Progress report on reducing energy consumption in the Informatics Forum

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It's a year since I took on the mantle of being Energy Coordinator in the Informatics Forum. In this report, I'll outline what progress has been made since then. I should say at the outset that everything presented here has depended on the willingness of a large number of people (listed at the end) to improve energy efficiency in the Informatics Forum. Also, this report doesn't cover waste and recycling issues, which we are making progress on thanks to Sharon Goldwater and the Waste and Recycling office, or the rooftop gardening project, which Guido Sanguinetti initiated in March, and which has involved about a dozen people.

1 First steps

On the basis of my participation in the engagement workshops run by Transition Edinburgh University, I was offered the job of Energy Coordinator by the University Energy Office. My first step was to inform the Head of School, Dave Robertson, who immediately suggested that I should attend meetings of the School's Building Committee. This has proved to be very useful. I also set up a blog[1], with the intention of informing building occupants informed. I've not managed to post to this as often as I would like, though I have had lots of responses to some posts in particular.

2 Finding out where the energy is going

Very much influenced by David MacKay's book *Sustainable energy without the hot air*, I felt it was very important to understand as much as possible about how much energy is being used and what it is being used on.

The Informatics Forum draws electricity and heat from the University's Combined Heat and Power unit in Charles St. Lane. Some cooling is also taken for the server rooms, but the Forum uses no gas directly. In most buildings, reducing the energy used by heating has a larger impact on reducing CO2 emissions than does reducing electricity use. However, I'm not sure if this is true in the Informatics Forum, for three reasons:

1. The heat supplied is partly a byproduct of producing electricity. I believe that gas is burnt in the CHP plant on cold days to supplement the waste heat from electricity generation, but I don't know how much.

2. The scope for reducing heating may be limited. Many rooms in the Forum are too cold for their occupants (e.g. 14°C on a Winter's day), even with the heating turned up.

3. Finally, the amount of electricity used in the Forum seems quite large – around 6,364kWh per day, or roughly 10kWh per occupant per day, assuming 600 people working the Forum. For comparison, the consumption of electricity in my 1909 tenement flat is roughly 1kWh per day per person (3 occupants).

I therefore decided to focus on electricity. Clearly, the reason for our high consumption must be all those computers. Informatics computers are managed within the School and in September 2011 they didn't go to sleep when idle, unlike the computers managed by the University Computing Service. Informatics Computing support (known as DICE) were working on introducing sleep on DICE machines; I was hopeful that this would take a huge chunk out of our electricity consumption.

[1] http://blob.inf.ed.ac.uk/energy/

However, I thought it would be interesting to confirm this suspicion, and I managed to get data with which to test it from three sources:

1. From Shona Buchanan in the Energy and Sustainability office, I obtained the half-hourly total electricity consumption of the Informatics Forum.

2. By a quirk of the wiring in the Forum[2] it is possible to break down, to an extent, how much power is drawn by compute servers, and how much power goes via power sockets in offices, some of which have desktop machines plugged into them. The readings from the UPSs are taken every 10 minutes, and George Ross (from Informatics Computing Support) told me how to access the logs and convert the voltage and current readings in them into an estimate of apparent power[3]. The actual power drawn by the UPSs is not known, and will depend on the actual power delivered and the efficiency of the UPS.

3. The Informatics Forum has a ventilation system that depends on large supply and extraction fans mounted on the roof. The power consumption of these fans is not monitored in real-time, but it is metered, and in a week in October 2011, Dougie Williams, the University's Control Systems Engineer, took readings, giving an estimate of the fans' daily consumption.

I used to script written in R[4] to produce the aggregate plot of energy consumption throughout the week starting 17th October 2011 shown in Figure 1. To my surprise, computing (both in server rooms and offices) accounted for at most 40% of the energy, servers taking 17.5% and offices 22.8%. Not all the power drawn via power sockets in offices is by computers; some is also taken by desk lamps and, in some offices, electric heaters. Of the remainder of the energy, about 25% was taken by ventilation. This left roughly 35% in the "Other" category. This includes lighting in corridors, toilets, seminar rooms &c, kitchen appliances such as the dishwashers, kettles and boiling water taps.

The variation of power over time was as might be expected. The servers have an almost constant load, office sockets (including computers) peak on weekdays, and the "other" use (including lighting and ventilation) has an almost twofold variation from trough to peak.

Figure 2 shows some samples of electricity use in different seasons. Although I have not analysed this for more weeks, it would seem that there is surprisingly little variation between the summer and the winter months. However, in the Christmas vacation, the weekly power consumption is about 80% of the term-time total.

Dave Hamilton and the technicians are also taking monthly readings from the 43 meters located in power closets throughout the Forum[5]. The total energy recorded by these meters is of the order of 100,000kWh per month, which is less than the total of 160,000–200,000kWh recorded by the automated meter readings for the whole Forum. I haven't worked out how to integrate this data with the other data, but it could prove valuable in pinpointing any large uses of energy in the building.

3 Steps towards reducing power consumption

There is always scope for saving some energy by changing individual behaviour. However, this analysis suggested there was a lot of scope for saving energy by altering the building's *systems*, and so I decided to focus on these issues. I was wary of appearing to "preach" directly too much, as some of the energy-saving messages being promoted in the University don't apply throughout the Forum; for example many lights cannot be switched off manually.

3.1 Ventilation

Part of the reason that the ventilation accounts for so much energy is that larger fans had to be installed shortly after the Forum was opened in order to make the working conditions bearably cool for many staff and students, particularly on the fourth and fifth floors, where offices could reach temperatures of 27°C and were stuffy.

[2] The server rooms are supplied by a Universal Power Supply, which has a battery back-up for if there is a power failure. Many (if not all) of the offices are supplied by a separate UPS; this was discovered during a power shutdown, when appliances in offices *didn't* turn off as expected.

[3] See `http://en.wikipedia.org/wiki/AC_power#Real.2C_reactive.2C_and_apparent_powers` for a discussion of apparent and actual power.

[4] http://www.r-project.org/

[5] http://groups.inf.ed.ac.uk/techs/INF/Forum/Forum_Power/index.html

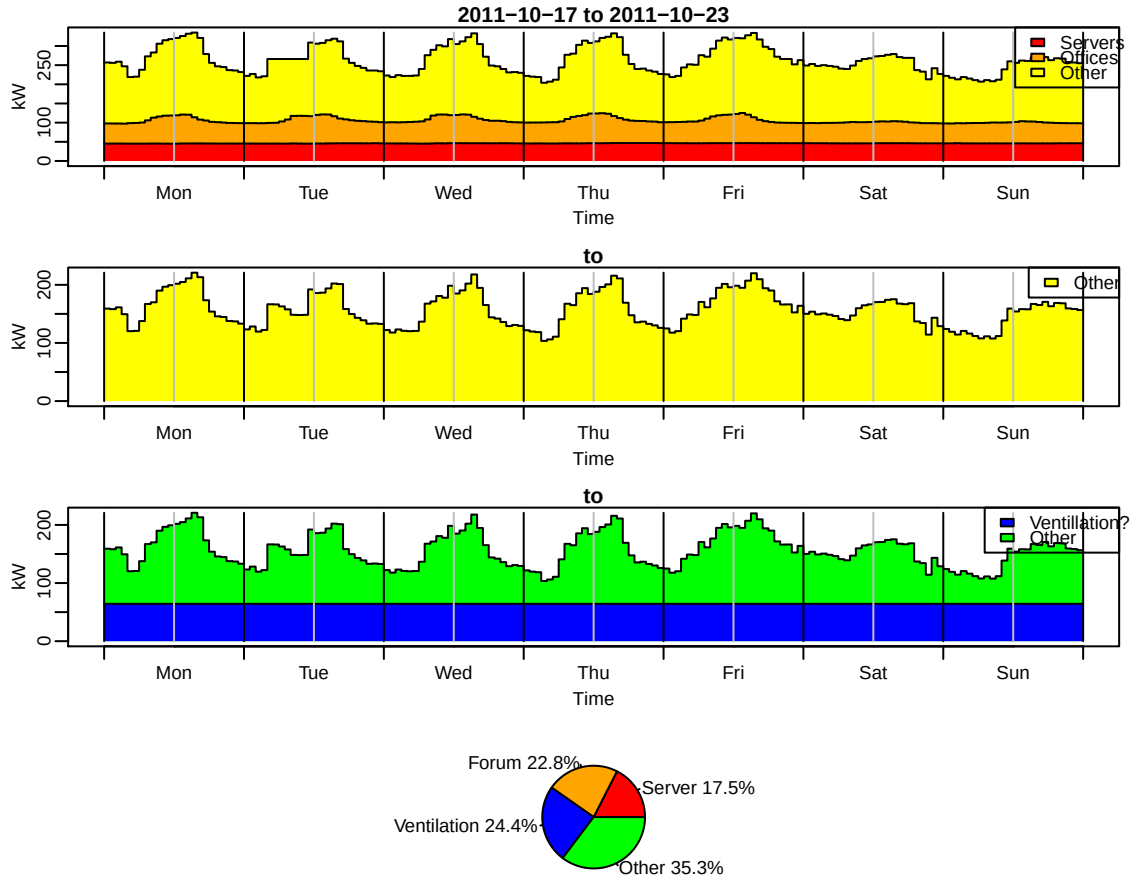

Figure 1: Hourly energy use in a term-time week in the Informatics Forum. **Top:** Total energy use, separated into components for servers, Forum offices and "other" use. **2nd graph:** Expanded view of the "other" energy use. **3rd graph:** "Other" decomposed into an inferred component for ventilation, and a remaining "other". **Pie chart:** Share of energy use of the four components: "Forum" means "Offices" in this chart.

For much of the day, the ventilation system pumps air at a temperature of around 17°C into offices via floor grilles. The air flow to sections of each floor is controlled by dampers, which close off the supply when the air temperature measured in that section falls below a certain level. Ideally, all the dampers should close at some point in the night, but this is not happening due to some sections of the building remaining too warm.

3.1.1 Automating opening and closing of roof vents

As well as the extract and supply fans, there are also some vents on the roof, which can be opened and closed and allow air to escape passively. However, this opening and closing had to be done by hand[6], and required access to the roof. Consequently the vent was only adjusted twice a year, being opened at the start of summer and closed at the end. Following attending a meeting of the Informatics Building Committee, Dougie Williams and David Barratt looked into, and obtained funding for, automating the ventilation system. This work has now been undertaken, though it is not yet known what effect it has had on the energy consumption of the ventilation system.

Dougie Williams adds: "We have made some programme changes in that when the automatic roof vents are open, there is no real requirement for the extract fans to run due to the ductwork configuration. Also, holding off the extract fans helps to keep any heat transfer down between the extract and supply ducts through the cross flow heat exchanger – which shouldn't occur due to the 'face/bypass' damper

[6]By Mike Riley, who had to endure a "traumatic" trip across the roof of the Forum.

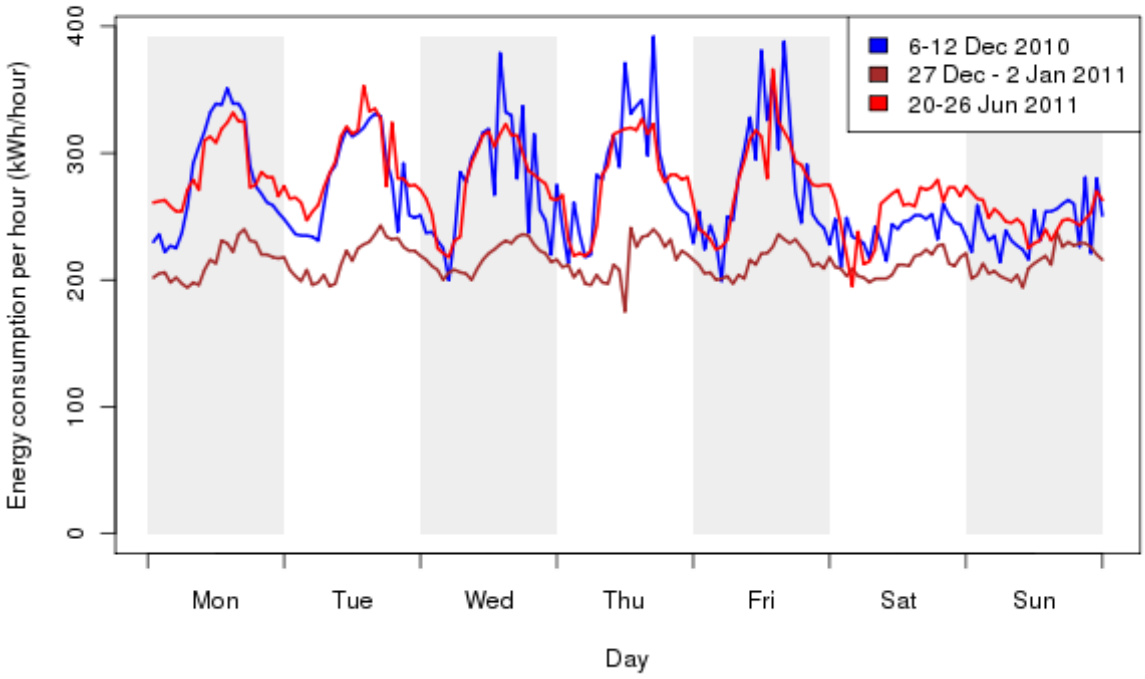

Figure 2: Variation in electricity consumption through the seasons. Hourly power consumption in a winter term-time week (blue), a winter vacation week (brown) and a summer week (red) are shown.

arrangement, but it does! Consequently, the roof vents are open for a large proportion of the night and day – dependant on external temperatures.

The changes were made in two stages on 18th June and then 2nd August so I would expect to see some considerable savings since these dates due to the large power consumption of the two extract fans on AHUs[7] 1 & 2."

3.1.2 IT cooling

Dougie Williams writes: "We have also made the programme changes to the IT hub cooling fan coil units but initial tests showed that we cannot implement these without relocation of the return duct temperature sensors within the FCUs[8]. i.e. we found that when the fan was switched off, the return duct temperature sensor was located too close to the cooling coil and so it recorded a much cooler room temperature than it actually was, holding off the fan. The solution to this would be to relocate the return sensors further down the wall as room temperature sensors so that the cooling coil has no effect. Not sure when/if we'll do this as it's quite low priority and the payback isn't huge – possibly circa £1500 per annum on the FCU fan power."

3.1.3 Comfort survey

Some offices in the building are often too hot, particularly in Summer, and some are too cold in Winter. Generally, the temperature increases higher up the building, but the readings from the Building Energy Management Sensors (BEMS) on a winter morning at 8am show that even on Level 5 there are rooms around 14°C.

At Building Committee in December, Dougie Williams had the idea that we could try to increase the ventilation are flow to offices that are too hot and reduce it to offices that are too cold. This can be done by adjusting the flow rate through, and in some cases sealing off entirely, the ventilation grilles in

[7] Air Handling Units

[8] "A fan coil unit (FCU) is a simple device consisting of a heating or cooling coil and fan." (http://en.wikipedia.org/wiki/Fan_coil_unit)

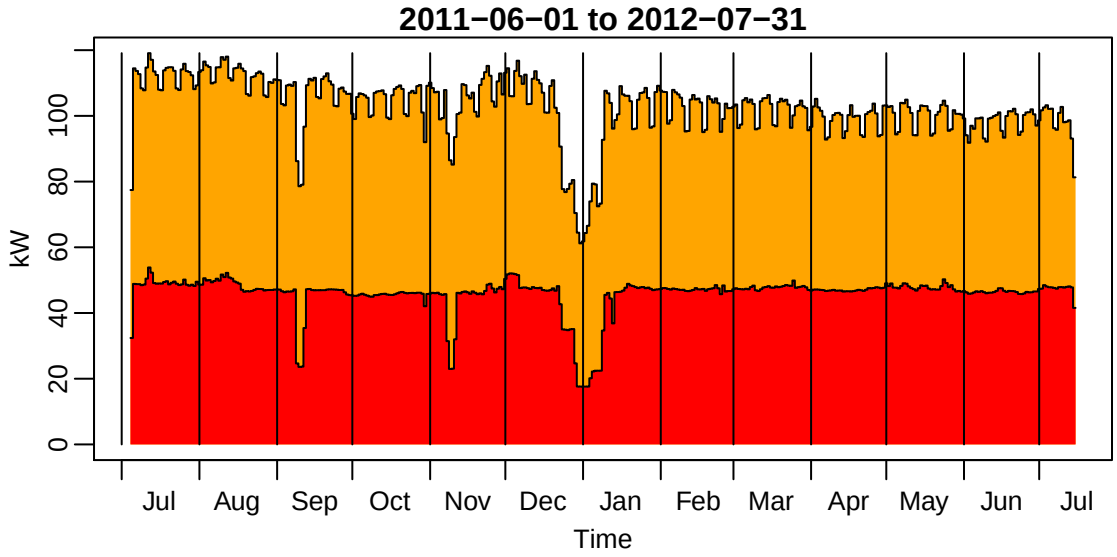

Figure 3: Energy use by servers (red) and computers and other appliances in offices (orange). Note that some of the dips in the server date (particularly in the Christmas vacation) are due to loss of data from the UPS rather than machines being turned off, though some servers were turned off in the vacation.

	Servers	Offices	Total Servers + Offices
August 2011 mean consumption (kWh)	48.8	64.0	112.9
June 2012 mean consumption (kWh)	46.5	52.1	98.6
Reduction (kWh)	2.4	11.9	14.3

Table 1: Computing energy savings, August 2011–June 2012. The percentage saving is 12.6%.

certain offices. The intended effect of this change would be to improve working conditions, and it should also increase the flow rate to areas where the dampers do not currently get closed at night. This might cause these areas to be cooled enough throughout the day so that the dampers close at night.

In order to target these changes most effectively, we decided that we should find out exactly where in the building people perceived themselves to be too hot or cold, and so we ran a web-based "comfort survey"[9]. This also asked questions about whether people use their windows and doors to control the temperature. Whether people do this may depends on external and internal noise levels; for example during the Fringe, there is a lot of noise BBC tent and area behind the Forum. The results from the Comfort survey are currently being analysed.

3.2 Computing

Figure 3 shows the electricity consumption of computing servers and offices (including desktop computers) from July 2011 to June 2012. It can be seen that there is a general downwards drift in energy use; the total power consumption was 12.6% lower in June 2012 than it was in August 2011 (Table 1).

I believe that there is considerable scope to reduce computing energy use further. The ability of DICE machines to sleep and be woken-on-LAN was introduced around December 2011. I had expected this to make a big difference, but it appears to have made a fairly small change. The reason for this is that DICE machines only go to sleep when users log out of them. Many (if not most) users don't log out of their machines at the end of the day, so machines don't go to sleep. As far as I understand, it should be technically possible to allow machines to sleep with users logged in.

3.3 Lighting

The remaining "other" component of the energy after ventilation has been taken out is difficult to dissect. It makes up 35% of the total, about 2200kWh per day.

[9] http://comfortsurvey.inf.ed.ac.uk

I had thought that lighting would be a fairly small component, but given how large the other component is, I am now not so sure. According to Estates & Buildings electricians, the fluorescent tubes in corridors are 49W, and the tubes in the offices are 35W. There are about 100 tubes on Level 2, and probably a similar number on Levels 1–5. So an estimate of the total number of tubes in the corridors is about 500. Were *all* these tubes on *all* the time, this would make 588kWh – a significant chunk of the remaining "other" category, and getting on for 10% of the total.

This calculation is just a ball-park figure: it neglects that some corridor lights may be off at night, but also doesn't include non-corridor lights and office lights. However, it does suggest that there is potential to save significant amounts of energy on lighting.

One of the concerns that many people have raised with me is the number of lights that are on and impossible to turn off, due to problems with the light sensors and circuits. This issue was raised at Building Committee in September. Dave Hamilton requested reports of problems with the lighting from building users. Contractors worked to resolve these issues (over 60 pages worth!) and train up Estates & Buildings staff, so that there were people in the University who know how to work the lighting controls. However, since the end of 2011 I haven't been aware of much activity on this front, and there are still a number of lights that are permanently on. It appears that there are a number of problems with the wiring in the building.

I have suggested that as they fail, we replace fluorescent tubes with LED ones, which are now available, and which use about 50% less energy. This comes at a considerable initial cost, but the lifespan of LED tubes is much longer.

Another way of reducing lighting consumption might be to reduce light levels in seminar rooms. According to David Somervell, Peter Lehany, Engineering Clerk of Works, has been trained in correcting light levels with a hand-held controller. There may be more scope for reducing lux levels in specific rooms to a reasonable level. Light levels were up to 1,000 lux in some seminar rooms David surveyed with Bill Bordass in 2011, and they only need to be perhaps 350 lux.

3.4 Other energy use – the "Switch and Save" campaign

We have tried to reduce energy use where possible; in particular Ewa Hill (Level 2 Secretary) has assisted greatly by placing energy saving stickers on a number of appliances and we have put up "Switch and Save" posters provided by Shona Buchanan in the Energy Office.

3.5 Energy displays

We have tried to inform building occupants by displaying messages and graphs on the touch screens and on paper print-outs – again, arranged by Ewa Hill. The displays of messages on screens has met with some scepticism from users, who question whether the energy used to display them is worth it!

Dougie Williams has worked with a software developer to produce real-time displays of energy for various buildings in the University (Figure 4). Due to technical issues, this isn't yet appearing on the screen in the foyer.

4 Conclusion and next steps

As can be seen from Figure 4, in recent months we have been using around 15–20% less electricity than the same months last year. The saving per month is around 35,000kWh, which equates to a continuous load of 50W. Around a third of this (14.3W) is down to the reduction in Computing (Figure 3). It is not clear how much of the remainder of the reduction is down to:

- The Switch and Save campaign
- Automating the roof vents to improve the ventilation system
- Reductions in lighting consumption (including tubes not being replaced)
- Weather factors – this year's dismal summer probably puts less of a load on the ventilation system

The next steps would seem to be:

- Implementation of sleep on computers whilst users are logged in
- Possible improvements in the ventilation, in the light of the results of the Comfort Survey

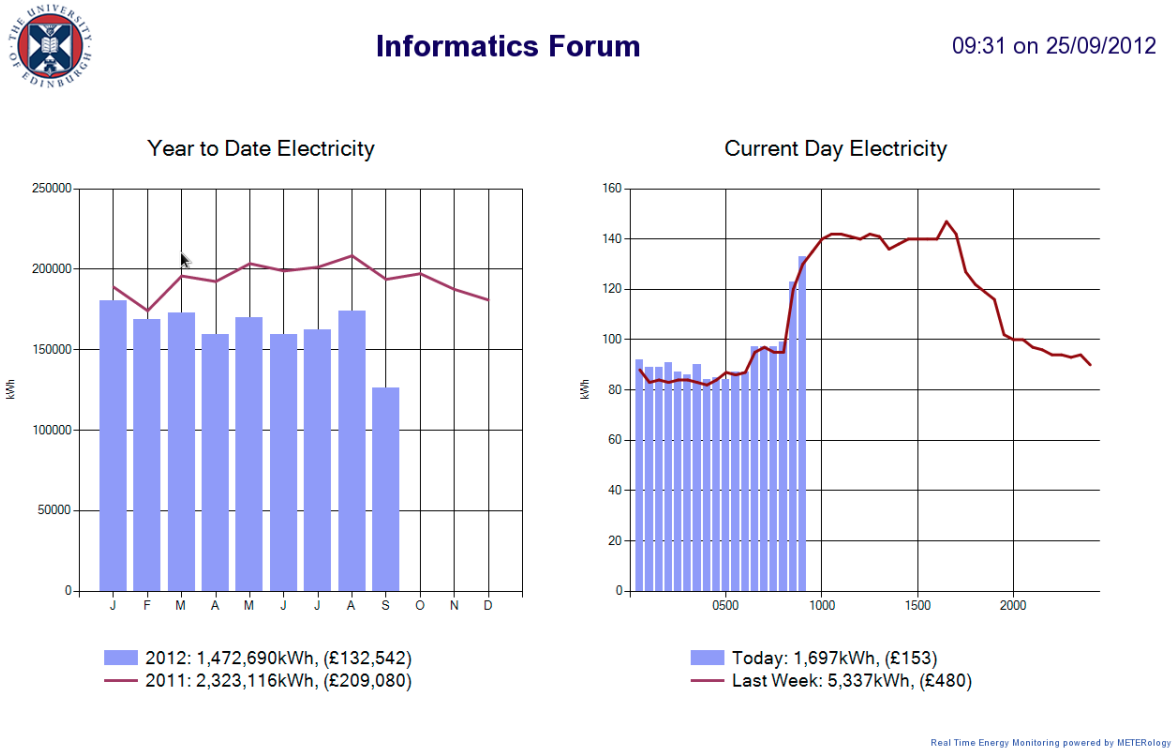

Figure 4: Real-time energy display.

- Fixing lights which are on permanently
- Replacing fluorescent tubes with LED tubes
- Continuing with the "Switch and Save" campaign

5 Acknowledgements

As indicated above, I've had excellent support from a number of people, including:

- Matthew Lawson and Joe Farthing of Transition Edinburgh University and the Sustainability Office, for getting me involved with this and helpful discussions.
- Shona Buchanan, Assistant Energy Manager in the Energy Office, who has supplied me with energy consumption data and helped me to understand it, as well as supplying "Switch and Save" materials.
- Ewa Hill, Secretary in Informatics, who has been supportive in getting the "Switch and Save" message across.
- Dougie Williams, Controls Systems Manager, Estates Operations, who has measured the consumption of the ventilation system, thought about how to improve it, and who has worked on the real-time energy display.
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6 Document history

- 14/07/2012: Initial draft, circulated to all in the Acknowledgements.
- 18/11/2012:
- 25/09/2012: Draft with comments incorporated.