SUSTAINABLE ENERGY IRELAND

Ventilation and Control Systems Upgrade, UCD Lecture Theatre

Introduction

University College Dublin's Science Complex opened in 1964, and was the first purpose-built academic structure to be built at the Belfield campus. The complex consists of a central lecture theatre building, which is connected by link bridge to the Biology, Chemistry and Physics buildings.

The "Lecture" building is 8,000 m^2 in size. It contains six lecture theatres, with capacities ranging from 200 to 400 occupants. Most theatres have their original heating and ventilation plant. The building also has a restaurant with seating for 200, a number of offices and large concourse areas.

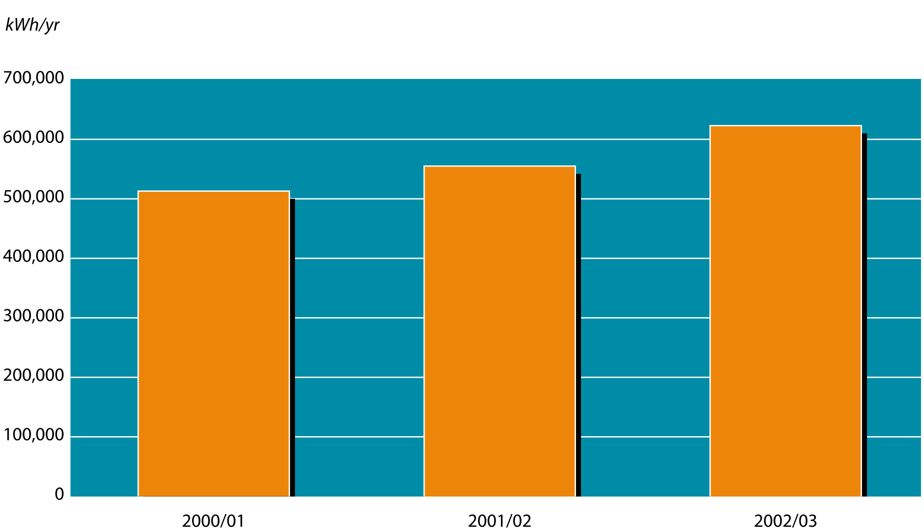
In 2003 it was decided to upgrade the 40 year old ventilation plant and controls for lecture theatre B (capacity 400 people, size $580m^2$), and a conscious effort was made to install highly efficient plant in conjunction with demand-based controls for its heating, ventilation and lighting.

Impetus for the project

Four factors combined to provide the impetus for this project:

- Rising prices per unit of electricity
- Rising electricity consumption in the Science Lecture building
- Changes in occupancy patterns making it increasingly difficult to closely match plant schedules with lecture theatre occupancy
- The existing plant had reached the end of its useful life.

Science Lecture Annual Electricity Use



Energy Saving Opportunities

A review of the existing installation suggested extensive opportunity for energy savings:

- *Heating and ventilation plant operating hours*
  The plant tended to operate according to a fixed time schedule reflecting a lecture schedule. While this was appropriate during term time, operating requirements changed regularly during revision periods, exams and winter, spring and summer breaks. Furthermore, usage during weekends and evenings was subject to frequent changes.
- *Ventilation rates*
  The lecture theatre was constructed when smoking was permitted and energy costs were low. The fixed speed ventilation fans provided 17 litres per second per person for a rated occupancy of 400 people. This resulted in high electricity requirements to drive large motors and high heating requirements as the ventilation system was flushing heated air out of the building without any heat recovery.
- *Improvements in technology*
  The fixed speed motors powered the ventilation fans via a belt drive (see photo). Belts are prone to slippage, wasting energy. Modern technology is more efficient and provides heat recovery options.
- *Lighting operating hours*
  The lecture theatre was equipped with reasonably efficient T8 fluorescent tubes; however, the lights were manually controlled and tended to be on from 7am (when the theatre was cleaned) until 10pm (when the building closed).

Old plant, still used in theatre C

An internal view of the new AHU, including extract air fan, thermal wheel, air inlet filters, and cylon control panel

New AHU

Solutions Identified

Improved Ventilation System

Based on these opportunities, UCD decided to purchase an Air Handling Unit (AHU) package with integrated variable speed motors and heat recovery. UCD selected a PM-Luft Gold AHU, complete with efficient direct drive motors equipped with variable speed control, energy efficient bag filters, and a thermal wheel which recovers heat from the extract air and supplies it to the incoming air (see photo).

Installing new plant was only part of the solution; careful selection of control strategies ensured that the potential of the AHU to deliver energy savings was fully realised. Control strategies employed include:

Matching Operation to Occupancy Hours

In order to match lighting, heating and ventilation plant operating hours with occupancy hours, high sensitivity occupancy sensors were installed that would trigger the lights and heating/ventilation plant when somebody entered the theatre. The sensors, which have two sensitivity settings, are connected to the Building Management System (BMS) and this controls the operation of the lights and plant.

Matching Ventilation Rates to Occupant Requirements

While CIBSE guidelines recommend ventilation rates of 8 litres per second per person, the lecture theatre is seldom fully occupied. Furthermore, as AHUs are manufactured in standard sizes, the selection usually involves selecting a unit a little bigger than air requirements. In order to optimise operation, and make full use of the variable speed drive, it was decided to regulate ventilation rates based on carbon dioxide (CO_2) levels in the theatre. CO_2, which is produced by people when they breathe, can be measured and used to provide a good indicator of air contamination due to occupants.

The CO_2 sensor was placed in the extract air duct, and its reading is sent back to the BMS. The BMS regulates the AHU supply and extract fan speed to maintain CO_2 levels below 600 parts per million (ppm).

Heating Regulation
The theatre is heated using heat recovered by the thermal wheel and a supply air heating battery. The BMS compares actual air temperature with a temperature setpoint and adjusts heating accordingly. The set-up could lead to an occupant experiencing cold temperatures on entering the space. To address this, temperature is maintained at 17ºC when the theatre is not occupied, but is scheduled to be occupied.

UCD has three control strategies for heating and lighting regulation:

(1) Occupied control - the optimum temperature of the theatre when occupied: Time schedule and occupancy detectors are in. Temperature setpoint is 20ºC. Main lights are on, access lights are off.

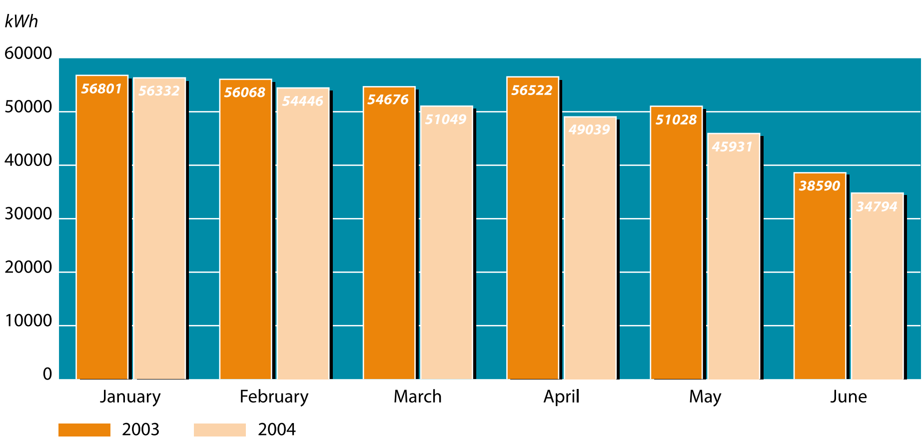
(2) Unoccupied control - the minimum temperature of the theatre when unoccupied: Time schedule is out (building closed). Temperature setpoint is 10ºC (for fabric protection). Access lights are on, main lights are off.

(3) Non-occupied control - the minimum temperature of the theatre when occupied but not scheduled for use: Time schedule is in, occupancy detector is out. Temperature setpoint is 17ºC. Access lights are on, main lights are off.

Fresh Air Cooling
There is no cooling battery, so mechanical ventilation is the sole means of maintaining comfort conditions in warm weather. In the event that air temperature rises above the occupied setpoint, the AHU supply and extract fan speeds will gradually increase, supplying more fresh air, so as to bring air temperature back to its setpoint.

Thermal Wheel Regulation
The operation of the thermal wheel is regulated by the AHU's internal controls. During normal operation the thermal wheel recovers heat from the extract air and transfers it to the fresh incoming air. If additional heat is required, the heating battery provides the supplementary heat.

UCD Science Lecture 6 Month Electricity Comparison



Evaluation of Performance
Due to the number of variables that control the operation of the AHU, it is difficult to accurately project what energy savings might be. A feasibility study prior to installation predicted annual electricity savings of 16,000 kWh and gas savings of 107,000 kWh.

Data obtained from monitoring the actual energy performance of the unit over a number of weeks was used to extrapolate what total annual energy use might be.

The new system was found to:

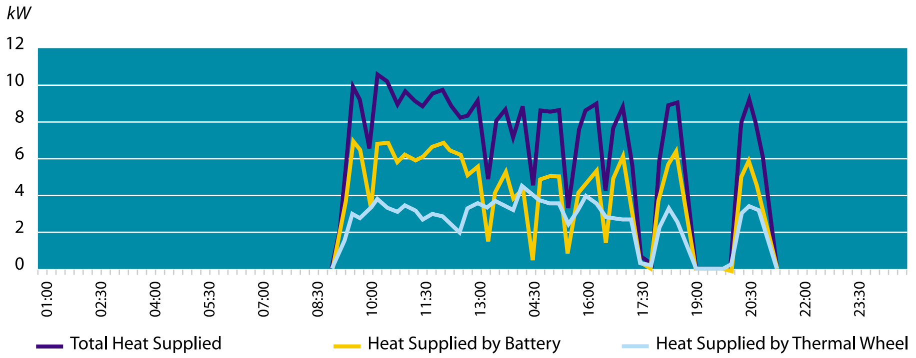
- reduce plant operating time from 63.5 to 55.5 hours per week during term (12% reduction), with savings even greater when outside term time;
- reduce ventilation rates from 6.7 m^3 per second to an average of 0.84 m^3 per second (87% reduction) when the AHU is on;
- reduce electrical load from 8.8kW to 0.64kW (93% reduction) when the AHU is on;
- reduce electrical energy consumed from 563kWh to 36kWh (94% reduction) per week during term;
- reduce lighting hours from 82.5 to 55.5 hours per week (33% reduction).

Electrical Performance
On the basis of system monitoring, it is estimated that annual electrical energy savings as a result of the new AHU and associated control strategies are 17,000 kWh. Furthermore, the new lighting control strategy has resulted in savings of approximately 3,000 kWh. The total value of electrical savings is €1,900 per annum.

A number of other developments have resulted in further savings being achieved in the Science Lecture building. For instance, the successful use of occupancy control to switch lighting and ventilation plant was extended to the other theatres. Furthermore, lights in the restaurant and on the concourses are now controlled depending on outside light levels. Finally, increased vigilance on the part of staff has reduced energy use at night.

The combination of all these measures has resulted in an overall reduction of 7% in electricity usage in the Science Lecture building when compared with the first 6 months of the previous year (see chart above). Based on this, annual electricity savings are projected to be 44,000kWh, which includes savings from the new AHU in Theatre B as well as the other changes described above. Similar historical data is not available for heat energy.

Daily Heat Supply and Recovery Rates



Thermal Performance

The reduction of 87% in ventilation rates has had a proportional effect on heating requirements. On the basis of system monitoring it is estimated that lower ventilation rates have resulted in annual thermal energy savings of 100,000 kWh. Furthermore, the contribution of heat recovery by the thermal wheel has resulted in further savings of 6,000 kWh. The total value of thermal energy savings is €3,000 per annum.

The chart above illustrates heat supply and recovery rates over the course of a day. The thermal wheel usually supplied between 30% and 50% of heat requirements. During days when the theatre was heavily occupied for long-uninterrupted periods, heat recovered and supplied by the thermal wheel is likely to be at its highest. However, it is interesting to note that in this instance, the major energy savings are attributable to the effect of the reduced source ventilation rates.

Cost-Benefit Assessment

The total cost of the project was €78,200, including removal and disposal of old plant, supply and installation of the new plant, and fire prevention upgrades. UCD staff managed the project and prepared the control strategies. The alternative option evaluated by UCD was to replace the existing system with a standard, fixed speed AHU. The cost premium associated with the energy-efficient AHU and associated controls was €14,500.

Conclusions

The upgrading of the ventilation plant and controls for lecture theatre B (400 occupants/580 m²) in the UCD Science Lecture building has had the following impact:

- savings of 20,000 kWh in electricity and 106,000 kWh in heat
- annual energy cost reduction of almost €5,000
- reduced carbon dioxide emissions of 45 tonnes per annum.

These savings are largely attributable to the use of energy efficient ventilation plant and lighting in conjunction with occupancy based controls.

Payback Analysis

Total Project Investment	**€78,200**
Cost of additional energy saving features over standard costs	**€14,500**
Value of annual electricity saving	**€1,900**
Value of annual heat saving	**€3,000**
Simple payback on total project investment	**16.0 yrs**
Simple payback on cost of additional energy saving features	**3.0 yrs**
Investment Rate of Return (20 year life)	**34%**

Prices exclude VAT.

While the total installed cost of the system far exceeds the value of energy savings, the existing system was in need of refurbishment and the premium associated with replacing the system with an energy-efficient alternative was modest. The simple payback on the cost of energy-efficient features was 3 years.

Equipment Details

Occupancy Sensors: Intellisense IS-215T.

AHU: PM Luft Gold 32 supplied by Entropic Ltd.

BMS: Cylon Controls Ltd.

Source Text & Performance Evaluation

Cian O'Riordan, PowerTherm Solutions Ltd.

Design and Installation Team

Project Manager: Noel O'Neill, UCD.

Controls: Brendan Robinson, UCD.

SUSTAINABLE ENERGY IRELAND

Glasnevin
Dublin 9
Ireland
t +353 1 8369080
f +353 1 8372848
e info@sei.ie
w www.sei.ie

Sustainable Energy Ireland is funded by the Irish Government under the National Development Plan 2000-2006 with programmes part financed by the European Union

NDP NATIONAL DEVELOPMENT PLAN