ENERGY USE IN CLEANROOMS CASE STUDY

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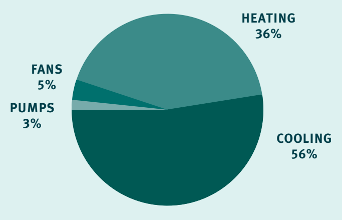
Cleanrooms at Hewlett – Packard.

Cleanrooms are highly controlled environments where the air quality is monitored to ensure the extreme standards of cleanliness required for the manufacture of pharmaceutical, electronic and healthcare goods. These stringent standards usually require high fresh air rates, extensive filtering, temperature and humidity control - all of which results in increased energy usage. Protection from uncontrolled ingress of external ambient air is achieved by creating a pressure differential between the cleanroom and its surroundings.

Within cleanrooms, HVAC energy is distributed on the following basis:-

GRAPH 1. HVAC ENERGY DISTRIBUTION



Ireland's high technology manufacturers have an estimated energy spend of €13 million for their cleanroom operations and this cost is rising annually with an increasing dependency on cleanrooms in general. The majority of this is for electricity consumption and savings of cost up to 20% are possible.

The Annual Self Audit and Statement of Energy Accounts Scheme is operated by the Irish Energy Centre for the largest energy consumers in the industrial sector in Ireland. Participation in the scheme is voluntary with member companies committing to annual energy savings targets, regular audits of their energy consumption, and the publication of an annual statement of their achievements. The Irish Energy Centre provides support to the membership by helping in the preparation of annual statements and also through workshops, seminars, newsletters and site visits, and by providing information on specific approaches to energy efficiency.

As part of the scheme, the Irish Energy Centre contracted Fluor Daniel EEL, in association with Virtual Environment Solutions (VESol) Ltd., to conduct a comprehensive energy audit of cleanroom facilities at Hewlett – Packard Ltd., Leixlip Co. Kildare.

The Hewlett – Packard Manufacturing Facility in Ireland was established in 1995 and produces inkjet cartridges for a variety of Hewlett – Packard inkjet printers and plotters. There are approximately 2,000 employees on the 200 acre site which has a floor space of 80,000 M^2, comprising office blocks, production areas, warehouses, cafeteria and energy centres.

Hewlett – Packard, Leixlip.

This audit presented a real challenge as energy efficiency was a key feature in plant design and selection at construction stage and Hewlett – Packard has an active ongoing energy reduction team.

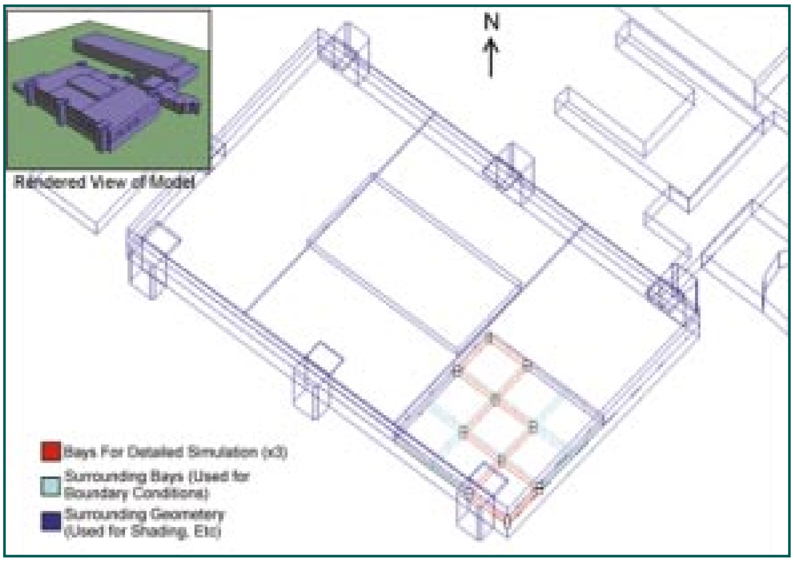


Figure 1. View of simulated bays

THE AUDIT

This energy audit was carried out by VESol Ltd to determine the impact of modifications to operating parameters within a cleanroom using Simulation Software and Computational Fluid Dynamic techniques. This overcomes the typical reluctance to make changes in cleanroom operating conditions for fear of affecting the integrity of the area.

The cleanroom studied for this audit is comprised of a number of identical bays of approx. 232 M^2 each. Each bay has 36 ceiling mounted HEPA filters operating at an average supply air velocity 0.4 m/sec. Half of the return air is extracted through low level grilles mounted in return air columns located at each corner of the bay, while the remainder is extracted through five ceiling mounted grilles, four at the perimeter and one in the centre of the bay.

Two Recirculating Air-Handling Units (RCU's) are utilised to recirculate air within each bay while a separate, shared fresh air unit supplies make up air which is added to the recirculating air, to maintain room pressure and environmental conditions. (See Figure 2.)

Humidity control is achieved by adjusting the makeup air supply to maintain a constant dewpoint temperature of 8.5°C. The unit has two preheat coils , the first recovers waste heat from chillers while the second supplements this as required, followed by a spray humidifier and finally a chilling battery. The heating and cooling coils in the RCU's are utilised only for temperature control.

An unusual feature of this facility is that the cleanroom has external glazing on its outer walls. The solar gain associated with this introduces additional variables not only in terms of energy usage, but also airflow patterns.

SIMULATION

Because of the quantity and diversity of variables associated with the plant it was decided that software simulation techniques be utilised to create a computerised model of the plant and determine utilisation and savings – if any. An added attraction of these techniques is that Computational Fluid Dynamics (CFD) modelling could also be used to determine the impact that the energy saving methods may have on cleanroom operating conditions.

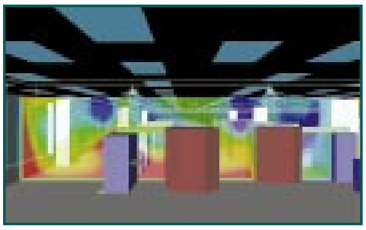


Figure 3. LMA and Airflow Slice Illustrating the Airflow Patterns and Mean Age of Air Around Tools.

A model was created around three bays of the cleanroom, one bay on an external corner with glazing on two sides while the other bays connected to this diagonally. (See Figure 1.) Data on the surrounding six bays was also included to account for any interaction across the boundaries. This design was selected as it gave a real cross-section of cleanroom operating conditions as well as the impacts of solar gain.

All other factors, which might impact on the area, were also entered in the model including construction materials, occupancy, lighting loads, boundary conditions, equipment and meteorological information as well as thermo-physical properties of the building fabric. (See Figure 4.)

Initially a pre-simulation report was issued which described in detail the computer model developed, the simulation strategies and analyses to be conducted as well as any assumptions made. This was then reviewed by the parties involved

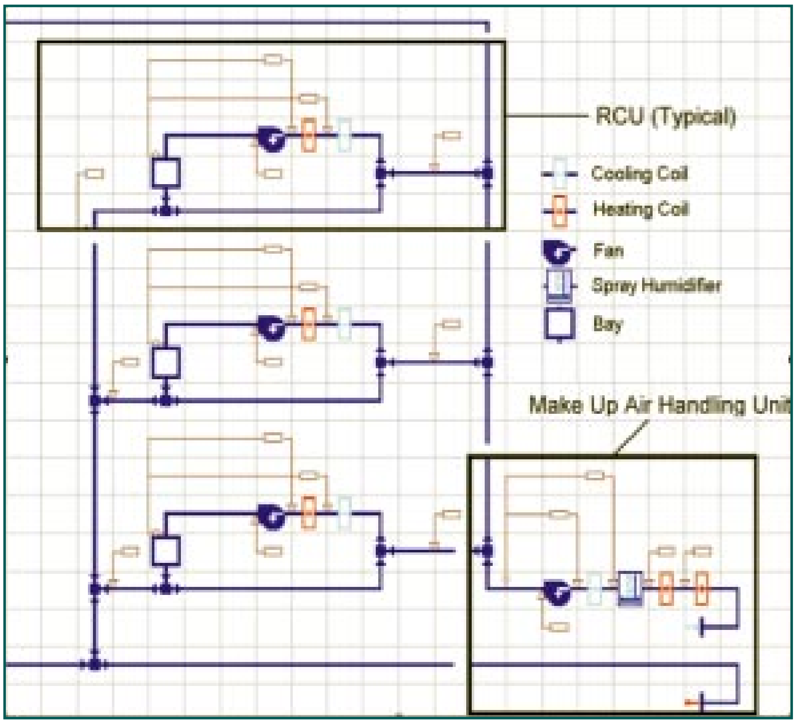


Figure 2. View of the plant network.

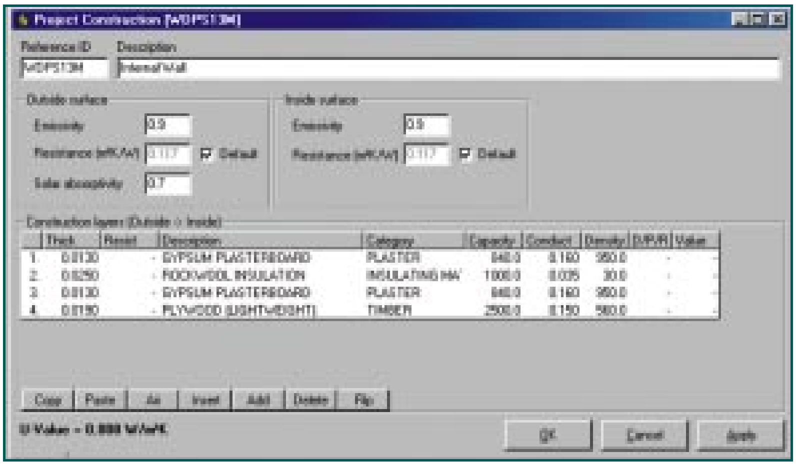
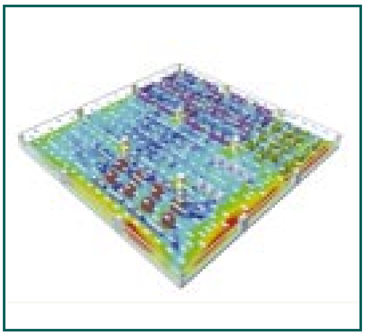


Figure 4. Typical construction detail used in model.



Figures 5. Isometric view of the CFD model showing the variation of velocity levels.

and the model, strategies and simulations were updated to accommodate any modifications required. Checks were carried out to verify the accuracy of the model against live data before the simulations were run. Following simulation, results were analysed and further simulations were carried out as required.

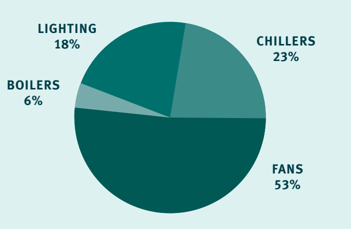
Four simulations were carried out. The first being a base-case to establish a benchmark while the remainder utilized three energy saving strategies.

The scenarios were:

1. **Reduction of Lighting Energy by 20%.**
2. **Reduction of Re-circulated Air Quantities by 20%.**
3. **Reduction of Make Up Air Quantities by 20%**

The base-case simulation was produced using annual Dublin weather data. The energy usage remained relatively constant throughout the year varying between 495,000 and 550,000 mega joules (MJ). The pie chart (Graph 2) illustrates the breakdown across the major consumption headings.

GRAPH 2. ENERGY CONSUMPTION BREAKDOWN



Additionally, monthly data for emissions of CO_2, CO, NOx and SOx were generated. The CFD simulation used data for the 21st of June to fully ascertain the impact of solar gain. The simulation illustrated air movement patterns, velocity gradient, solar interaction as well as Local Mean Age (LMA) of air at critical locations throughout the facility. (Figure 3)

RESULTS

1. **The first scenario while resulting in a 20% energy saving still maintained an average lighting level of 723 Lux at the working plane and resulted in an overall energy saving of 315,805 MJ and an 89,171 Kg reduction of emissions. Taking the average price per kWh of electricity to industrial customers as being €0.0604, this means an annual financial saving of €5,300.**

   Savings resulted from the direct energy to the luminaries and the resultant reduction in heat load.

2. **Reduction of Recirculated Air Volume (RAV) generated direct savings in fan energy and resultant heat load. An overall energy saving of 776,460 MJ with a reduction in environmental emissions of 219,242 Kg. resulted. Taking the average price per kWh of electricity to industrial customers as being €0.0604, this means an annual financial saving of €13,030.**

   Hourly air change rate was reduced from 52 to 42 with minimal impact on comfort conditions. LMA of air showed increases with the occurrences in the 70 to 90 second range becoming much more frequent (red areas on LMA Diagram Fig. 3 & 5).

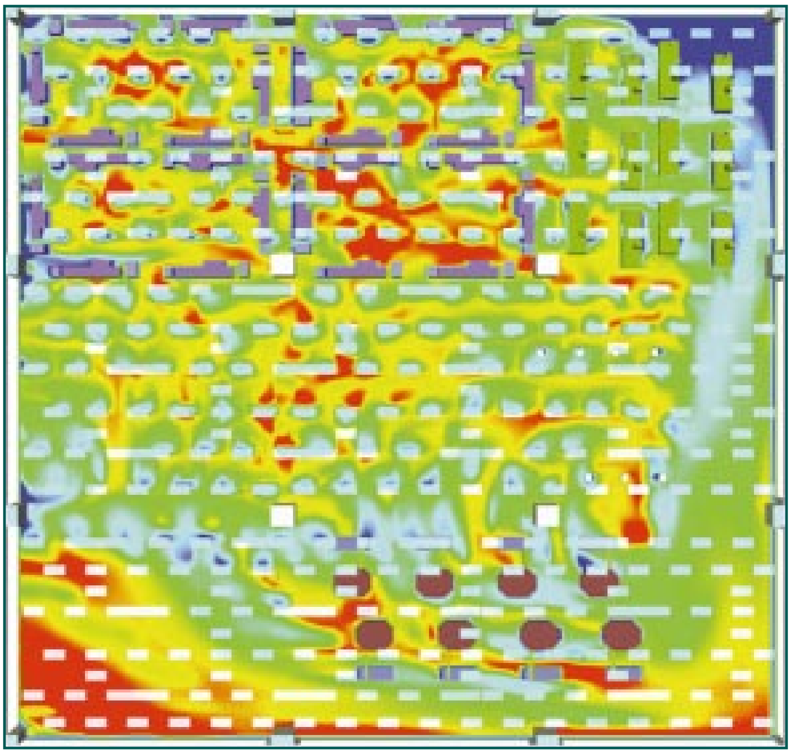
3. **Reduced Make Up Air produced a saving in overall energy of 11,419 MJ and a saving in environmental emissions of 119,776 Kg.**

   Taking the average price per kWh of electricity to industrial customers as being €0.0604, this means an annual financial saving of €200.

   This scenario produced only a very small saving in fan energy, other savings were made in boiler energy, which is the minor factor in overall consumption terms (See Table 1). Chiller energy consumption increased due to greater RCU cooling requirements to compensate for the reduction at make up stage, i.e. fresh air make up air in a clean room serves a dual role in that it is used for room pressurisation and frequently for humidity and temperature control. Thus to maintain room pressure with reduced make up, methods of minimizing and controlling air losses would need to be found.

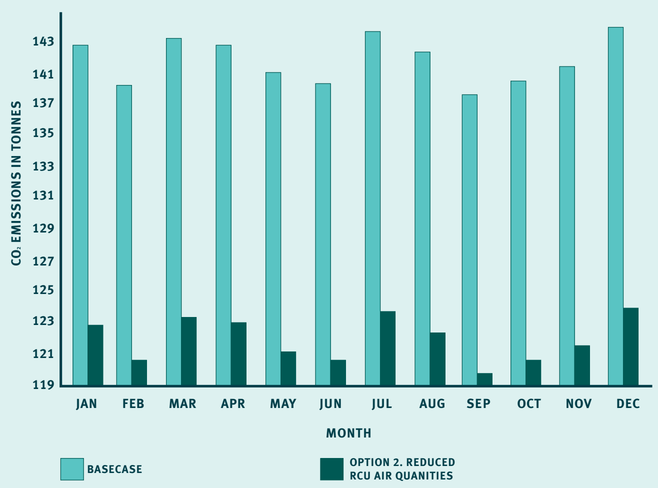
TABLE 1. % ENERGY SAVINGS AND EMISSION REDUCTION VS. BASE CASE

	SCENARIO 1	SCENARIO 2	SCENARIO 3
ENERGY	REDUCE LIGHTING LEVELS BY 20%	REDUCE RCU FAN CAPACITY BY 20%	REDUCE MAKE UP FAN CAPACITY BY 20%
BOILER ENERGY	0.00%	0.00%	32.31%
CHILLER ENERGY	2.43%	9.74%	-1.32%
FAN ENERGY	0.00%	19.10%	0.22%
LIGHTING ENERGY	25.00%	0.00%	0.00%
TOTAL ENERGY SAVING	**5.02%**	**12.35%**	**1.90%**
APPROXIMATE FINANCIAL SAVINGS	€5,300	€13,030	€200
EMISSIONS			
CO_2 PRODUCTION	5.22%	12.85%	0.68%
CO PRODUCTION	0.00%	0.00%	32.31%
NOX PRODUCTION	5.30%	13.02%	0.25%
SOX PRODUCTION	5.37%	13.20%	-0.19%
TOTAL EMISSIONS SAVING	**5.23%**	**12.85%**	**0.67%**



Figures 6. View Showing the LMA Values with Reduced RCU Fan Capacity.

GRAPH 3. POTENTIAL CO_2 EMISSIONS SAVINGS



Utility services for cleanroom.

CONCLUSION

In conclusion the Reduced Air Volume scenario yielded the maximum energy and emission benefit. However this must be balanced against the site process demand for environmental control within the cleanroom. Therefore process modelling should be carried out before full implementation and amalgams of the scenarios may be required.

This type of 'virtual' energy auditing has potential to be used in a wide variety of applications but is especially useful in situations where making actual change to process operating conditions may cause difficulty.

For further information on energy saving technologies and initiatives, contact:
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NDP NATIONAL DEVELOPMENT PLAN

The Irish Energy Centre is funded by the Irish Government under the National Development Plan 2000 – 2006 and part financed by the European Union.

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