District Energy

FOURTH QUARTER 2006

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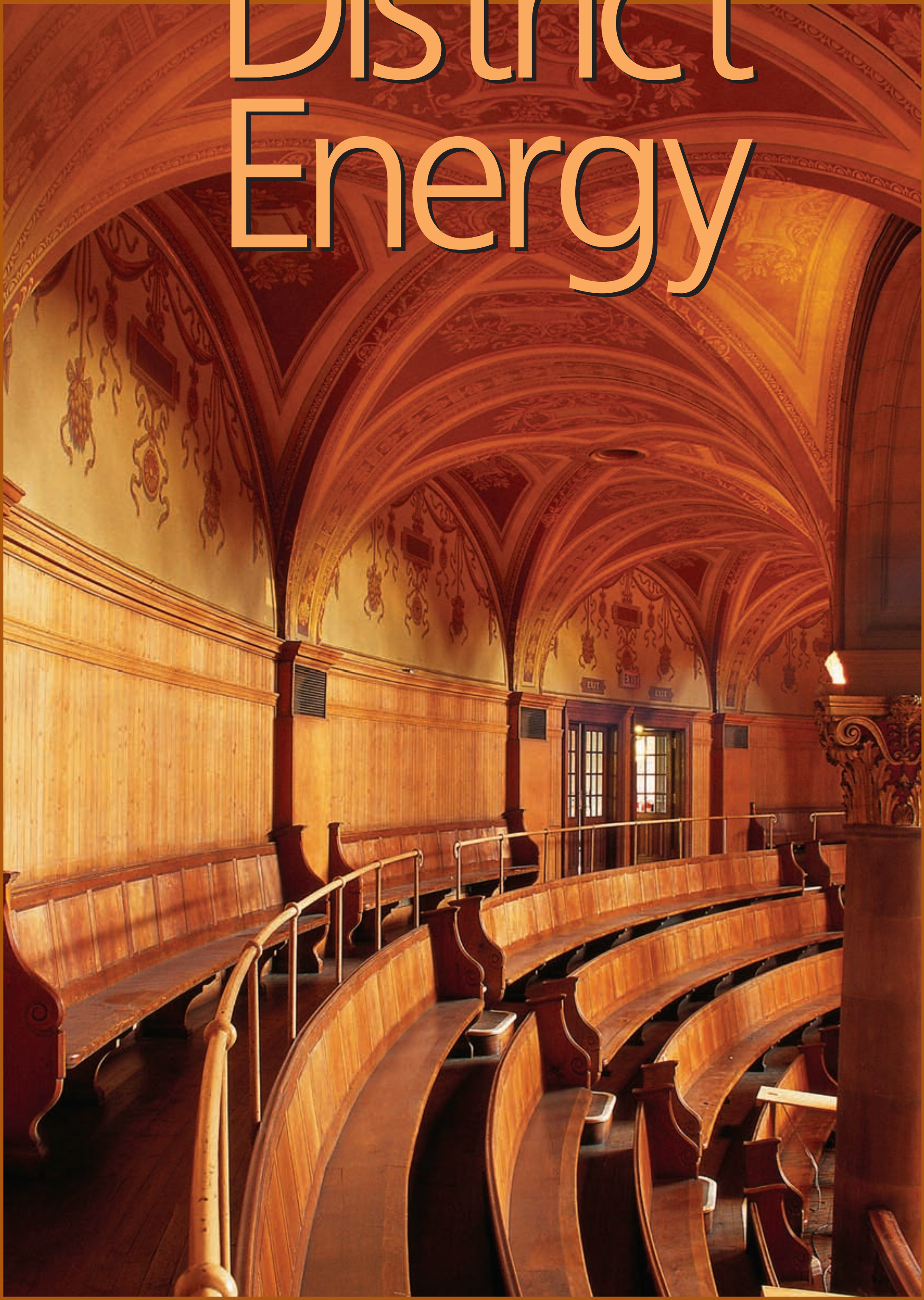

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

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Cover Story

University of Edinburgh's Sustainable Future:

CHP Key to Low-Carbon Strategy

David Somervell, Energy and Sustainability Manager,
University of Edinburgh

Founded in 1583 as the Tounis College (town's college), the University of Edinburgh in Scotland is one of the largest and most esteemed universities in the United Kingdom. By the 18th century, the university had established a world reputation, which it retains today. It boasts a long line of famous alumni – from Sir Walter Scott to Charles Darwin – and notable rectors, including Winston Churchill. Given its venerable past, not to mention its historic landmark architecture, the University of Edinburgh may seem a bastion of tradition. Yet the institution is wide-ranging in its teaching and research activities and stands at the forefront of development in many subjects – including medicine, microelectronics, biotechnology and climate change.

The University of Edinburgh also has distinguished itself as a leader in energy and sustainability practices. Ahead of other universities in the U.K., Edinburgh launched an 'environmental initiative' in 1990 that evolved into a comprehensive energy and sustainability program. This program's efforts have dramatically improved campus energy efficiency, saved money and slashed carbon dioxide emissions. A major component of the sustainability agenda has been the introduction of three campus 'energy centers,' or combined heat and power installations, an investment of £12 million (more than \$22.7 million) since 2002. Widely recognized for its outstanding commitment to energy efficiency, the University of Edinburgh was honored in 2004 with a Green Energy Award for Best Environmental Initiative, bestowed by Scottish Renewables, an association representing Scotland's renewable energy industry interests.

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Sustainability Focus

This story began with the university's appointment of an energy manager in 1989. The following year, the university hosted a pioneering conference on energy management in higher education institutions, which prompted adoption of an environmental policy with three themes: environmental teaching, environmental research and environmental practices. The latter evolved into a comprehensive sustainability program directed by an Energy & Sustainability Office (ESO) created within Estates & Buildings – the department responsible for managing more than 250 buildings, including the energy centers. The program is overseen by a Sustainability and Environmental Advisory Group, convened by a vice principal.

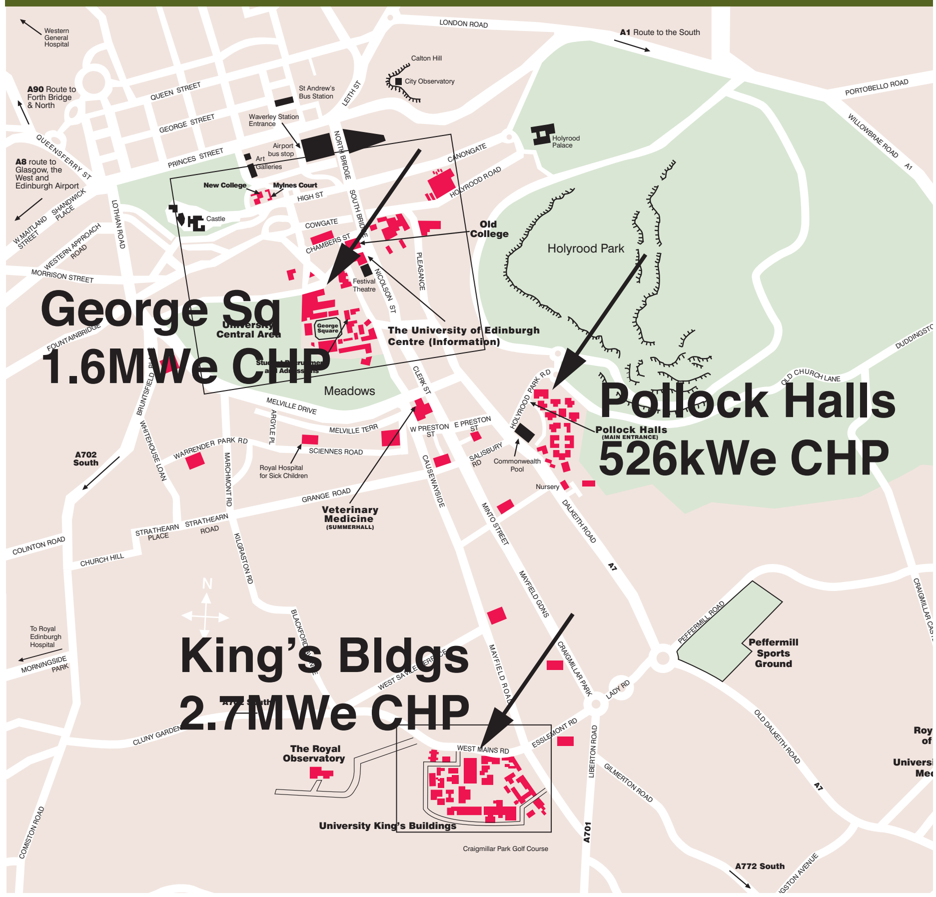
With a staff of 10, the ESO is charged with promoting a more sustainable university and reducing the university's environmental impact. This involves guiding the institution to make the most effective use of natural resources, promoting whole life-cycle costing to contain utility costs, supporting continuous improvements in campus infrastructure, contributing to the university's missions of promoting excellence in research and teaching, and liaising with other institutions and government agencies such as the Scottish Environment Protection Agency to promote best practices on campus.

Within the ESO, four utilities staff manage procurement - including day-to-day metering, monitoring and reporting on consumption of energy and water across the campus – and identify opportunities for energy efficiency investments. They liaise closely with the engineering operations manager and maintenance colleagues on managing the three energy centers. In addition to its work with campus utilities, the ESO has five staff members focused on waste reduction – providing a campus-wide recycling and waste management service and five staff members working on transportation issues and parking management issues – with the goal of reducing the university's transport-related impact both locally and nationally.

These activities have paid off for the University of Edinburgh. Since 1989, more than 5 percent of the university's utilities spend has been invested each year in energy efficiency projects delivering cumulative savings of £6 million ($11 million). From 1990 to 2004, energy costs were reduced by 5 percent in real terms while student numbers have doubled to nearly 23,000 and building area has increased by 25 percent.

To date, Edinburgh's particular organizational approach to energy efficiency is found in only a minority of U.K. and European universities. According to ESO estimates, while about 50 percent of U.K. and European universities have an energy manager, less than 10 percent have a manager position encompassing both energy and sustainability or an energy and environmental/sustainability office. Although perhaps 60 percent of U.K. and European universities have environmental policies in place, less than half of these policies address sustainable development.

Figure 1. Locations of the University's Three Energy Centers.



Source: University of Edinburgh.

Energy Centers

Driven by its commitment to sustainable practices, its central heating tradition, the imperative to reduce CO_2 emissions and the need to contain an annual utilities bill now approaching £9 million ($17 million), the University of Edinburgh has installed three state-of the art CHP systems on three of its five campuses (fig.1) since 2003. Aging steam systems have been replaced with high-efficiency boilers and three spark-ignition gas engines with 85 percent

Thanks to CHP, the university is now on track to achieving a 40 percent absolute cut in 1990 CO_2 emissions by 2010.

overall efficiency. Currently serving more than half of the university's 5.5 million sq ft of property, the new systems lie two to three miles apart and are not interconnected. The university has a 10-year operation and maintenance contract with Clarke Energy, UK agents for the GE Jenbacher engines, which undertakes all routine maintenance and has engineers on 24-hour call to respond to any engine problems.

Campus buildings not served by the new energy centers are typically heated by high-efficiency natural gas boilers, some feeding a small group of buildings. A small number of specialist laboratories, etc. are cooled by electric chillers in the warmer months.


Courtesy University of Edinburgh.

St. Leonard's Hall houses administration and function rooms at the university's Pollock Halls of Residence – site of the institution's first combined heat and power installation.

Pollock Halls of Residence

Edinburgh's first CHP project was the 2003 installation of a 526 kWe GE Jenbacher gas reciprocating engine to operate as the lead boiler serving the Pollock Halls of Residence, home to more than 2,000 first-year undergraduates. Already in place were three 2 MW dual-fuel (natural gas and light oil) shell-and-tube boilers that continue to provide top-up and standby heating capacity. This system supplies heat to 1,400 dormitory rooms in six houses plus two administrative/refectory buildings via an existing two-pipe low-temperature hot water distribution system in walkway ducts serving the north half of the site. The new engine was simply lowered into the lower level of the boilerhouse under the refectory and connected in to provide a slip-stream input on the site return main prior to the existing boilers.

Since installation, the Pollock Halls system has cut annual CO_2 emissions by 450 tonnes and reduced noise nuisance in an adjacent conference suite. The £1 million ($1.9 million) project was funded in part through a £250,000 ($475,000) grant from the Community Energy Programme jointly managed by the Energy Saving Trust and the Carbon Trust, established by the U.K. government to help business and the public sector reduce carbon emissions.

King's Buildings

Next, the University of Edinburgh turned its attention to the 45-year-old steam heating plant and distribution network at its King's Buildings campus, home of the College of Science and Engineering. The university considered four different energy options for this project:

1. Close the existing central plant and install individual boilers in each building: Expensive, intrusive and involved a higher price for firm gas.
2. Strip out the existing central plant and steam distribution system and install a CHP system with new low-temperature hot water distribution system: Lowest life-cycle cost with only 5 percent standing heat losses versus 30 percent losses from the old steam system.
3. Replace the existing central plant with CHP, but retain the existing steam distribution system: Still inefficient with high heat loses and problem of how to eventually replace the aging distribution network.
4. Maintain business as usual, with only replacement of steam boilers in years five, six and seven: Stuck with energy-inefficient distribution system and constrained for future firing options; highest life-cycle costs when taking into account rising fuel prices.

The university chose option 2 – to replace the old steam system with a new CHP and piping system – as this option provided the lowest whole life cost.

The entire former system – comprising four boilers with combined capacity of more than 80,000 lb/hr of steam, plus steam pipes in walkway ducts – was stripped out early in 2003 to make way for the CHP technology, installed later the same year. The new equipment includes a 2.7 MWe gas reciprocating engine and two 7.5 MWth


Courtesy University of Edinburgh.

The university's second CHP system, at its King's Buildings campus, supplies heating to nearly 30 buildings including the Michael Swann Building for biological sciences. Built in 1996, the building (shown here) was named for Professor Michael Swann, under whose academic leadership the university established the first department of molecular biology in Britian.

low-temperature hot water boilers with low-nitrous oxide burners. A new highly insulated low-temperature distribution system was also installed in the existing ductwork and the duct covers replaced. For this installation more than 1.4 km (0.87 mi) of steel pipe was employed – all insulated in situ with mineral fiber insulation sealed in a flexible cover.

Serving nearly 30 buildings, the system reduced CO_2 emissions by more than 2,600 tonnes in its first year of operation. The CHP system reduced fuel bills by £450,000 ($850,000) per year in the short term, with even greater savings achieved when reduced employee costs are taken into account. These savings will free up scarce budgetary resources for essential building improvement projects elsewhere. Financing sources for this £4.3 million ($8 million) CHP project included a second Community Energy grant of £1.63 million ($3.1 million).

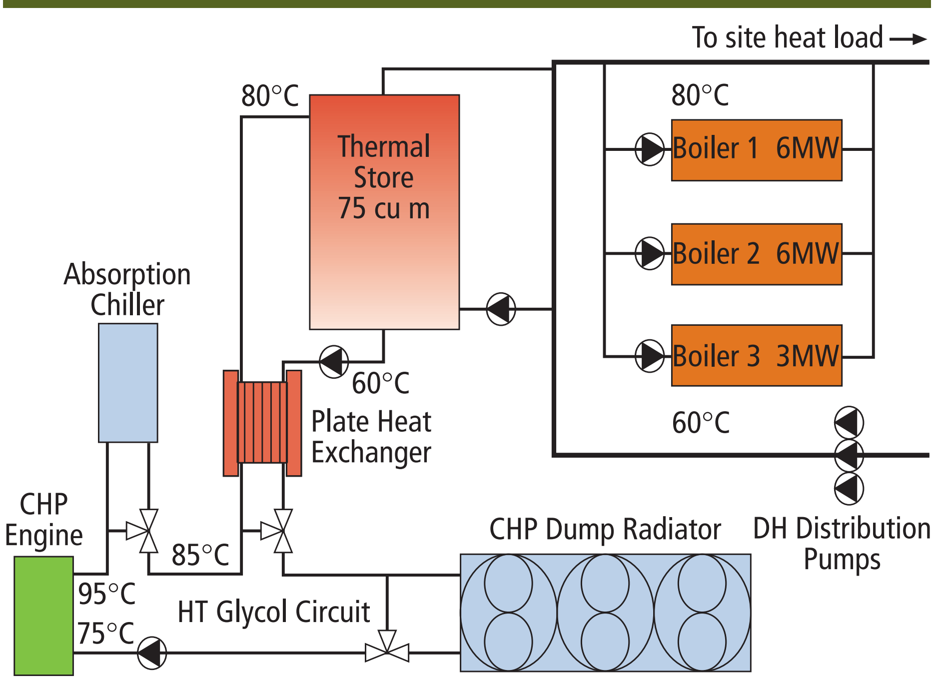
The King's Buildings CHP project was the largest energy efficiency upgrade in the U.K. university sector at the time of its installation in late 2003.

George Square

The University of Edinburgh's third CHP project, completed in 2005, included replacing 50-year-old steam boilers with a trigeneration system (fig. 2) to heat and cool the George Square campus – now occupied mainly by the College of Humanities and Social Science. The new equipment includes a 1.6 MWe gas-fired GE Jenbacher 612 CHP engine; two 6 MW and one 3 MW low-temperature hot water boilers; a 600 kW absorption chiller exploiting byproduct heat to cool specialist laboratories in summer; and 75 cu m (2,650 cu ft) of thermal storage. Fourteen buildings were originally connected to the system. Another seven are to be added over the next five years, as their electric under-floor systems are displaced as part of a major refurbishment of 1960s-era academic buildings. This expansion has already begun, with heating and cooling pipes laid to the Main Library in summer 2006.

This innovative £7 million ($13.1 million) installation was supported by a £2.7 million ($5 million) Community Energy Programme grant. The importance to the university of optimizing overall energy efficiency is reflected in the fact that £1.9 million ($3.6 million) of the budget was allocated to internal building controls. In its first full year, the trigeneration system saved £220,000 ($420,000) in energy costs and 1,250 tonnes of CO_2 emissions. When running to optimize electricity production (after the April 2006 doubling of unit prices from the external supplier Scottish Power) – it will reap annual savings of nearer £500,000 ($930,000).

Figure 2. Schematic of Trigeneration System at George Square Energy Center, University of Edinburgh.



Source: University of Edinburgh Estates & Buildings.

Credit Due to Partners

The University of Edinburgh credits the success of these three projects to a tremendous network of partnerships with the following entities: the Community Energy program from the Energy Saving Trust and the Carbon Trust for development and capital grants; main contractor Crown House Technologies, which developed the designs engineered by PB Power and Carl Bro Group; Estates & Buildings staff, led by the university engineer, who supervised the implementation; and Clarke Energy, the international agent for GE Jenbacher, which now maintains the engines. The university and these partners are proud of what has been achieved through their intensive and committed teamwork.

Remote Management

A vital component of Edinburgh's three CHP systems is the university's Building Energy Management System (BEMS) and associated controls, which allow building heating and ventilation equipment to be remotely controlled to optimize comfort conditions while minimizing energy costs. There are now more than 350 microprocessor-controlled BEMS panels in university buildings, monitored and managed from computers in Estates & Buildings maintenance offices. The BEMS is used as the primary determinant of whether the engines fire and at what rate – set to meet all site power loads while retaining a small inflow from the grid. In other words, each engine is run in non-island, non-exporting mode. There is currently no benefit gained from exporting, as the income value per kWh is so low.

The main primary circuit for all three systems is managed as a single hydraulic entity with the boiler water running right through to the radiators. This circuit is run as a constant-pressure, variable-volume circuit: a pressure sensor is used at an index point at the far end of the circuit to control the speed (via variable-speed drives) of the three pumps in each energy center. This means the least possible amount of water is moved, and the highest temperature differential (Delta T) is achieved between flow and return. The latter is essential when the efficiency of the engines (42 percent electrical efficiency, 43 percent thermal efficiency on the big one) relies on a return-water temperature of a steady 70 degrees C (158 degrees F). In effect, the whole system is controlled based on that return temperature, and the primary flow temperature is allowed to modulate to achieve the desired return temperature.

This is all very different from traditional U.K. heating, ventilating and air-conditioning design, which has necessitated a considerable amount of continual commissioning over the first years following installation. System operators still find that they often have too small a Delta T; so, going forward, a differential of at least 20 C (36 F) is sought from design consultants working on any new buildings being connected to the system.

Future Directions

The University of Edinburgh had at one time considered a major extension of its George Square system but has postponed the effort indefinitely in light of the current gas market fluctuations. While no additional CHP plans are in the works at this time, the university remains committed to ongoing sustainability improvements to its energy infrastructure. One major proposal is a biomass-fired district heating system that will serve buildings at the Easter Bush Veterinary Centre five miles south of the city. This is to be considerably expanded to house an entirely new School of Veterinary Studies and associated research institute. This system could potentially be fired using surplus forest industry byproducts, providing a zero-carbon heat source for the growing campus.

Although the Community Energy Programme managed by the Energy Saving Trust and The Carbon Trust has ended, the university continues to participate in a carbon management partnership program offered by The Carbon Trust in Scotland, the organization's local office. Through this partnership, the university receives a small amount of funding support for consultancy and advice on two ongoing initiatives: (1) an energy reduction campaign – titled 'Switch and Save' – to engage all staff and students and (2) installation of an automatic utilities metering, monitoring and targeting (AMR) system to facilitate the devolution of the whole utilities budget down to schools and departments across the university by 2008.

On a day-to-day basis, the ESO continues to help the university minimize its environmental impact and maximize its energy efficiency. It plays an active part in national networks to share best energy practices with other U.K. universities. And it maintains its innovative approach to building a sustainable university, determined to stay a successful international research leader for another 400 years.

David Somervell is the energy and sustainability manager in the Energy & Sustainability Office, Estates & Buildings Department, at the University of Edinburgh, Scotland. Trained as an architect, he was attracted to energy policy issues following the near meltdown of the Three Mile Island reactor. After five years as technical services manager at Heatwise Glasgow – an innovative training, community development and practical project tackling fuel poverty – he joined the university as energy manager in 1989. Active in the U.K.-wide Environmental Association for Universities and Colleges, he has been instrumental in the establishment of the Scottish Campus Sustainability Programme. He can be reached at David.Somervell@ed.ac.uk. For more information on the University of Edinburgh's Energy & Sustainability Office and its activities, visit www.eso.ed.ac.uk.

An Energy-Efficiency Performance Indicator

As most universities, the University of Edinburgh has a huge number of changing variables affecting its energy consumption and emissions levels. While the Utilities Policy adopted in 2003 sets an absolute CO_2 reduction target of 40 percent against 1990 emission levels, the university has expanded considerably in size and complexity since 1990. Therefore, to accurately report the impact of its efforts to contain energy consumption increases, the Energy & Sustainability Office sought to derive an energy-efficiency performance indicator that would take the increased campus activity and size into account.

This ratio uses two fairly standard components of a Normalized Performance Index: kWh/sq m and annual degree-days. To reflect the substantial increase in activity, however, the university has also added a component – occupant – that takes the full number of all full-time-equivalent (FTE) employees plus 10 percent of all FTE students. The formula (kWh/sq m/degree day/occupant) recognizes that while staff are consistently on campus and working and occupy desk and/ or lab space, students are transitory and have less intense energy requirements.

Courtesy University of Edinburgh Estates & Buildings.

Old Lancashire steam boilers being cut out at George Square Energy Centre in preparation for new equipment installation.

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