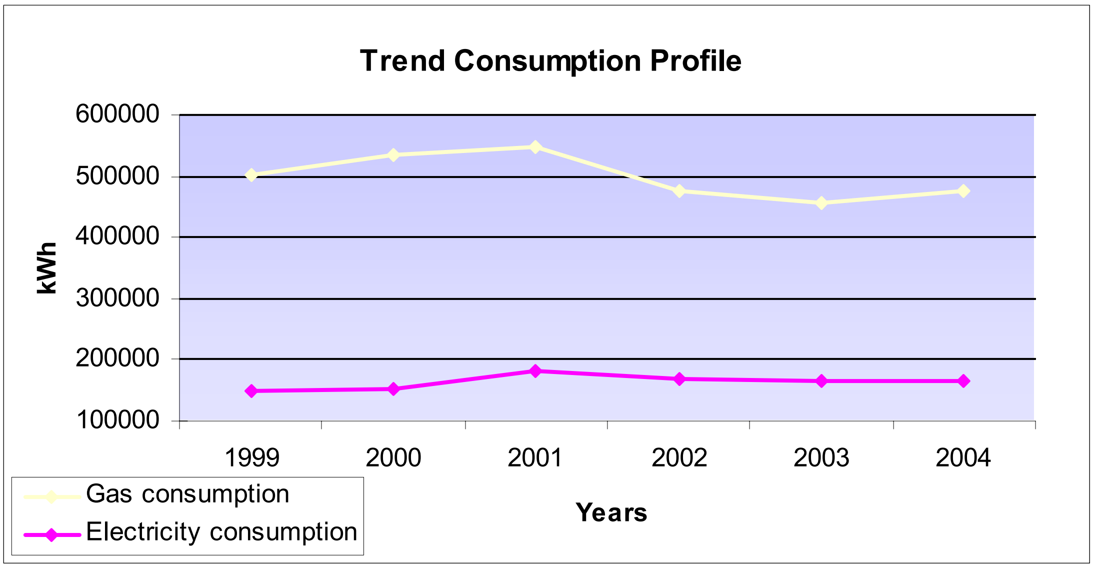
For 2005, the changes were made to the proportional gas and electricity consumption related to the Block A floor area.



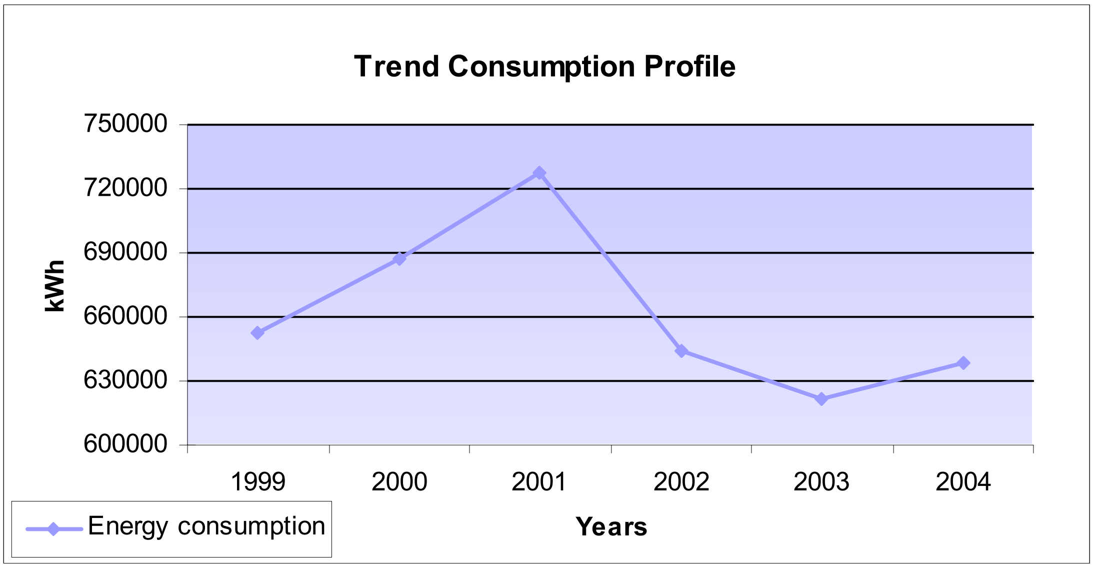


Appendix IV - Halls of residence energy consumption profiles

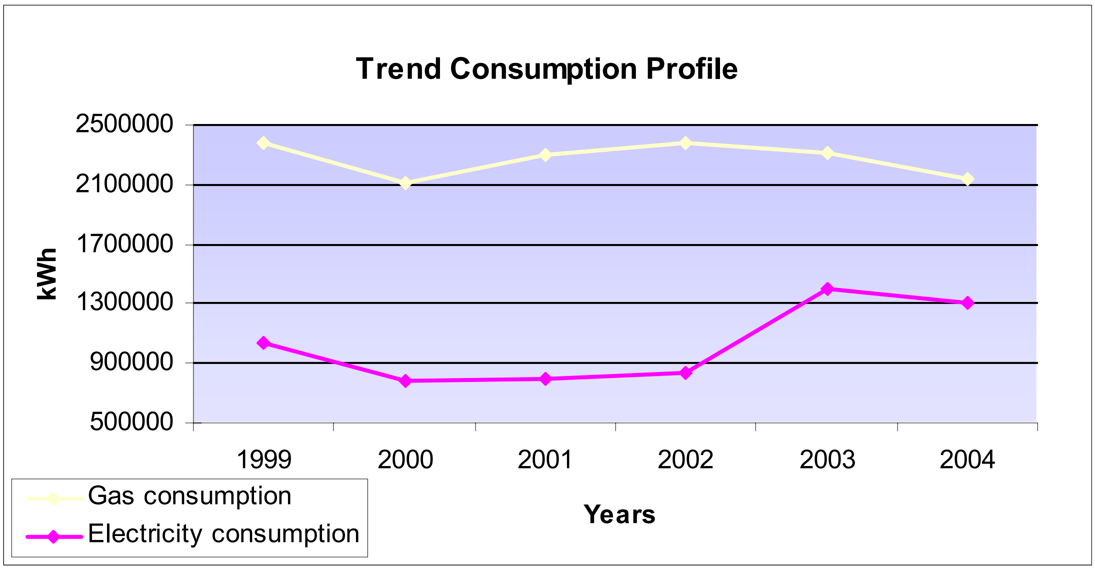
The resulting trend of gas and electricity consumptions of the James Goold Hall (Block A) is shown below:



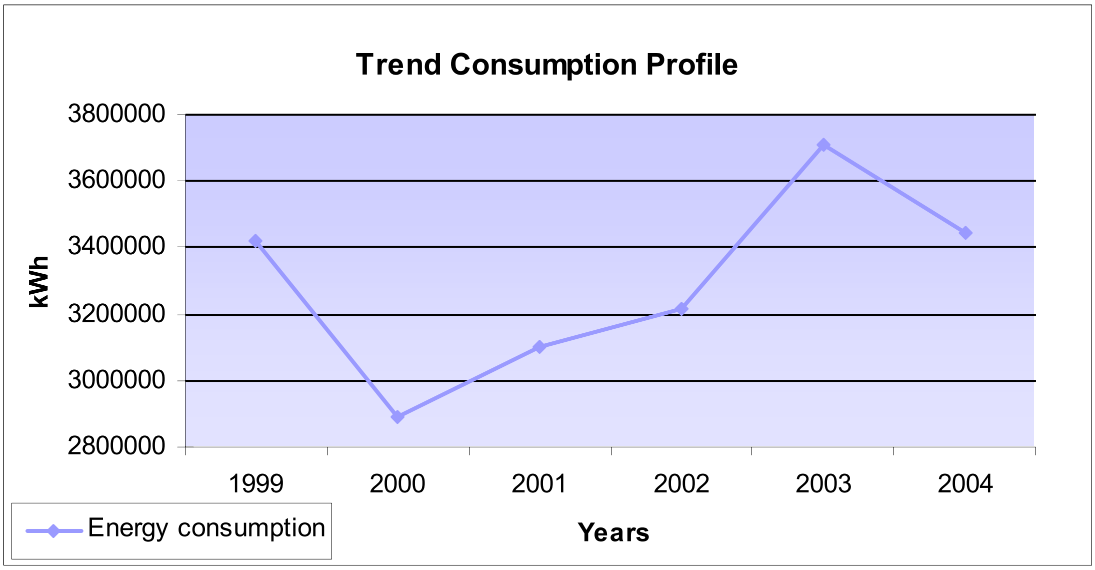
The resulting trend of energy consumption profile is shown below:



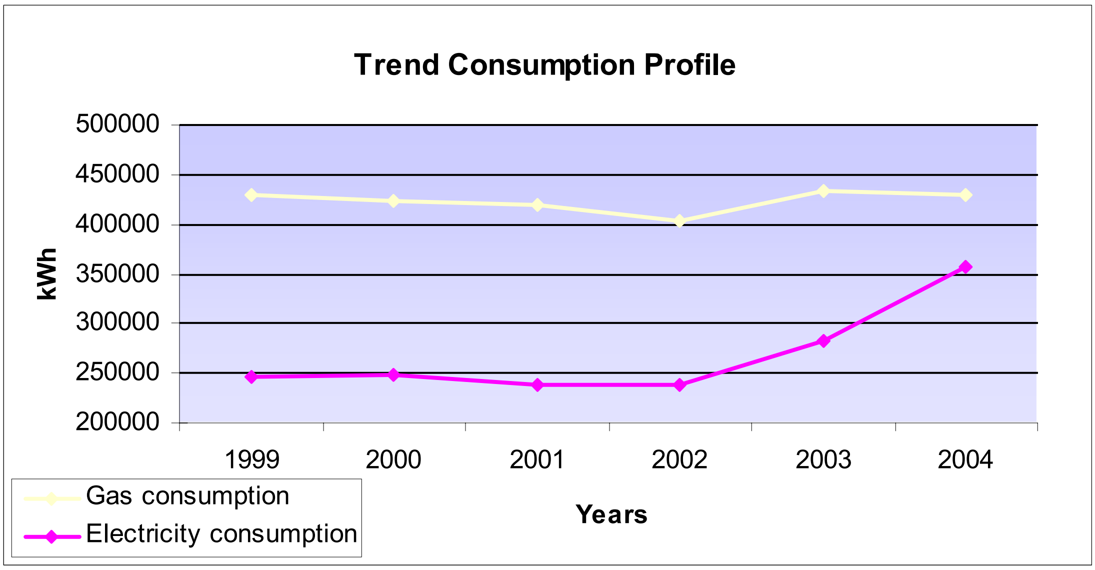
Birkbeck Court's profiles are illustrated below:



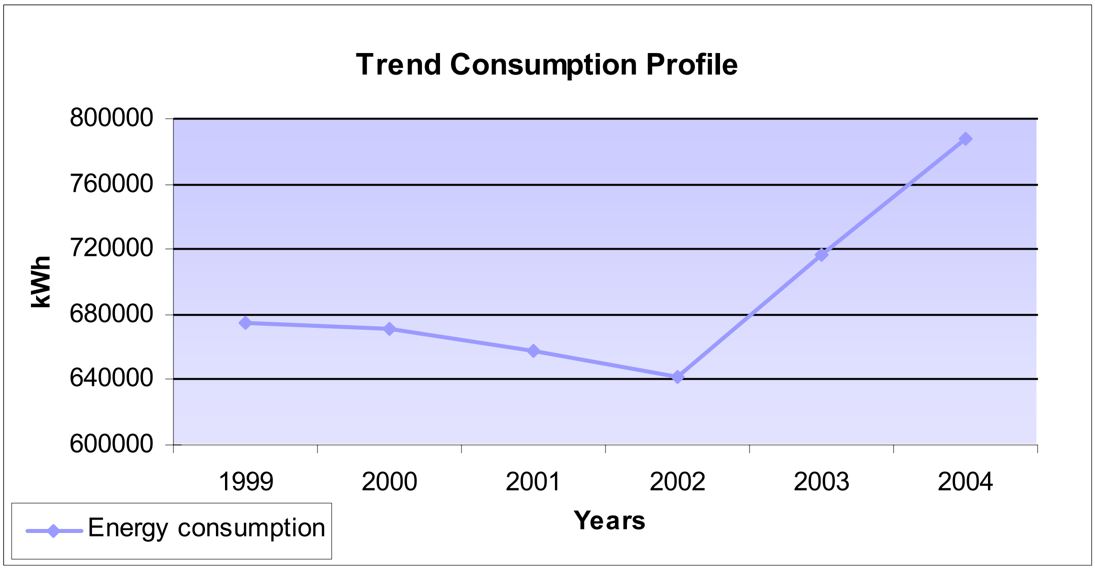
The resulting trend of energy consumption profile is shown below:



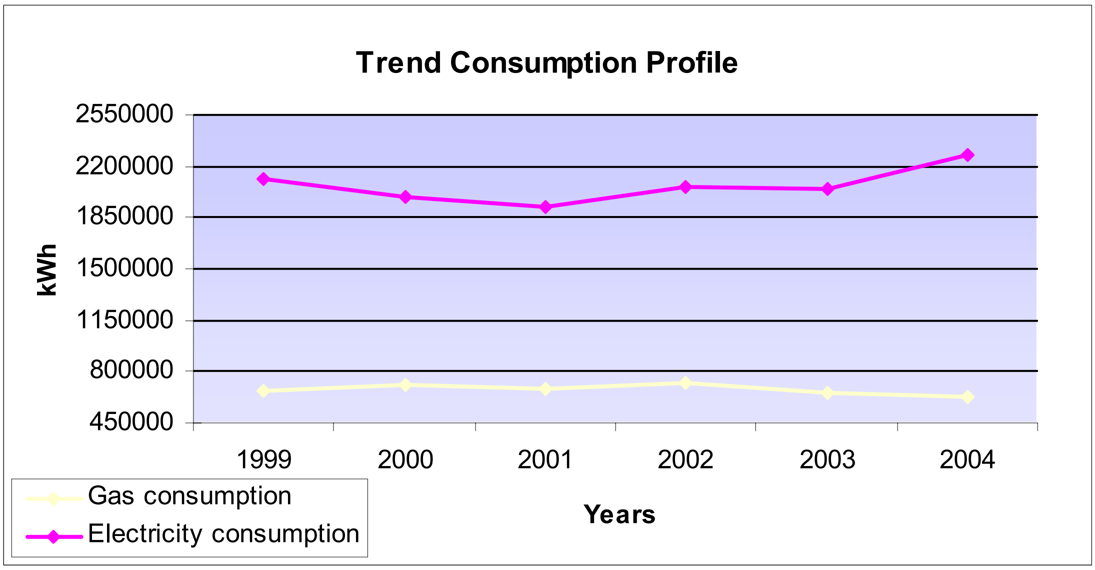
For the Thomas Campbell Court, the trend consumptions' profiles are as follows:



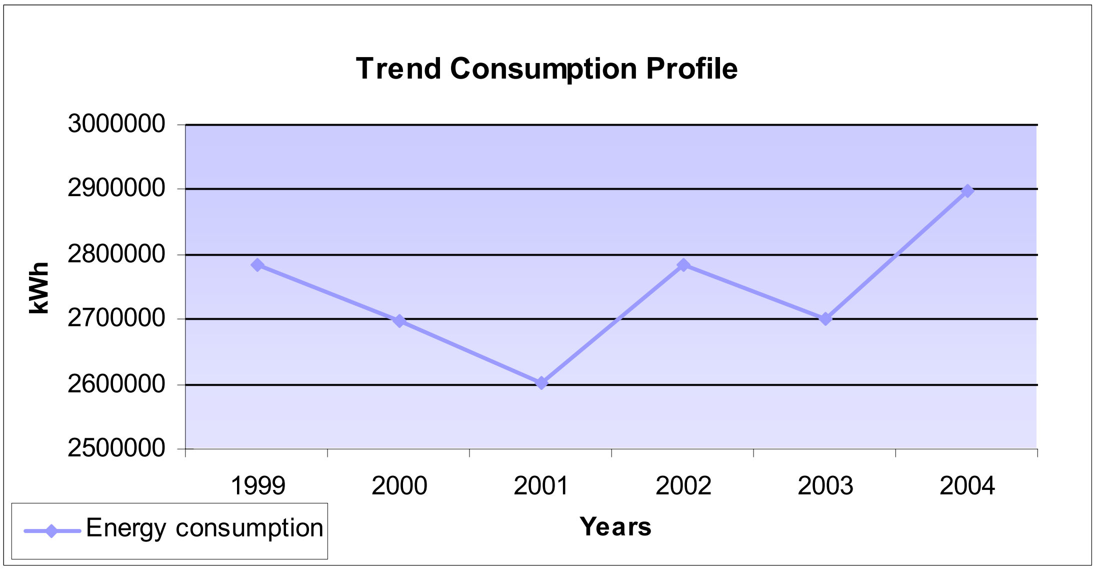
The combined energy consumption profile is illustrated below:



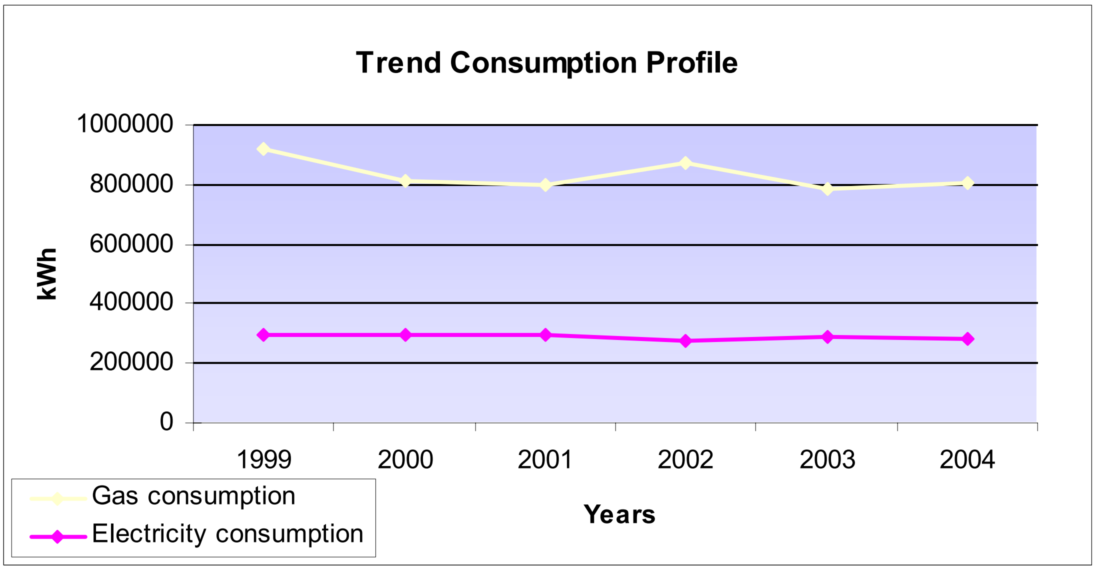
James Blyth Court's profiles are illustrated below:



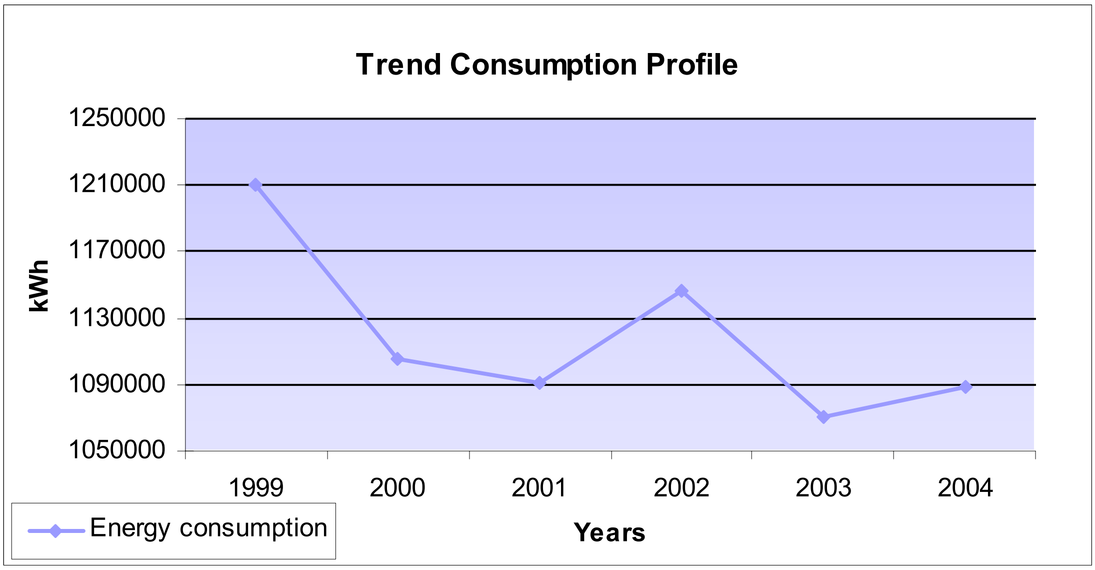
The resulting trend of energy consumption profile of the James Blyth Court is shown below:



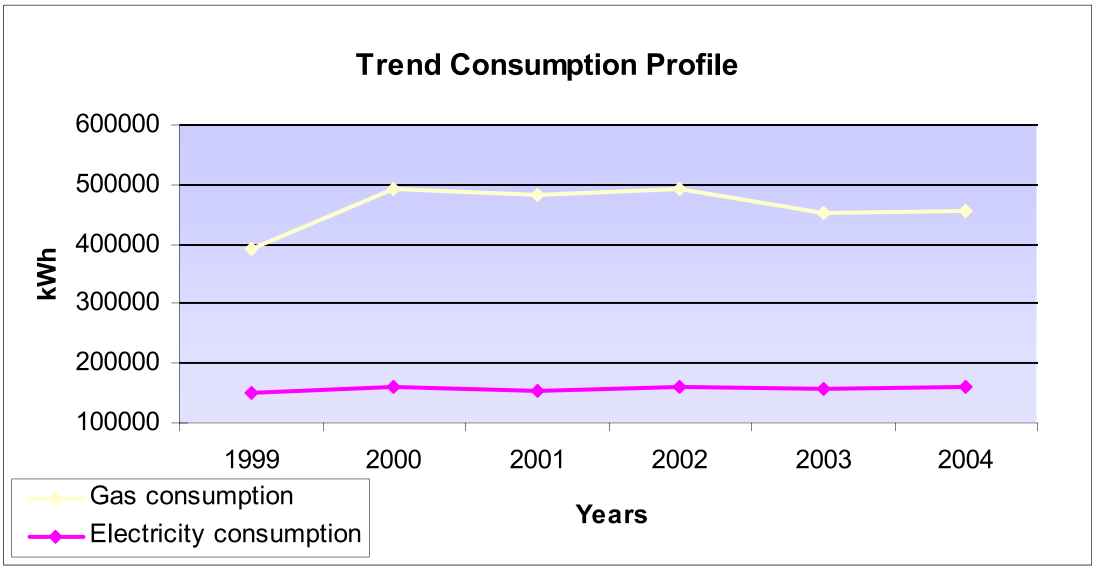
For Chancellors Hall, the trend consumptions' profiles are as follows:



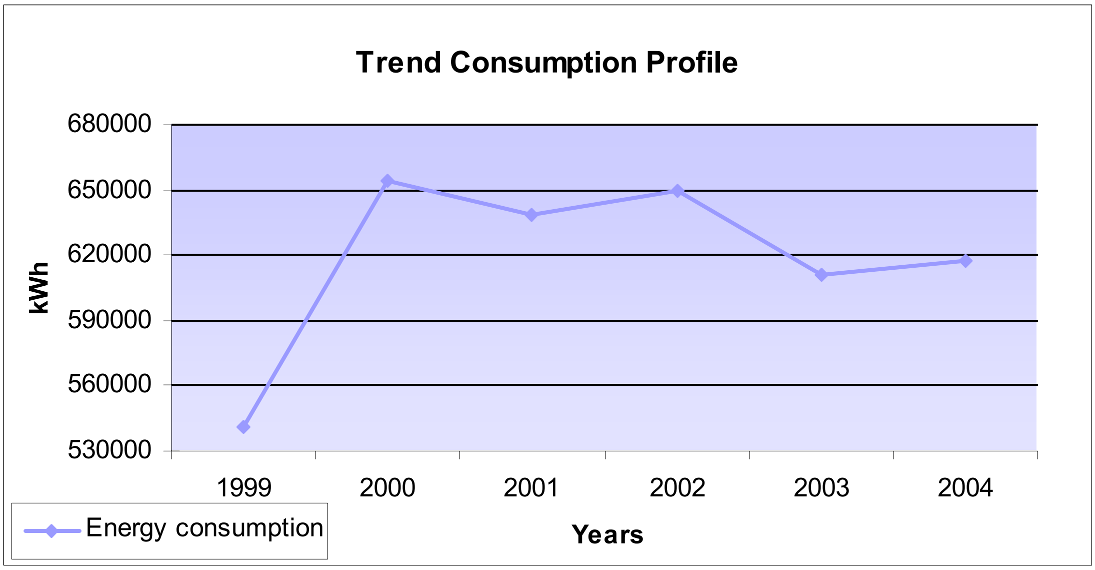
The combined energy consumption profile of the Chancellors Hall is illustrated below:



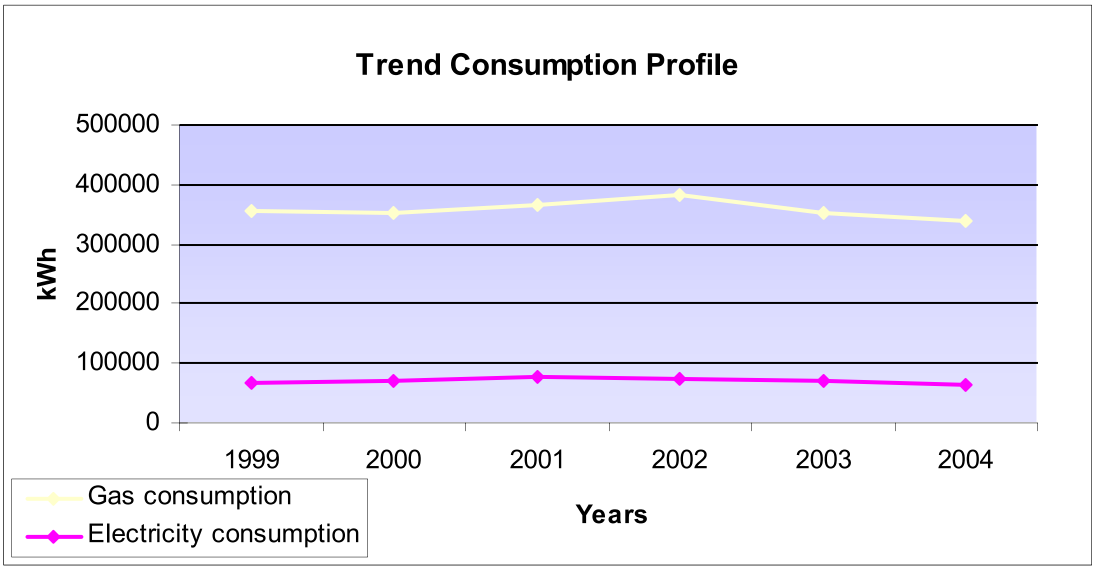
Forbes Hall's trend consumptions' profiles are:



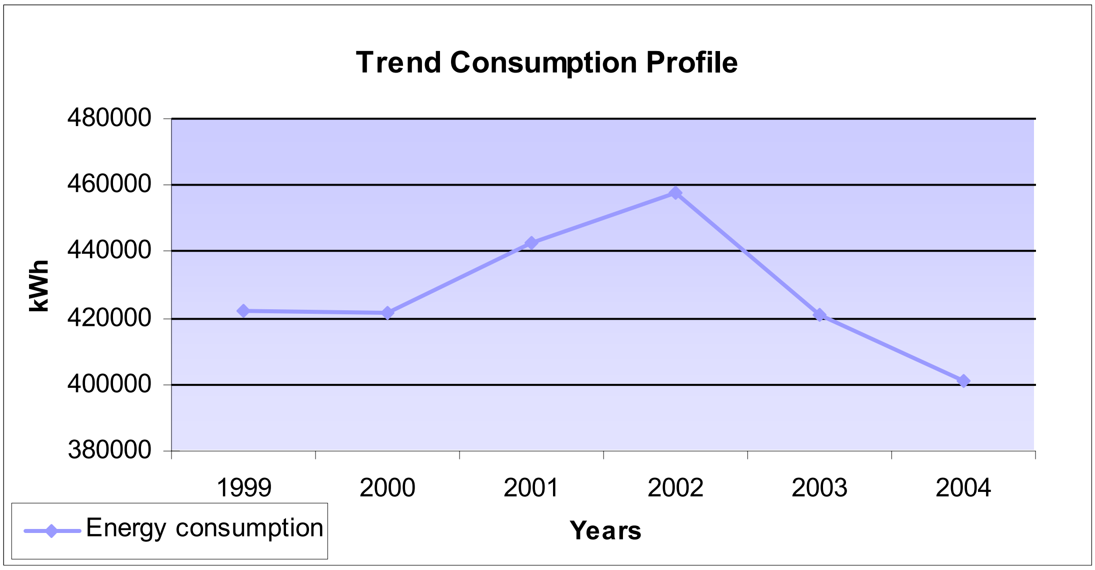
The combined energy consumption profile is illustrated below:



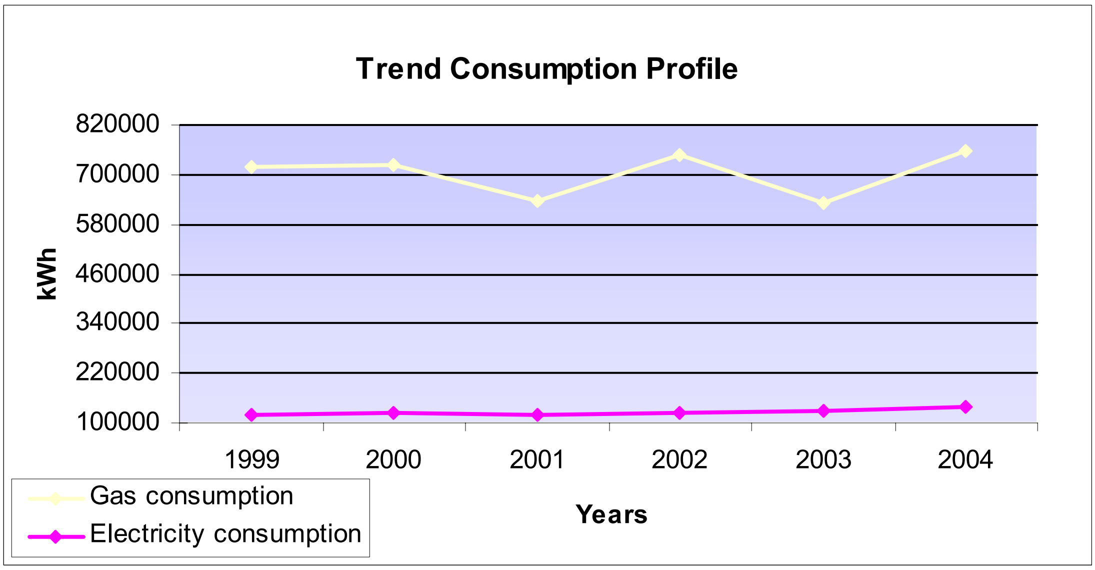
For James Young Hall, the trend consumptions' profiles are as follows:



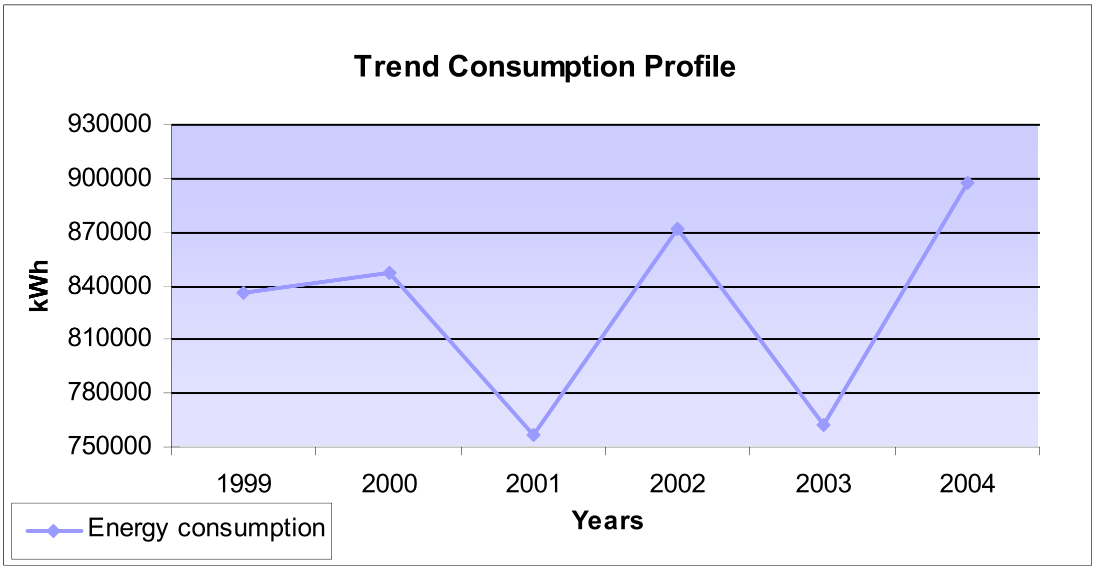
The resulting trend of energy consumption profile is shown below:



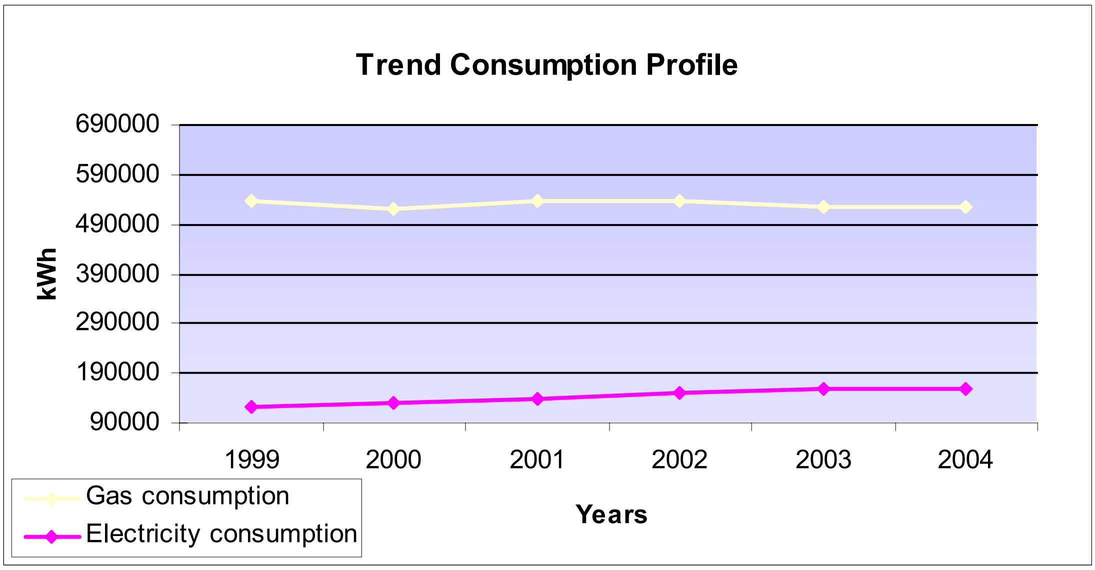
The Murray Hall's profiles are illustrated below:



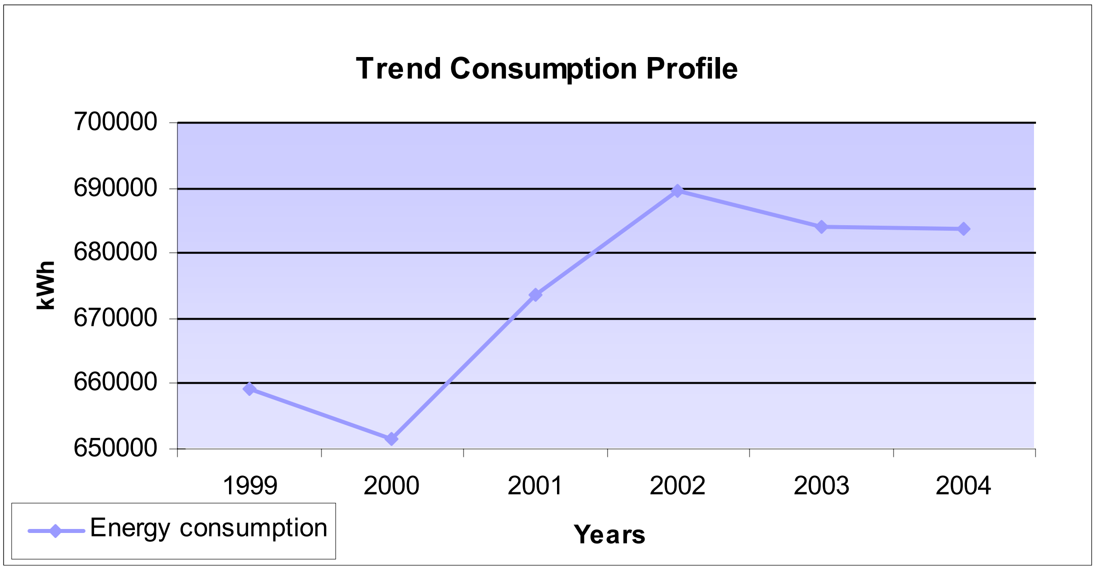
The combined energy consumption profile of Murray Hall follows:



Garnet Hall's trend consumptions' profiles are:

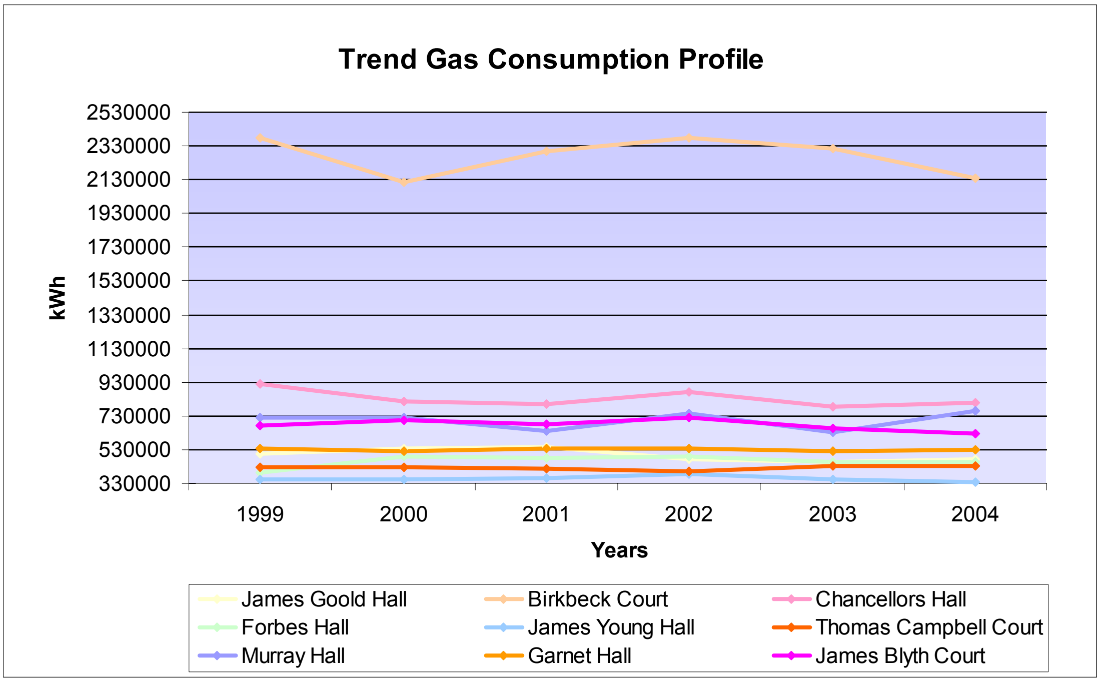


The combined energy consumption profile is illustrated below:

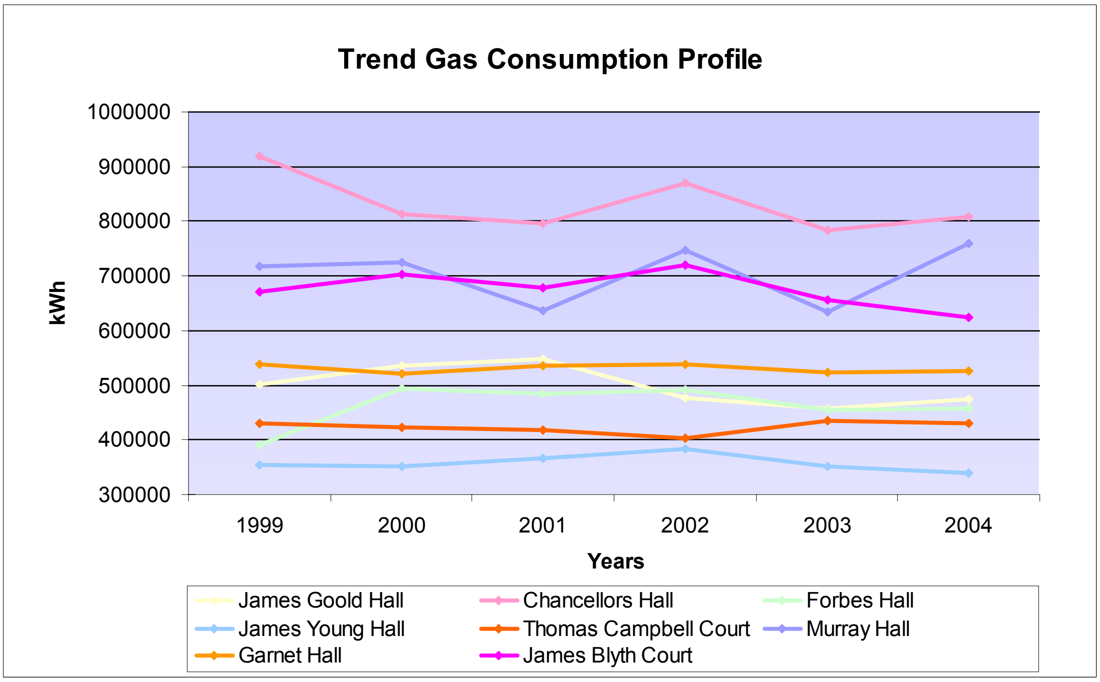


Appendix V - Halls of residence grouped energy consumption profiles

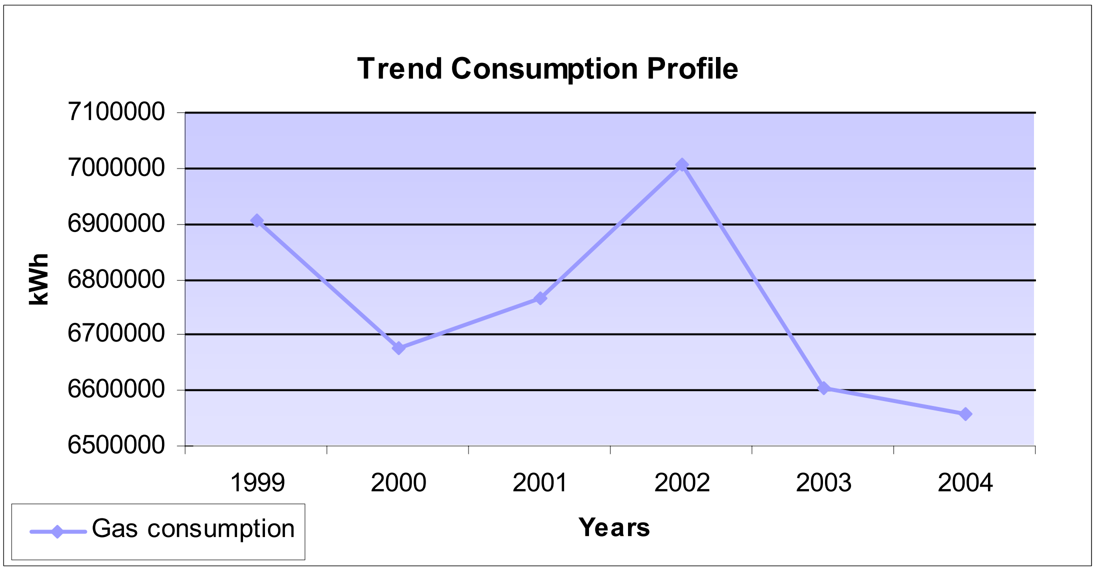
The gas consumption profile of each hall of residence is shown below:



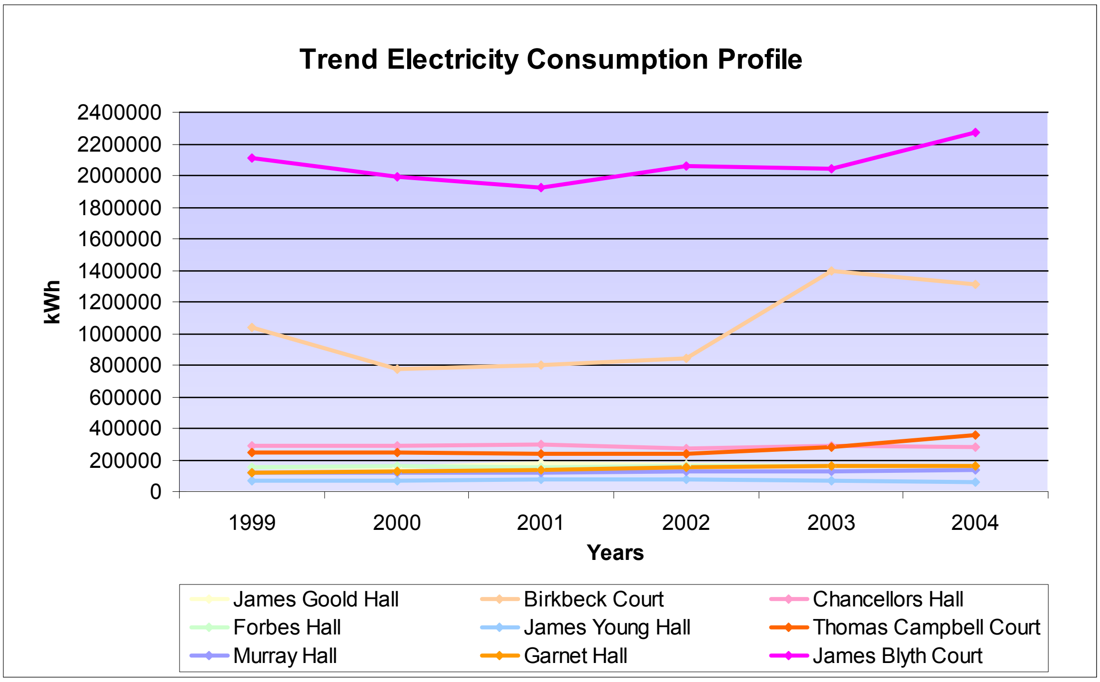
Excluding Birkbeck Court, the chart above changes to the following:



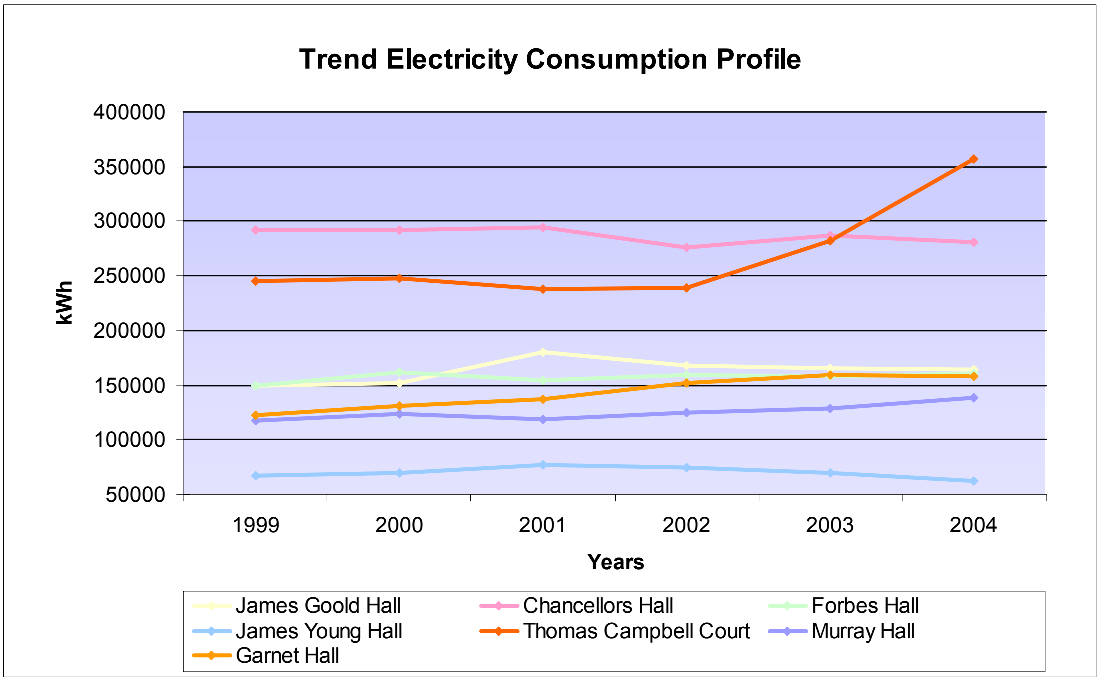
Combining the halls' of residence gas consumption, the result has as follows:



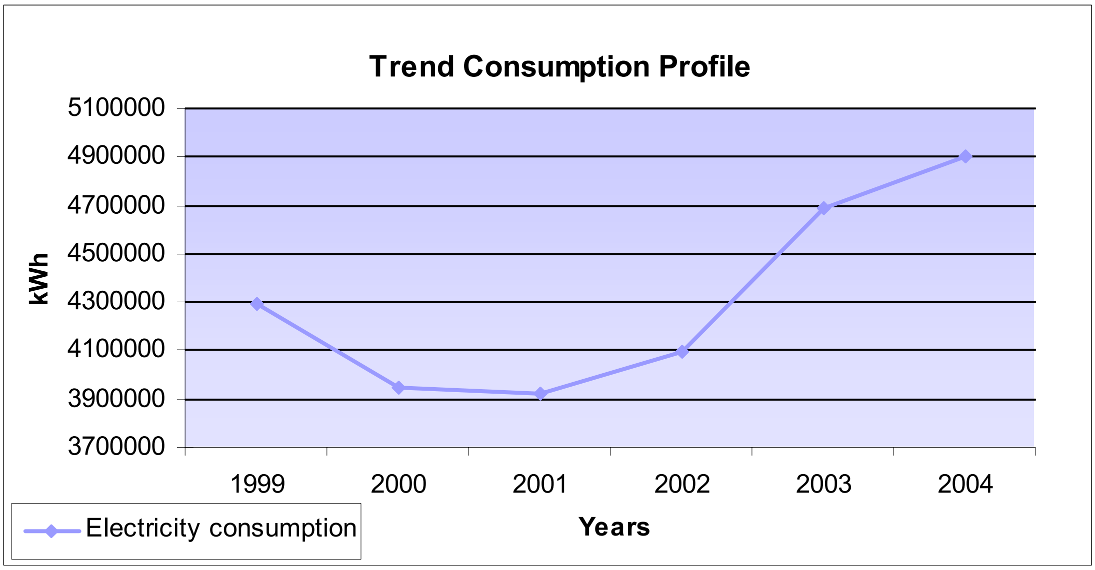
The electricity consumption profile of each hall of residence is shown below:



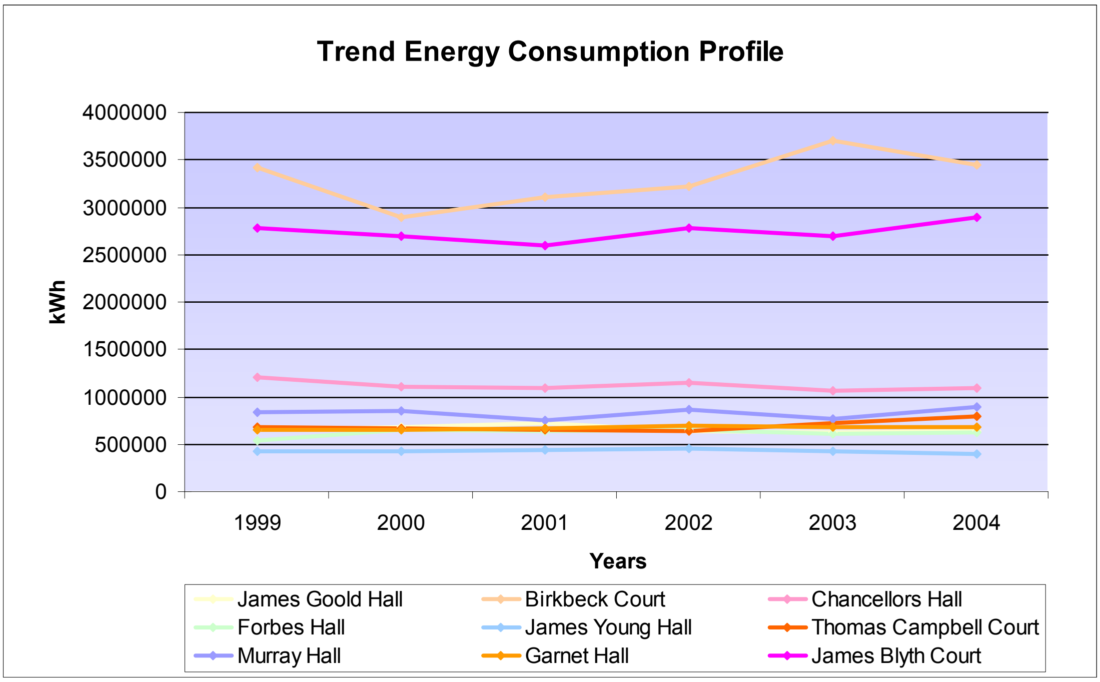
Excluding James Blyth Court and Birkbeck Court, the chart above changes to the following:



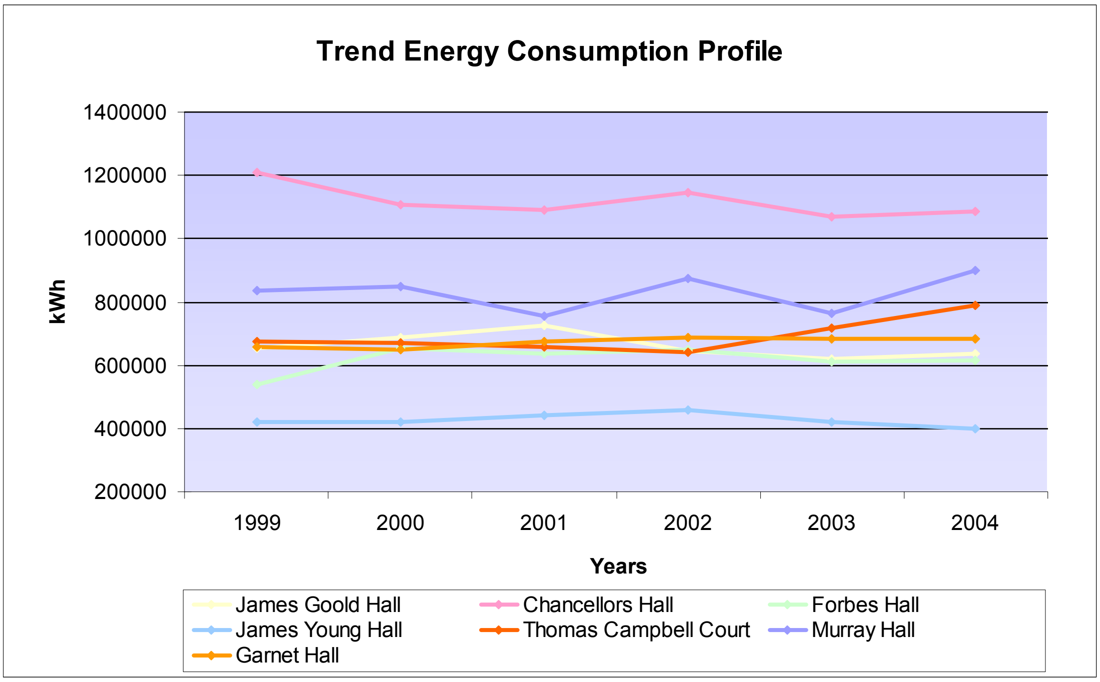
Combining the halls' of residence electricity consumption, the resulting one has as follows:



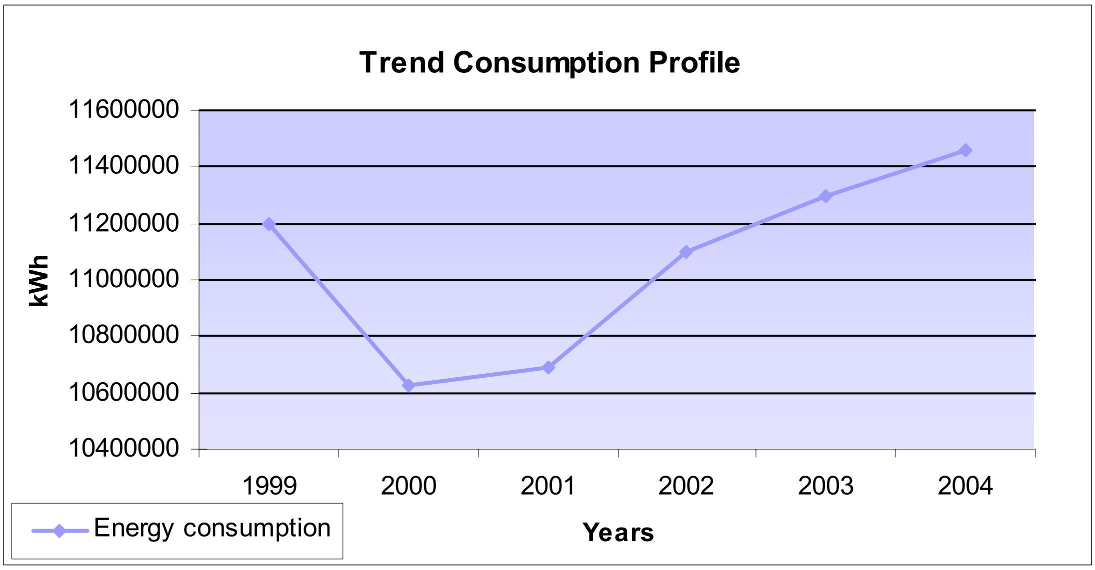
Each hall of residence' energy consumption is illustrated below:



Excluding Birkbeck Court and James Blyth Court, the chart above changes to the following:

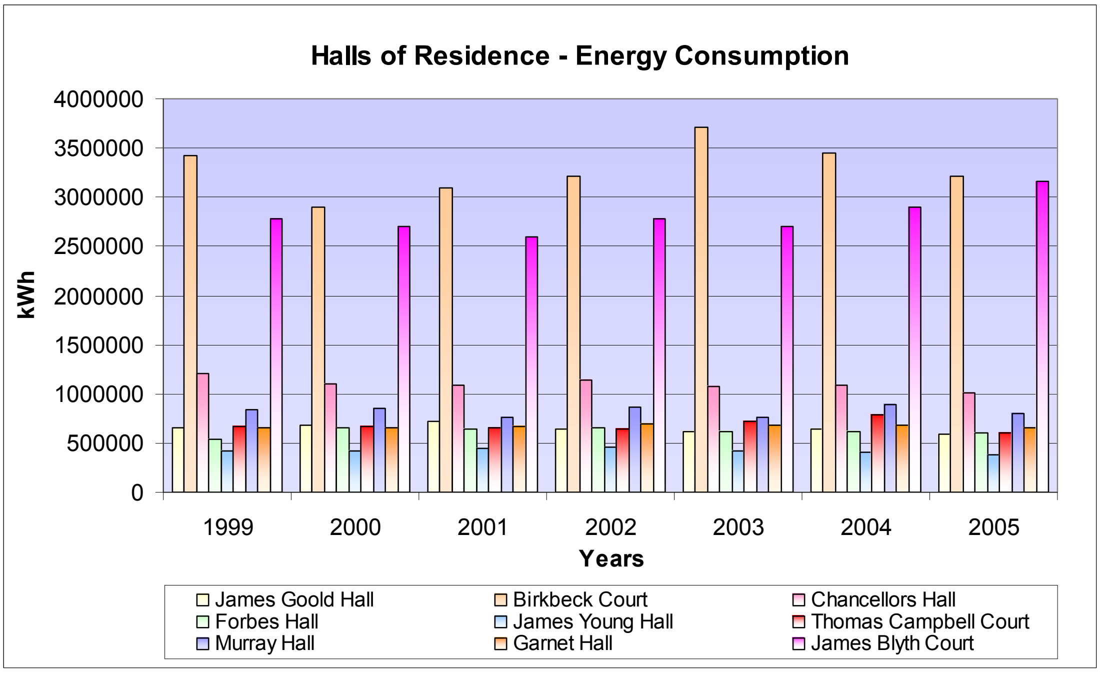


Combining the halls' of residence energy consumption, the result has as follows:

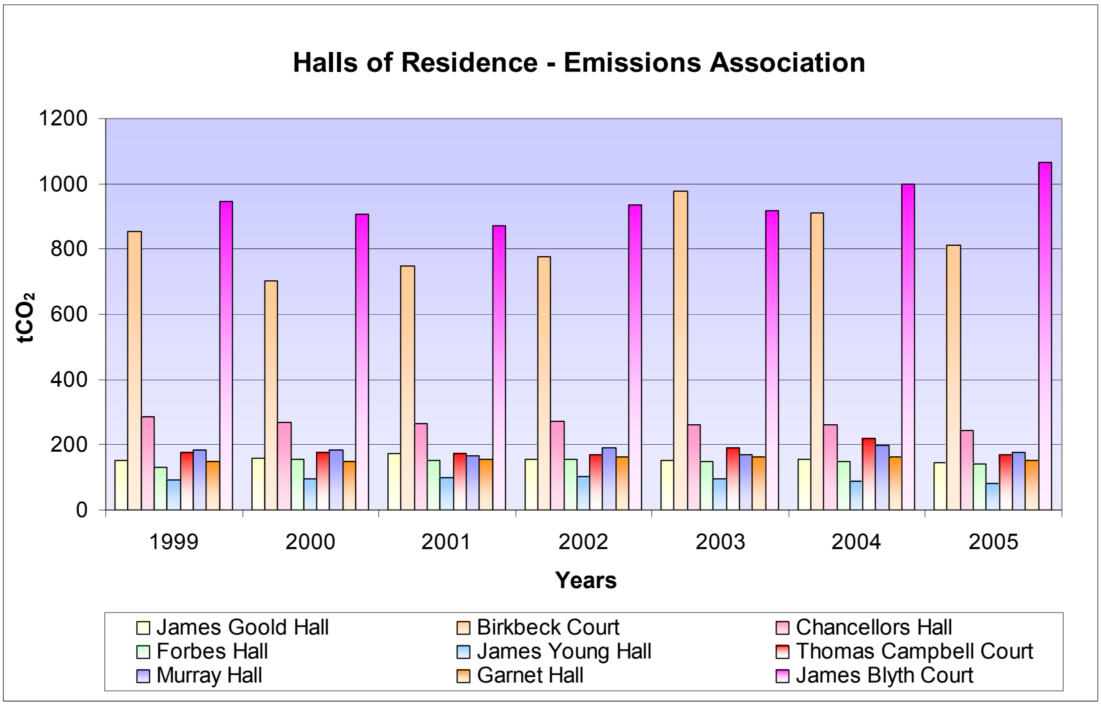

Trend Consumption Profile
11600000
11400000
11200000
11000000
10800000
10600000
10400000
kWh
1999
2000
2001
2002
2003
2004
Years
Energy consumption

Appendix VI - Halls of residence energy consumption and CO_2 emissions

The graphical representation of all halls of residence energy consumption is illustrated below followed by each buildings associated emissions. The overall picture for the halls shows the increased energy consumptions by Birkbeck, James Blyth and Thomas Campbell Court.

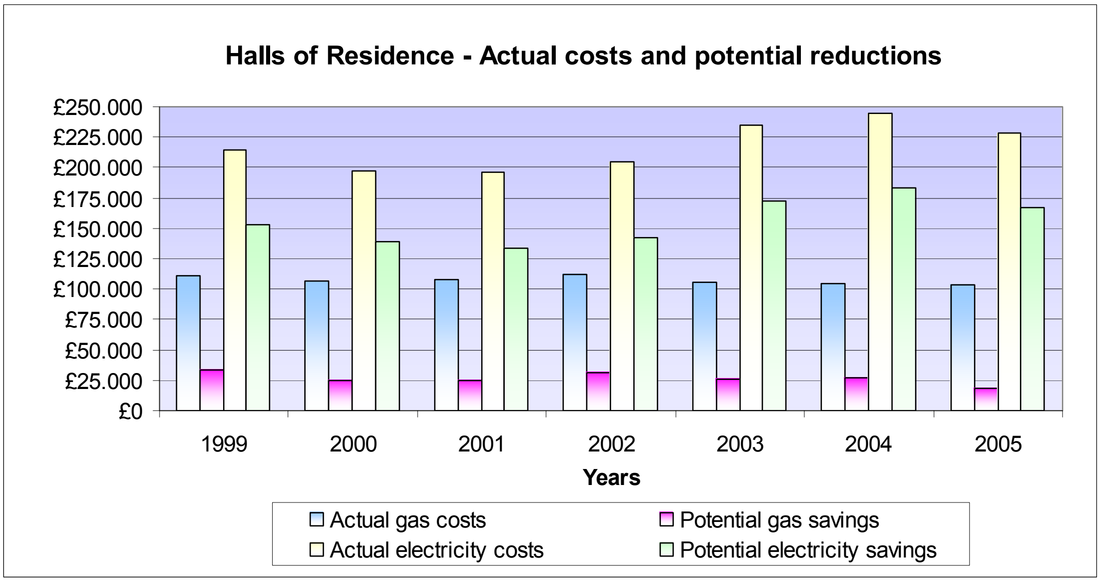


The carbon dioxide emitted by the halls of residence is as follows:

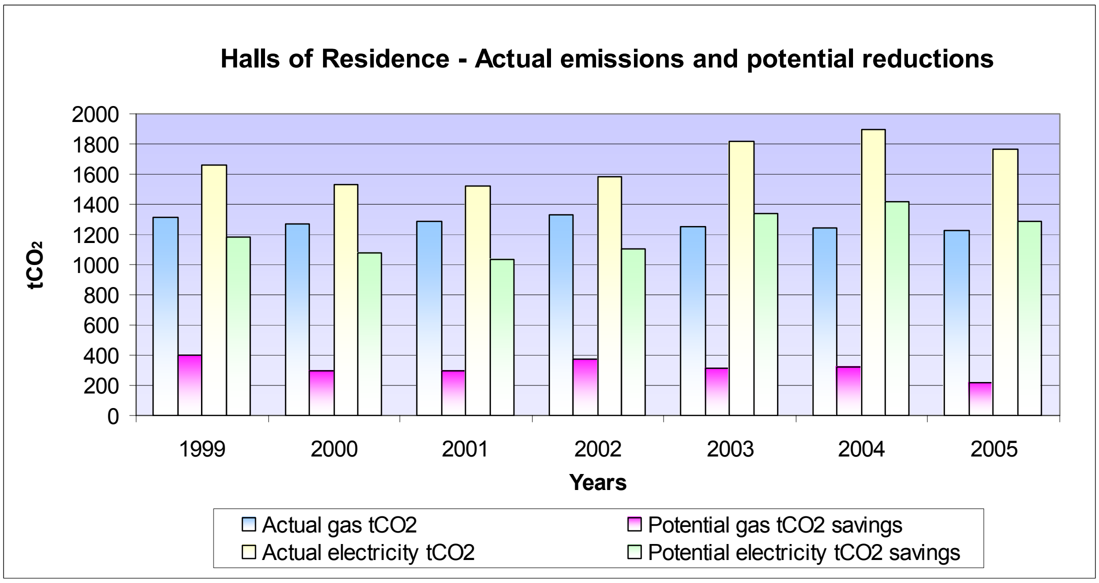


Appendix VII - Overall quantification of the cost and CO_2 emissions savings

The halls' of residence total potential energy cost savings, according to the actual consumptions against the good practice benchmark, are illustrated below.



Once more, these costs were interpreted in CO_2 potential savings versus the good practice benchmark, following below.



Appendix VIII - Halls of residence in G.I.S.

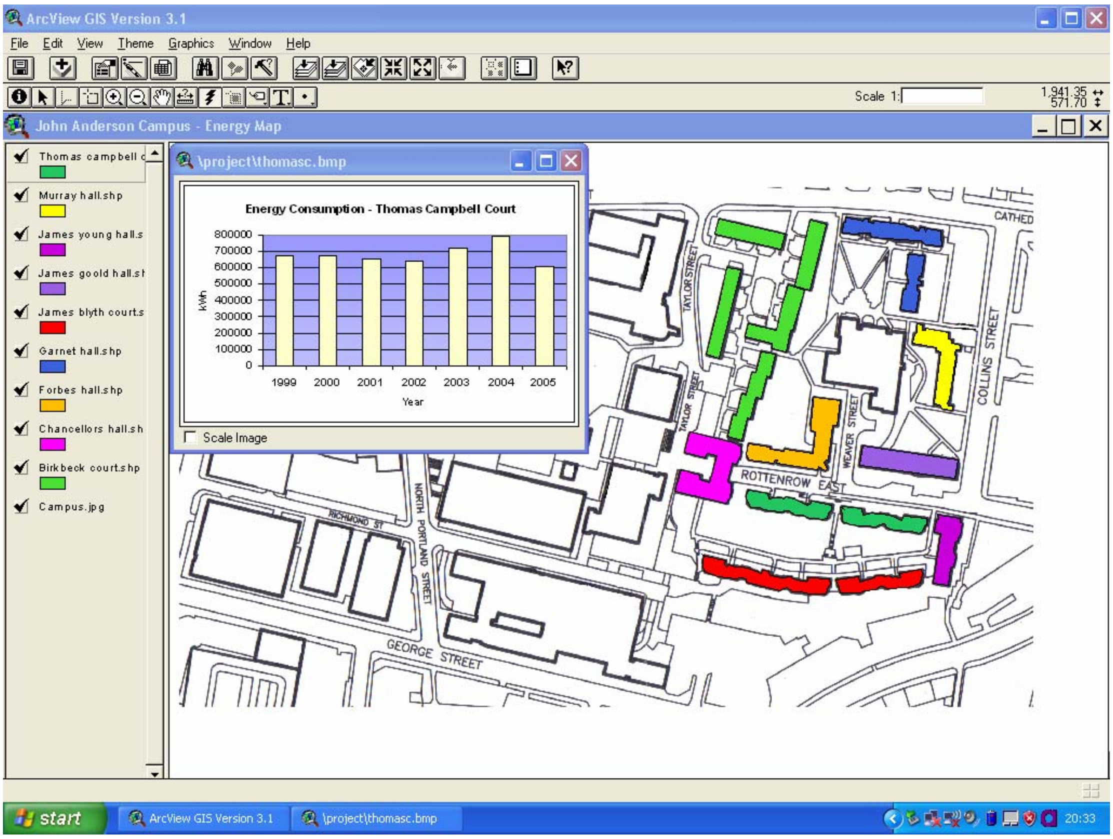


Figure VIII.1: Thomas Campbell Court's energy consumption

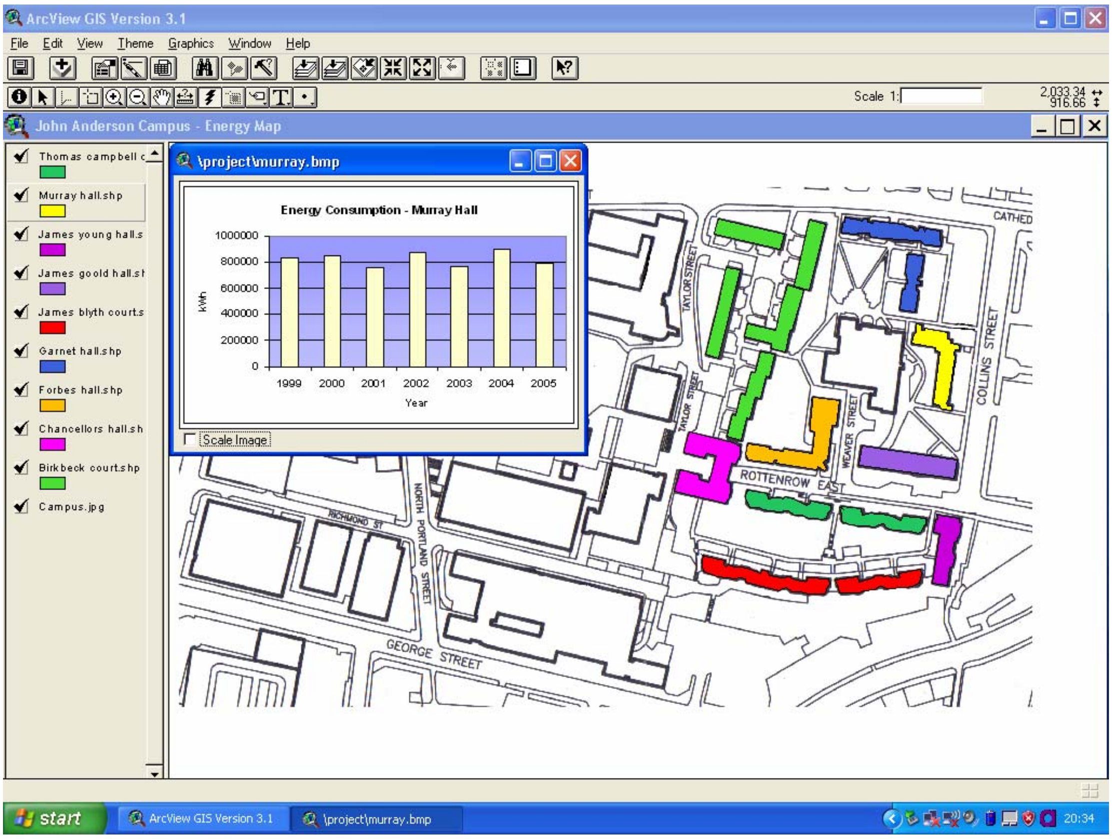


Figure VIII.2: Murray Hall's energy consumption

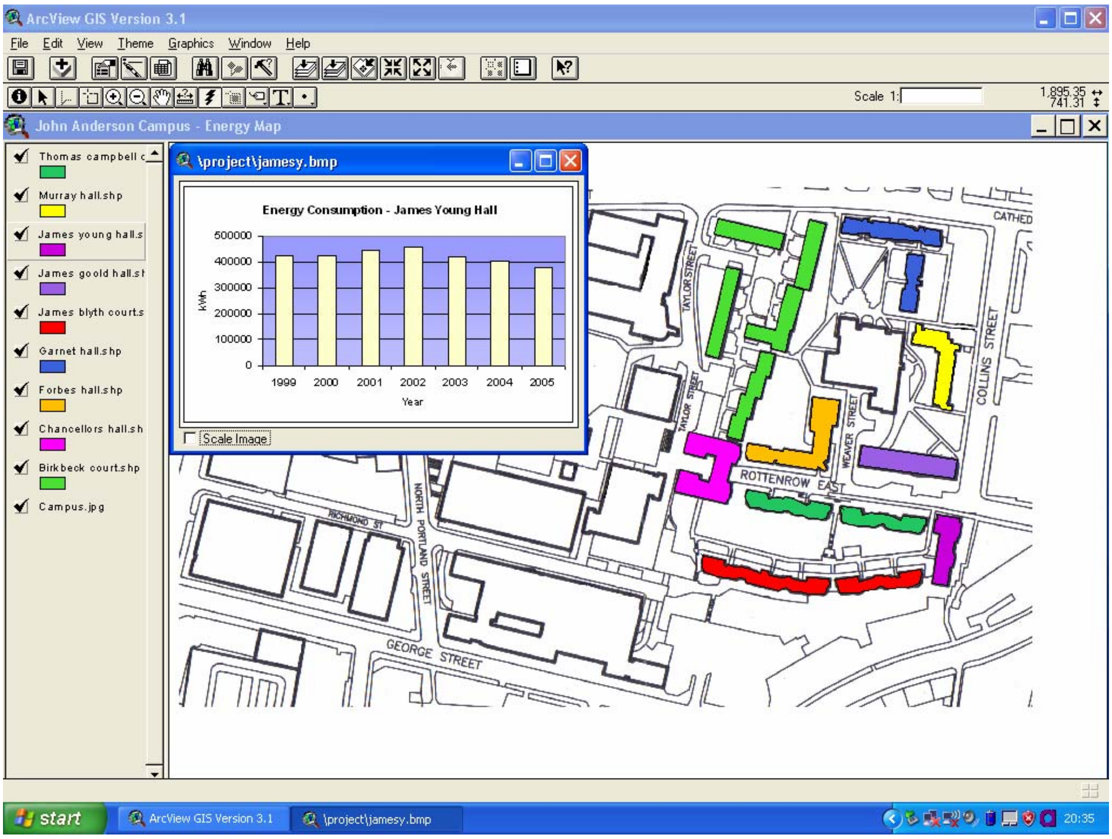


Figure VIII.3: James Young Hall's energy consumption

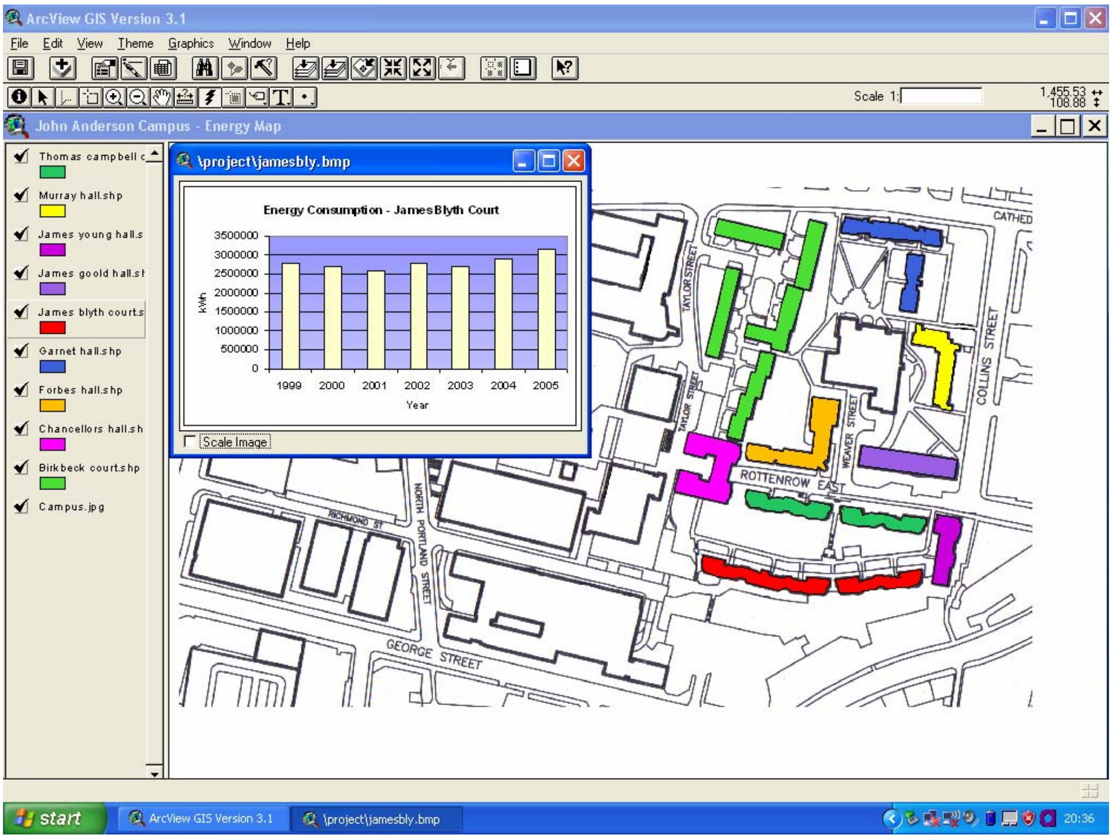


Figure VIII.4: James Blyth Court's energy consumption

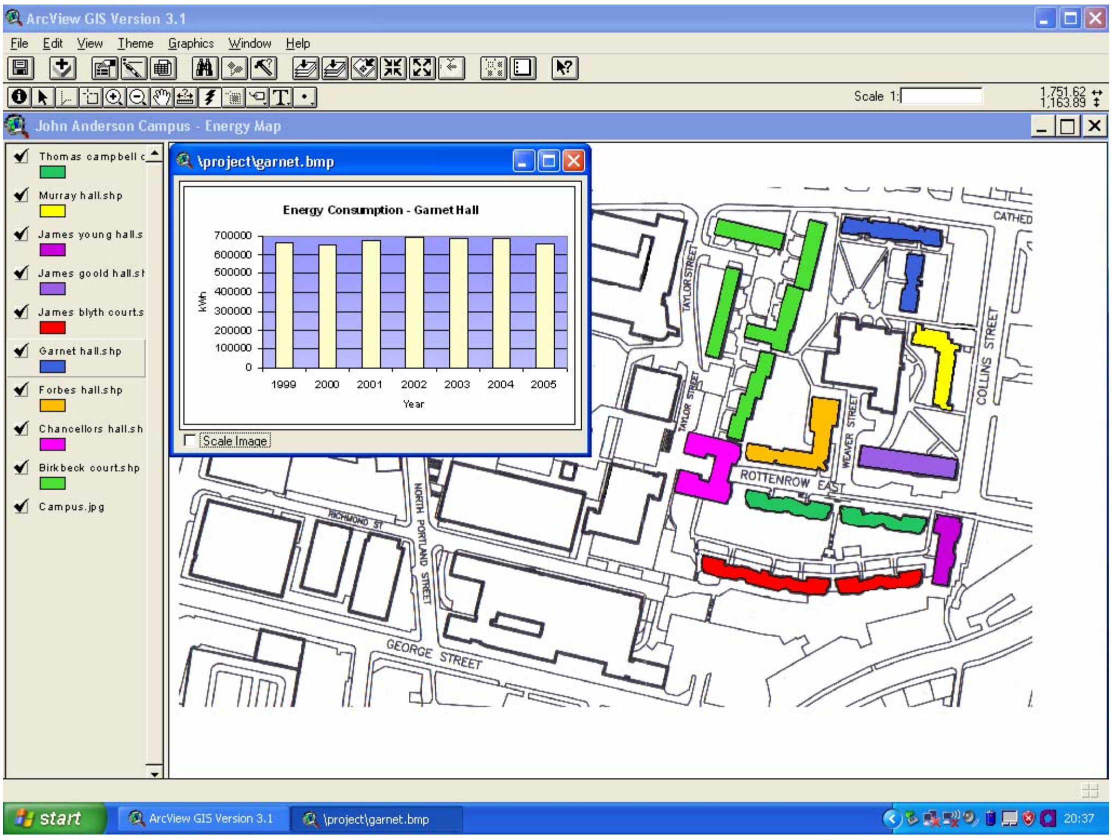


Figure VIII.5: Garnet Hall's energy consumption

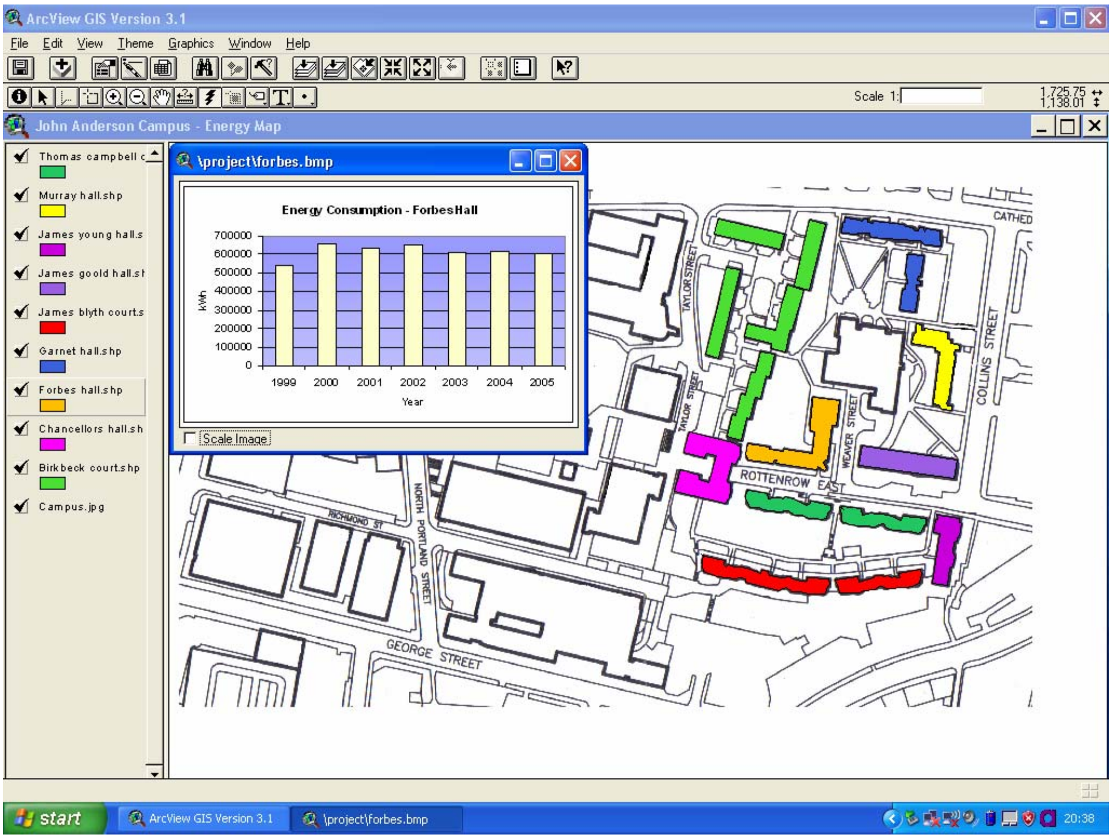


Figure VIII.6: Forbes Hall's energy consumption

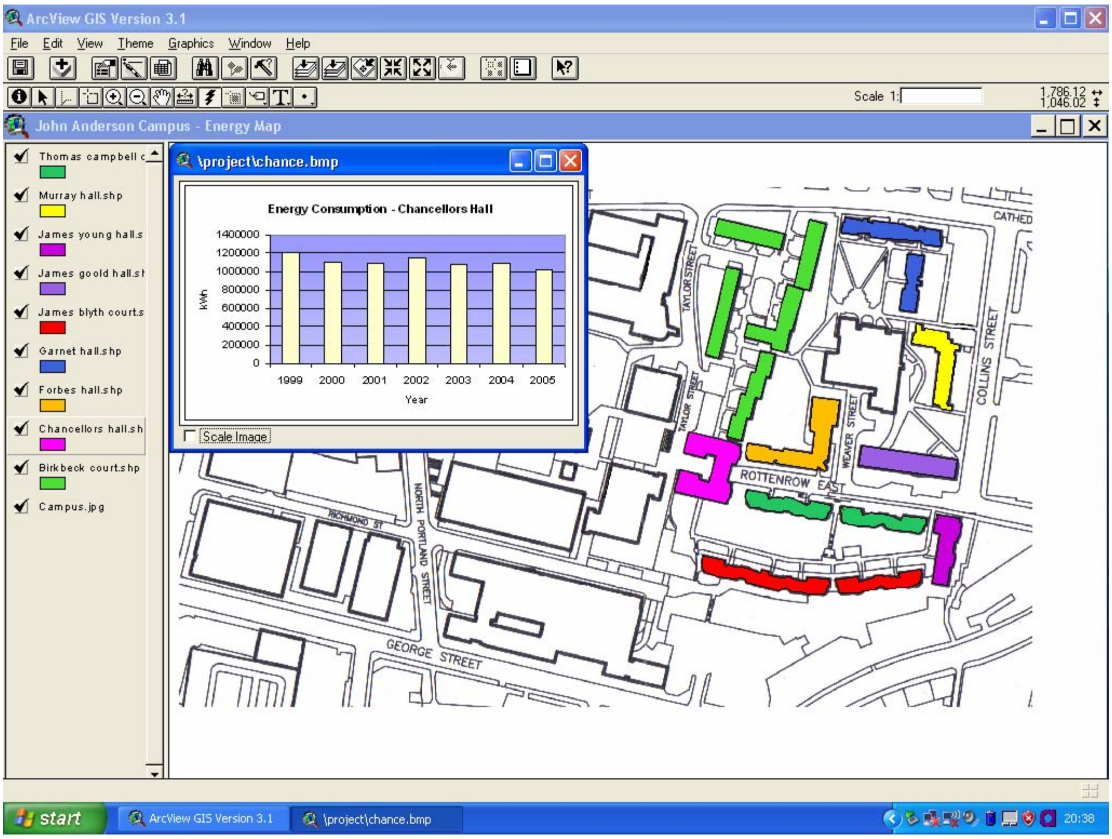


Figure VIII.7: Chancellors Hall energy consumption

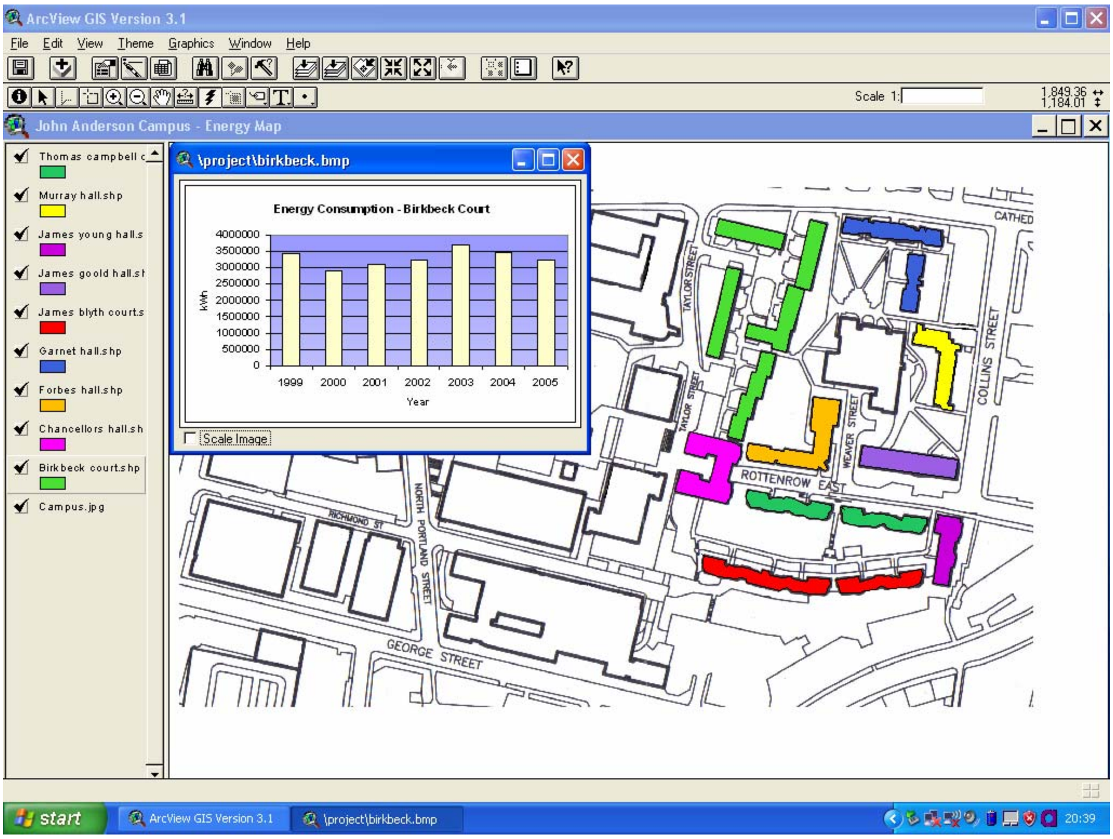


Figure VIII.8: Birkbeck Court's energy consumption

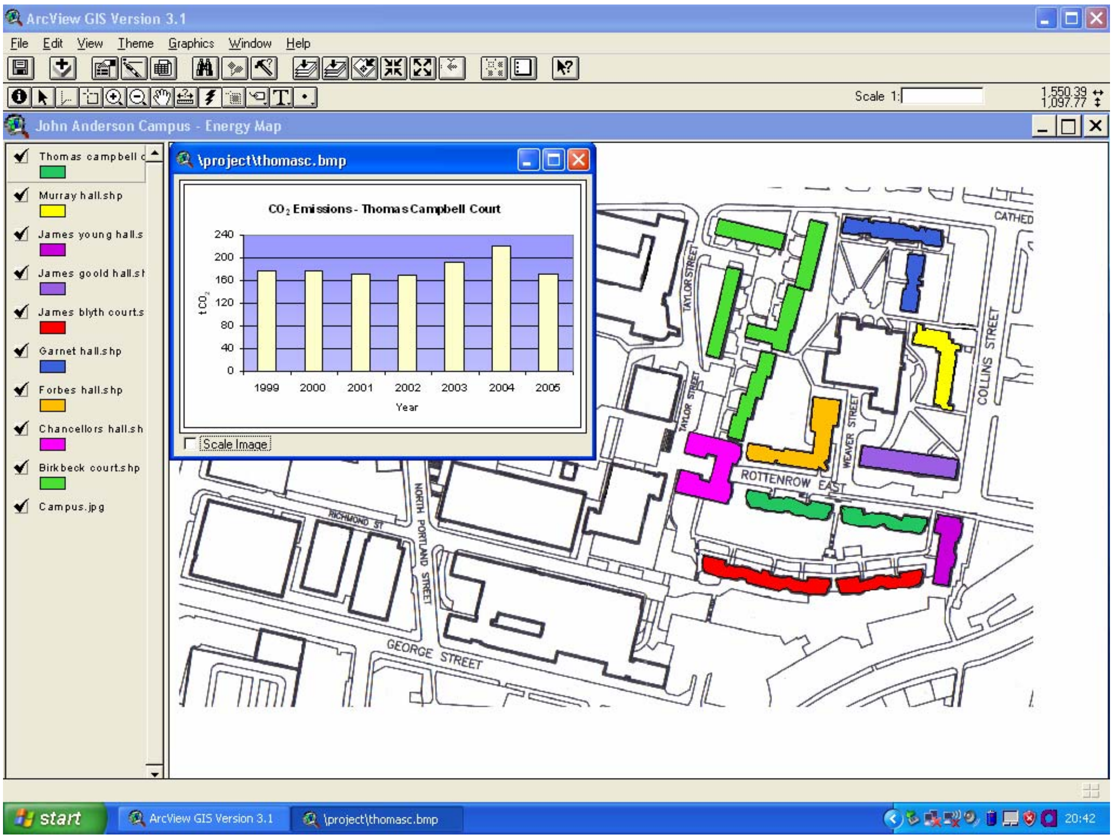


Figure VIII.9: Thomas Campbell Court's CO_2 emissions

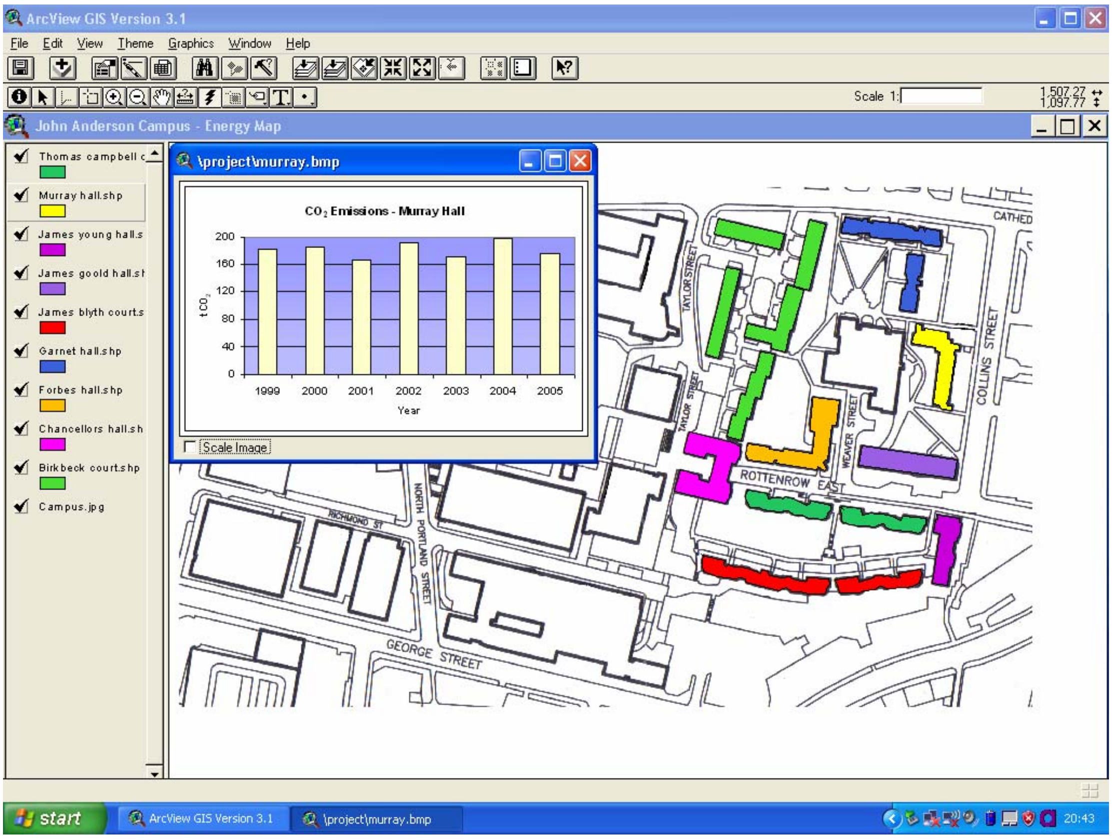


Figure VIII.10: Murray Hall's CO_2 emissions

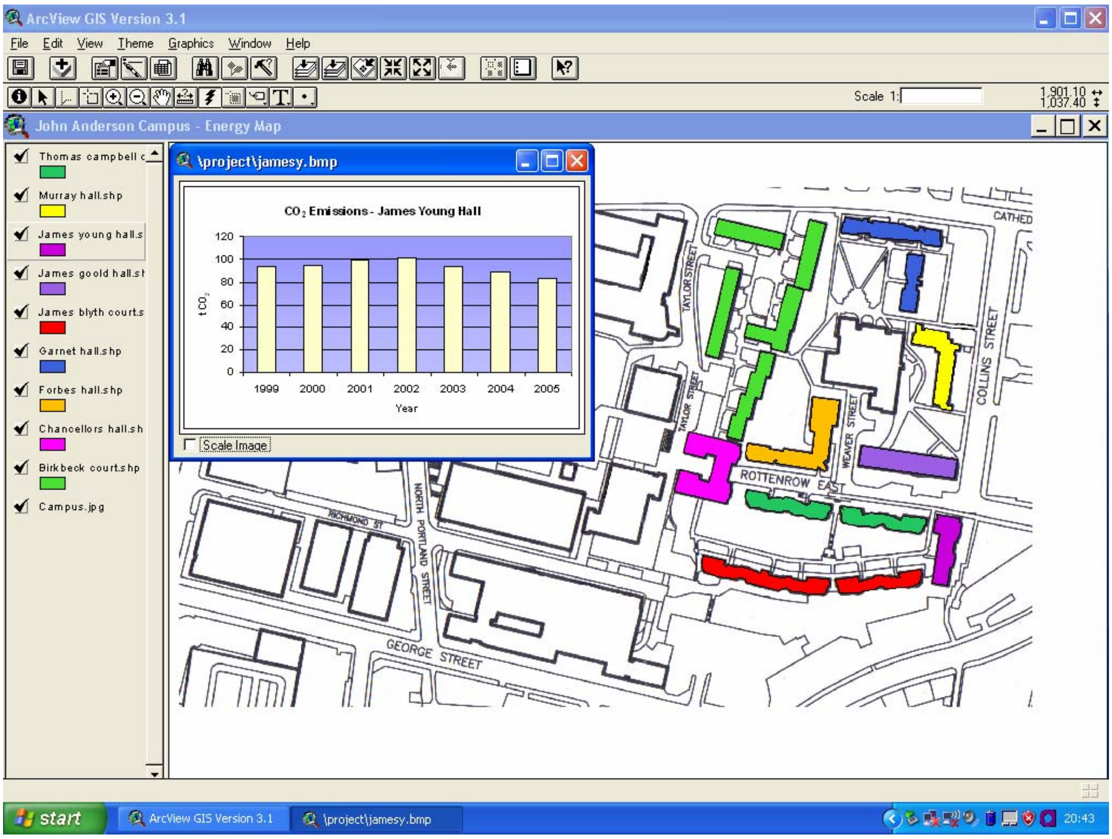


Figure VIII.11: James Young Hall's CO_2 emissions

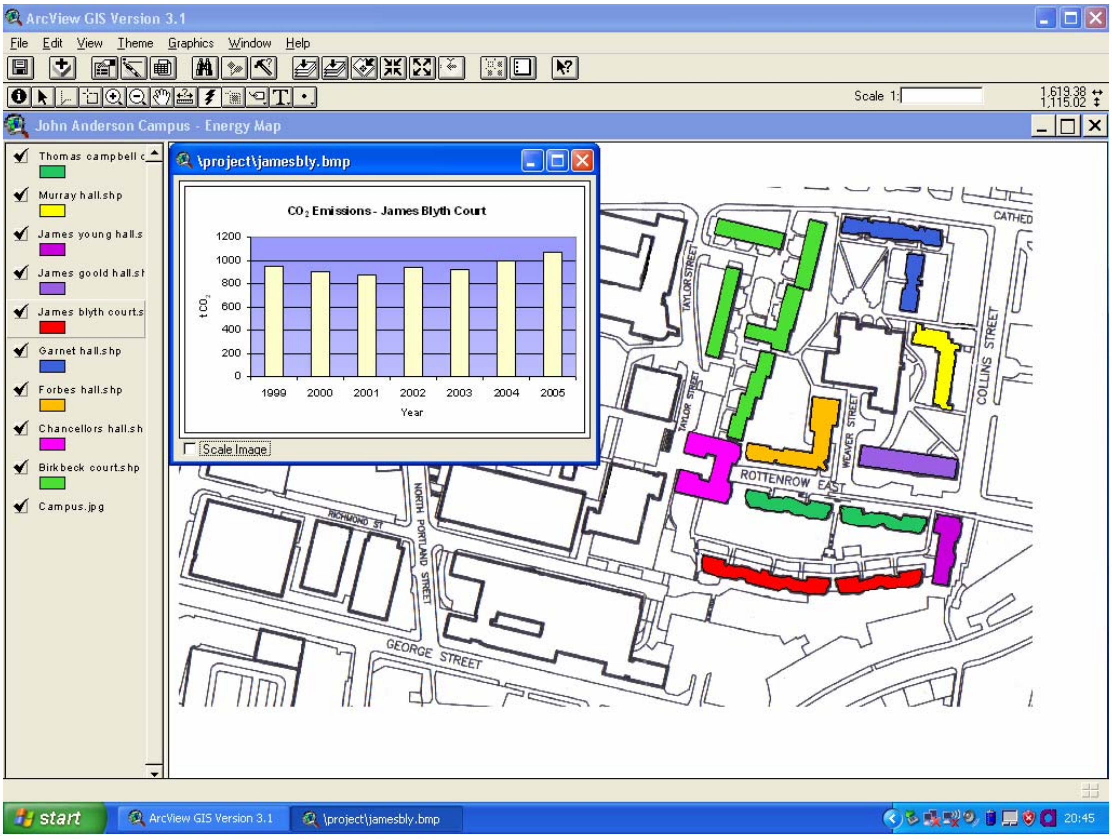


Figure VIII.12: James Blyth Court's CO_2 emissions

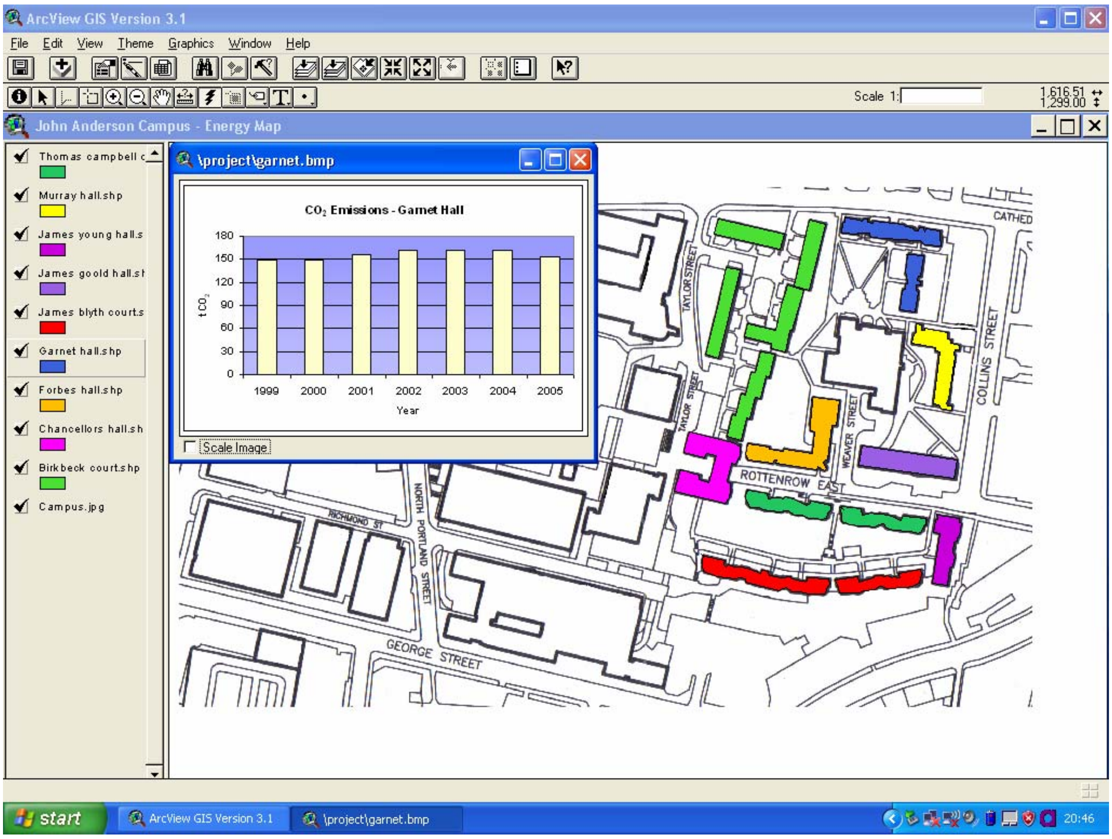


Figure VIII.13: Garnet Hall's CO_2 emissions

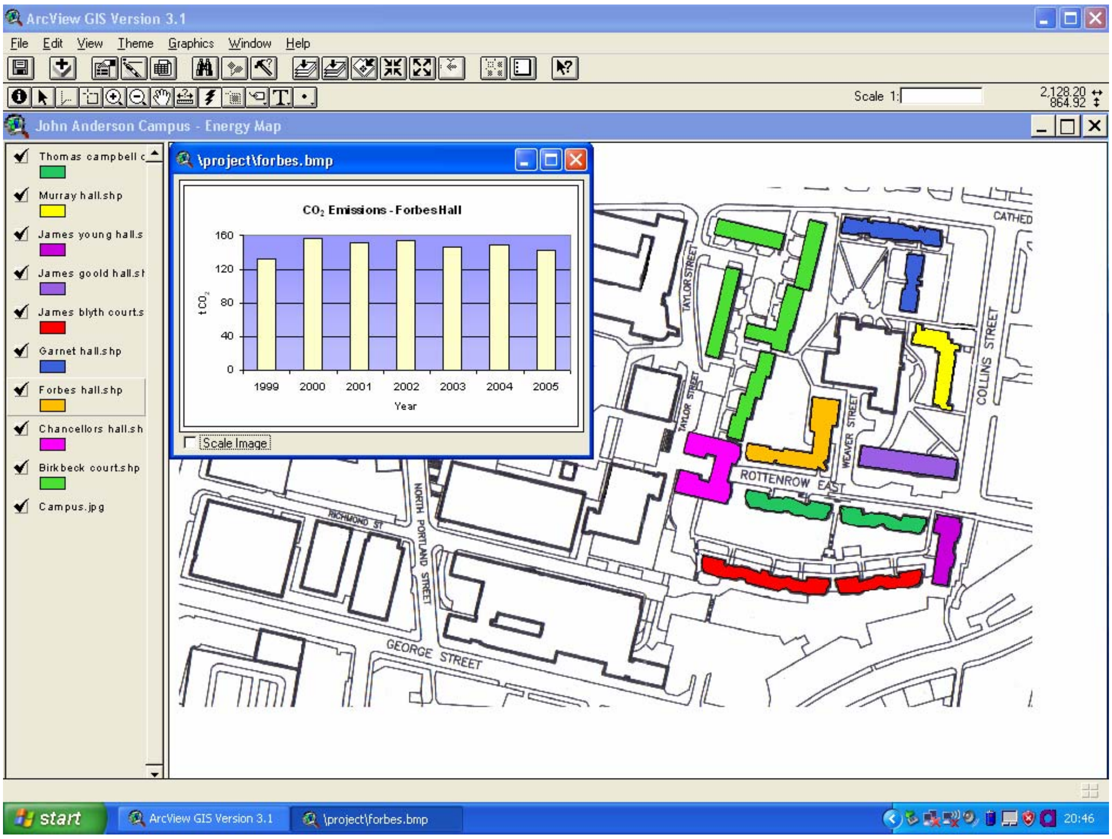


Figure VIII.14: Forbes Hall's CO_2 emissions

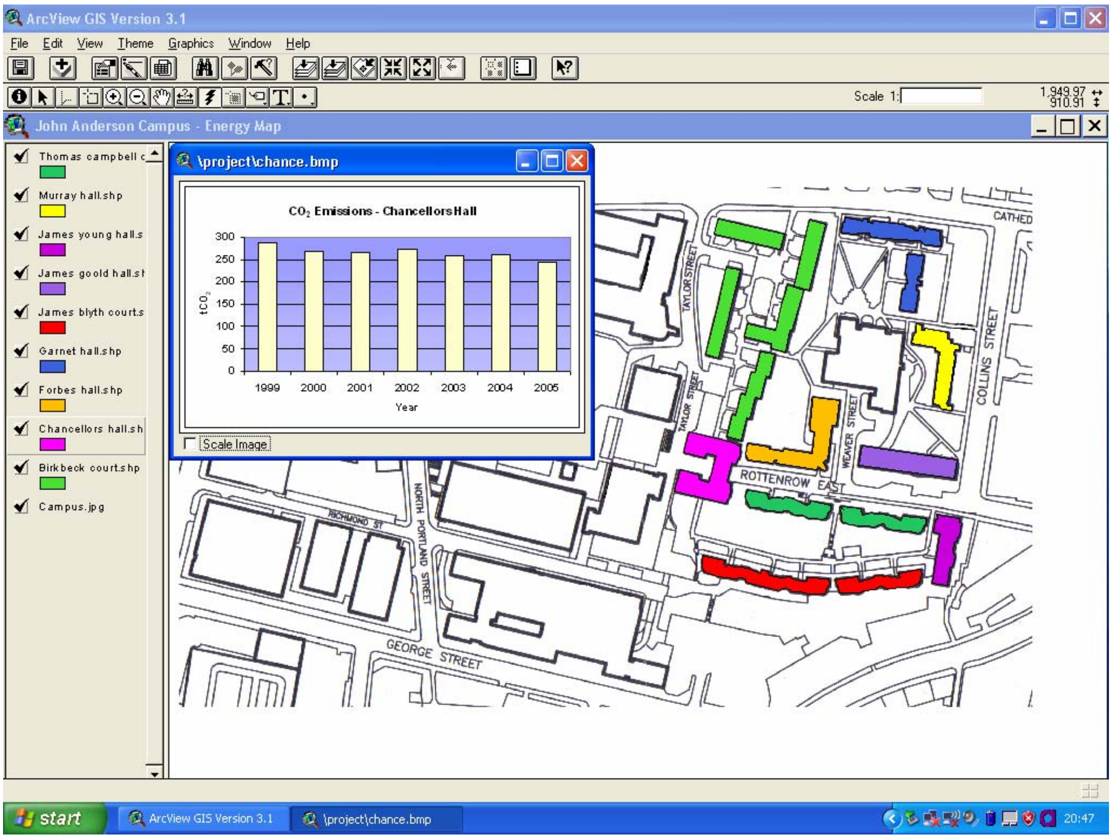


Figure VIII.15: Chancellors Hall CO_2 emissions

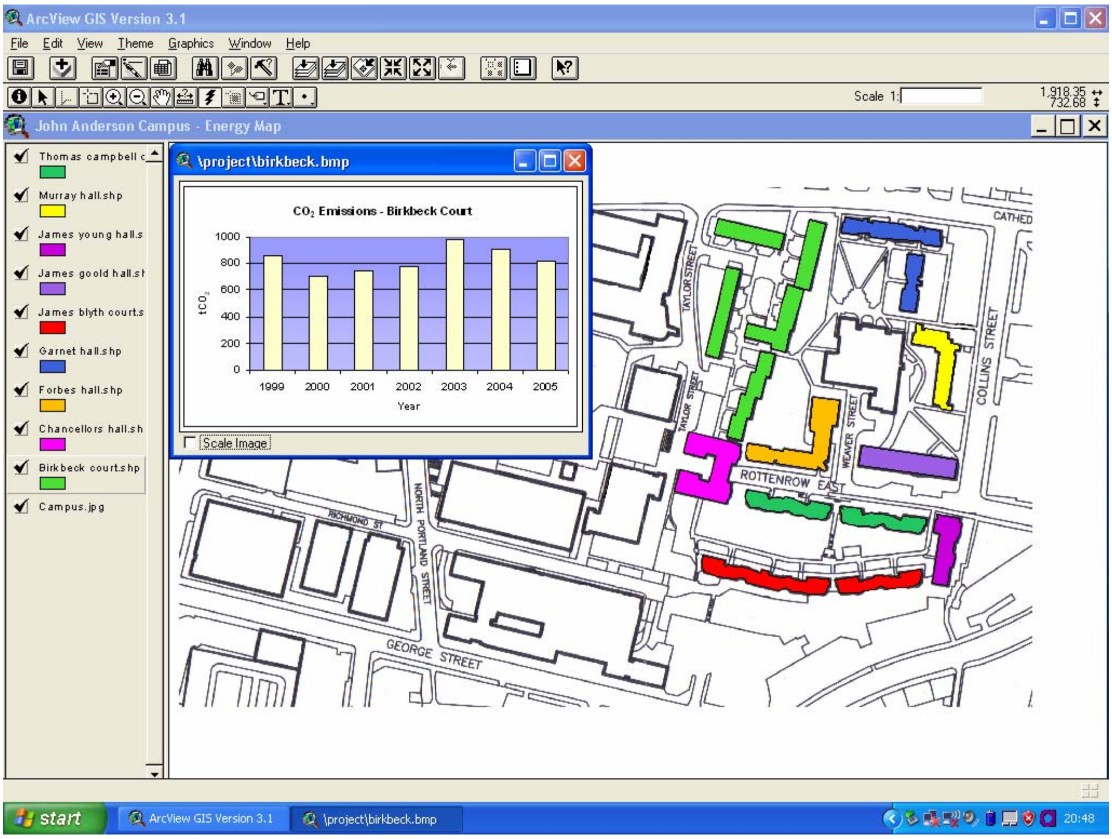


Figure VIII.16: Birkbeck Court's CO_2 emissions

Appendix IX - Investigation of main meters and sub-meters

Full records of the main and the sub-meters reading existed for the examined period of time illustrated in Chart IX.1.

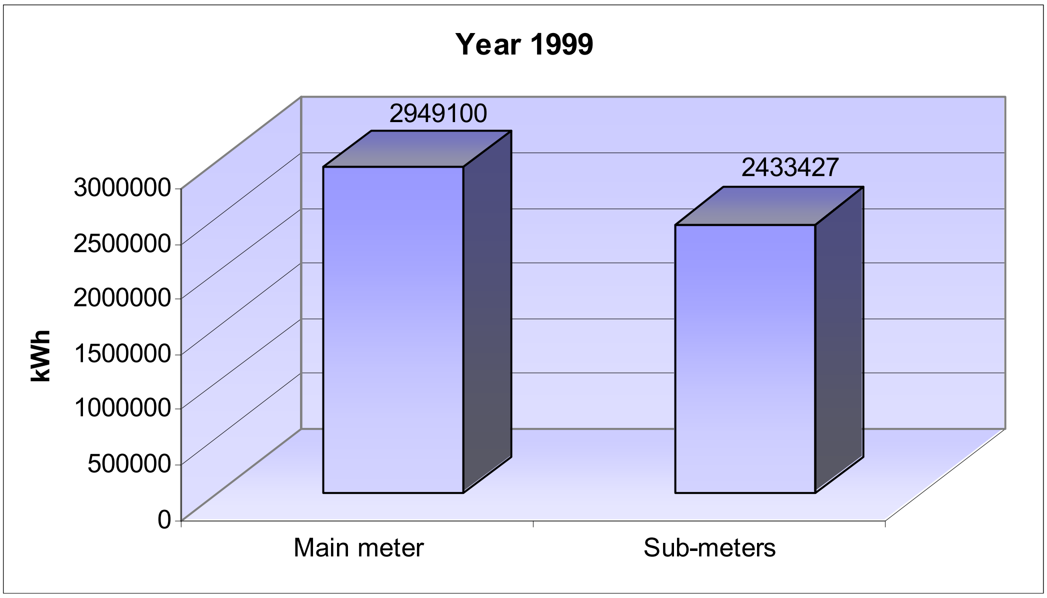


Chart IX.1

As the November 2000 (inclusive), meter reading data, did not exist for one Block of James Blyth Court. However, the November's and December's consumptions of this meter, only for the year 2000, were calculated using the process mentioned earlier and the result is presented in Chart IX.2.

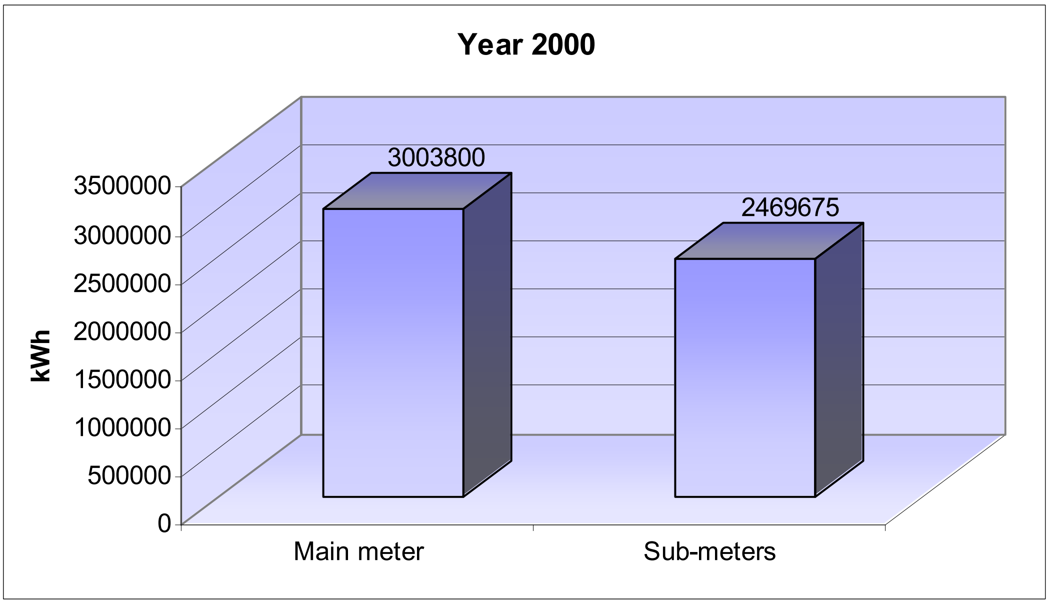


Chart IX.2

The resulting plot of the main meter and the sub-meters is shown in Chart IX.3.

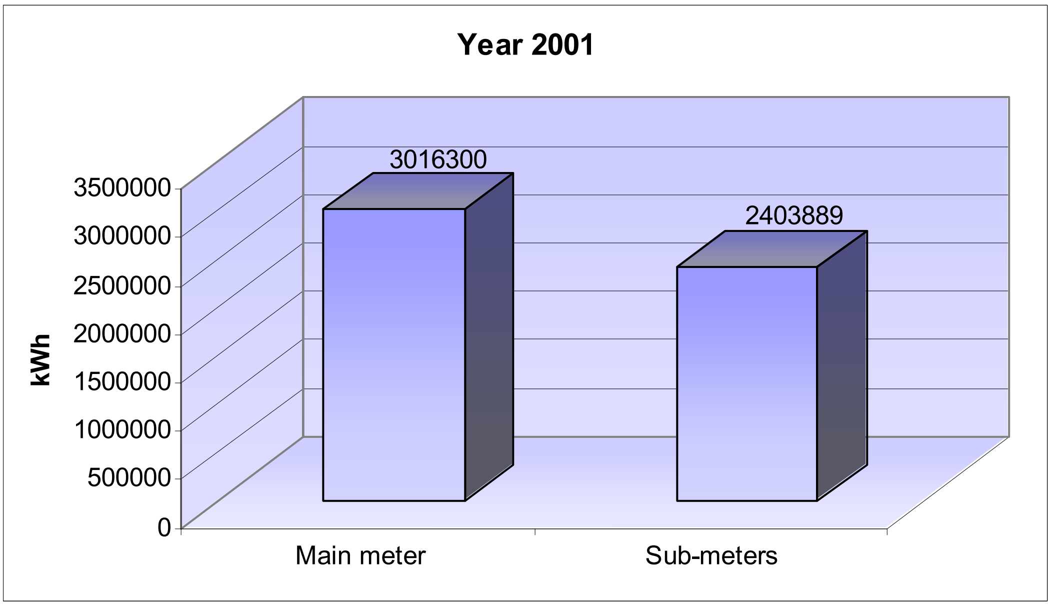


Chart IX.3

As far as year 2002 is concerned, data records of one Block of Chancellors Hall did not exist for two months. The same process was followed to fill in the gaps shown in Chart IX.4.

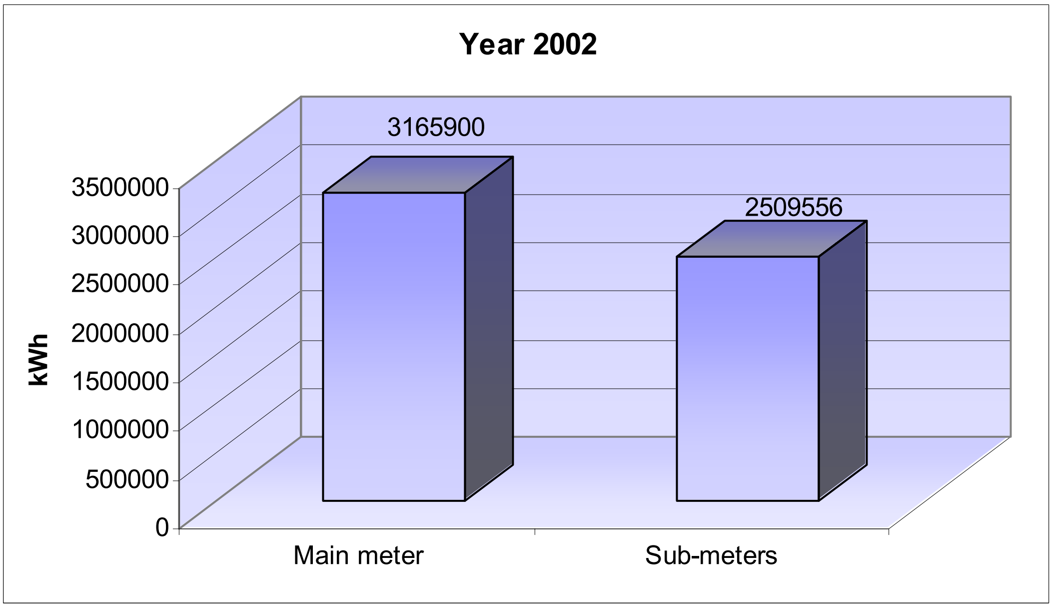


Chart IX.4

While for year 2003, two monthly records of the main meter of Graham Hills Building were missing, the results are shown in Chart IX.5.

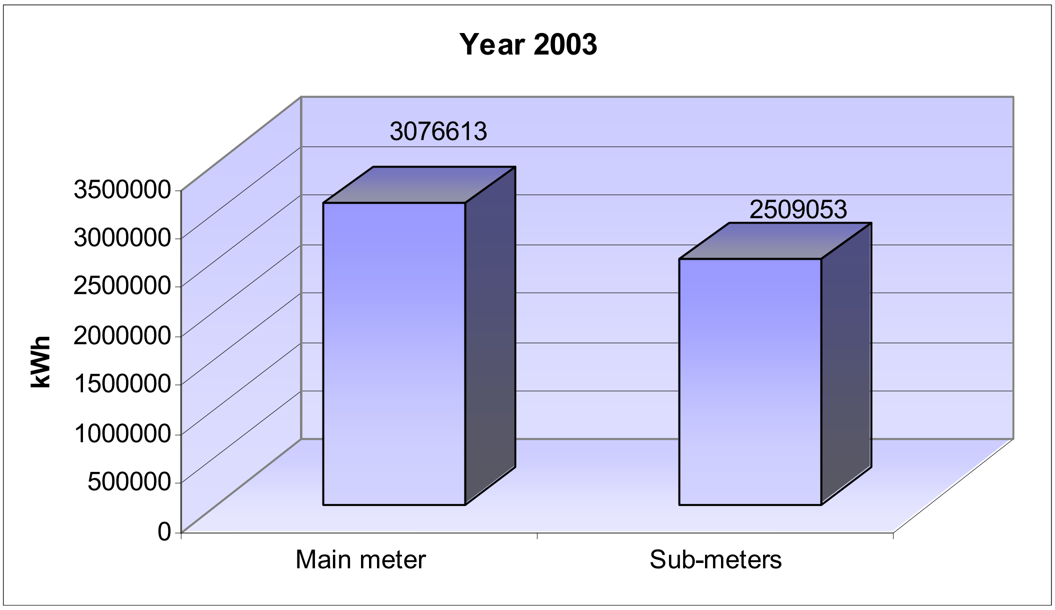


Chart IX.5

However, for year 2004, a monthly record of Barony Hall building as well as the meter considered to supply the Forbes Hall building was missing. Moreover, the consumption concerning the main meter resulted from Scottish Power's invoices, as the meter reading data existed for 4 months and this was considered to be a more accurate approach.

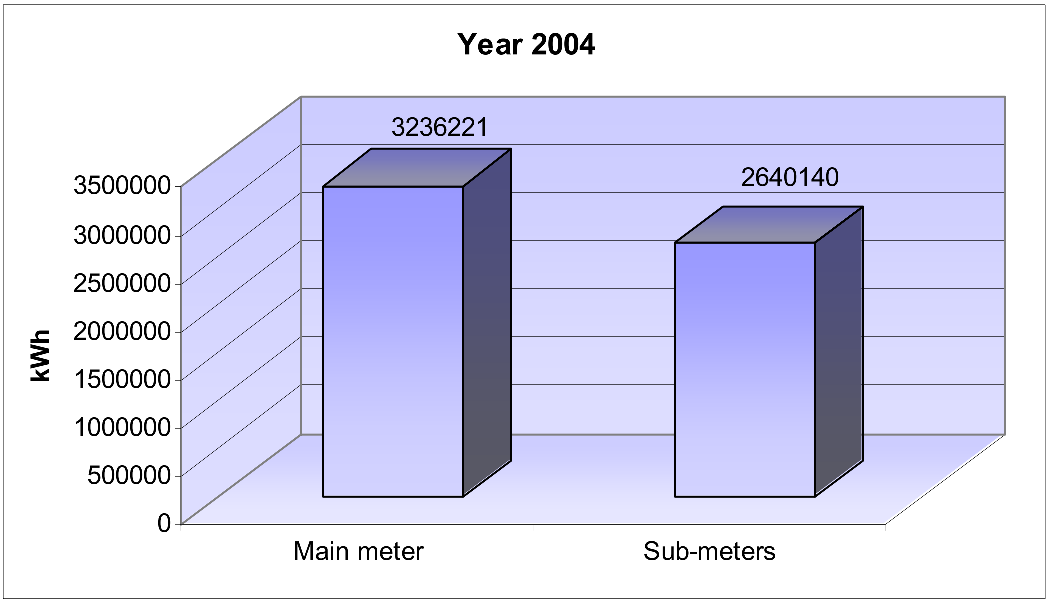


Chart IX.6

Appendix X - Flow chart for carbon footprint evaluation

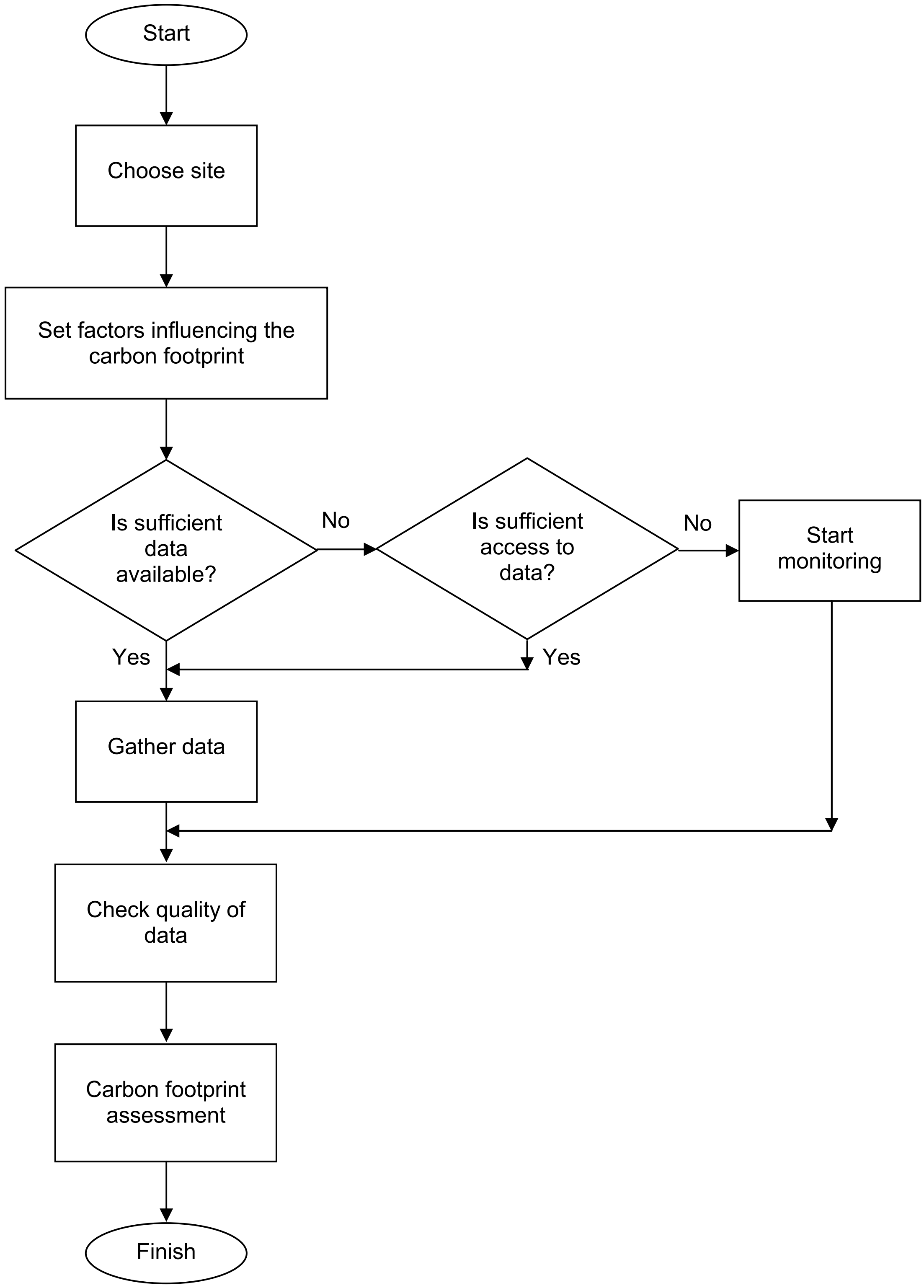


Figure X.1: Carbon footprint assessment flow chart