Abstract
This is a research by design project, made possible by a live project engaging a historic building on the University campus. The Eliot Hall was originally one of three residences for undergraduate students built in the nineteen thirties. The authors collaborated with the Estate Office and the User Center of Journalism and Media Studies to put in place their research agenda as “Green Architecture - the Eliot Experiment 2001” to study the following hypothesis: (1) passive environmental design strategies; (2) man-nature interactions; (3) user interactive controls of environmental performance; (4) green education. This paper underlines the process from design, construction, fitting out/re-modeling (completed in the Summer of 2003), and the setting up of a data monitoring and display system (Spring and Summer, 2004).

Keywords: green design; under-floor air-conditioning; daylight dimming control; data acquisition and monitoring

1. Sustainability in Hong Kong
Hong Kong has shown her way to sustainability in terms of urban density and resources deployment. She has one of the heaviest population loads in the world. Shortage of flat land and a relentless population increase are perpetual problems that have been haunting the Hong Kong government for over a hundred years. Under such circumstances, Hong Kong has developed, by default, as a compact city (Zaman, Lau, 2000). A strategy employed by the government is the reclamation in Hong Kong Island and Kowloon Peninsula in hope to increase the supply of buildable land, however, narrowing the shorelines on both sides of the Victoria Harbour. Because of the shortage of buildable land, urban expansion in Hong Kong is not only horizontal but also vertical. A skyline full of skyscrapers has become an ipso facto image of Hong Kong. Today, this urban form of Hong Kong is preceded by her emergence as a World City - a city of life with diversity and vitality. (Fig. 1)

It is believed that such concentrated urban strategy is a pragmatic and profitable solution for Hong Kong (Choi, 1997). Although there are arguments that suggest a compact form will generate problems of incompatibility of land uses, overcrowding and congestion. Hong Kong has nevertheless interpreted such compact form as an advantage in its own way, in which Hong Kong finds an efficient use of land resources through vertical space utilization, high accessibility enjoyed by short journey-to-work, mass transit transport networks and low energy use. The developed area is only about 21 percent of the total land area in which urban encroachment to the hilly countryside is minimized, leaving intact the rest of the natural resources untamed.

In a consultancy study on sustainable planning for Hong Kong, the SUSDEV 21 Study completed in August 2000, sustainable development for Hong Kong is defined as “a development strategy that balances social, economic, environmental and resource needs, both for present and future generations, achieving a vibrant economy simultaneously, social progress and a high quality environment, locally, nationally and internationally, through the efforts of community and government (Planning Department, 2000) (Crosbie, 1994).” The Eliot Hall at the University of Hong Kong is an experimental project responding to ecological, cultural and economical sustainability in which conservation and environmental technologies together constituted a sustainable building.

2. The Eliot Experiment 2001
2.1 The Campus
Since the University of Hong Kong started in 1912, there were successive expansions to meet the growing demand on tertiary education in Hong Kong. During the past twenty years, a crest for build-able land on the mountainous campus, fueled by a madness driven expansion program had led to an overlook of heritage - old buildings, that witnessed the growth of the University,
were gradually demolished and replaced by taller new buildings to meet an increase in number of students. Nowadays, only a few of these heritage buildings remained on the campus, Eliot Hall being one of them.

2.2 Background

The nowadays Eliot Hall and May Hall are situated on one of the tranquil corners of the University campus. In the summer of 2001, the Eliot Hall renovation project was carried out. This project involved a three Million Hong Kong dollar refurbishment of the ex-dormitory for teaching use by the Centre of Journalism and Media Studies to train web-editors and writers. It a green project realized by concerted efforts to proclaim sustainable design as a prominent commitment by the University of Hong Kong, for its campus improvement program (Abramson, 2001, Betts, 2001).

2.3 Project Aims

The Eliot Hall Project set an example for the implementation of green application to cultural sustainability.

In a sustainable sense, the building is an adaptive re-use of an otherwise dilapidated and badly serviced building met with disrespect and misuse (Hermannsson, 1997). With the renovation, the building was transformed and borne a new life - redeemed to serve new purposes and new functions, re-creating an active learning space for students and teachers alike. This coincides with the theoretical argument of green researcher and architect N. Kohler - the object of sustainability is not to improve qualitatively the building stock, but to improve without growth by reducing material throughput and improve functional quality and durability. Therefore we should develop techniques to maintain, refurbish and adopt the existing buildings to new requirements and adopt new techniques to fit the existing buildings.

Alongside the spirit of cultural sustainability, the consultant team paid painstaking efforts in maintaining and highlighting the charms of the architectural style, the atmospheric feeling one would expect for an old building, by grafting the existing building with carefully preserved high ceiling decorated with architectural motifs, upgraded with intelligent technologies in such a way to satisfy new needs for functional and technological enhancements. These strategies include passive daylight design, under-floor air-conditioning system, artificial lighting dimming system, energy data record and analysis, intelligent building controls and indoor climate monitoring. It is targeted to be a model for energy-saving building (Edwards, 2001).

More importantly, for the University community, the Eliot Hall project projects an educational model to give a green message and to promote a sustainable built environment (International Conference Sustainable Building, October 2000).

3. Project Details for sustainability

3.1 Three Main Strategies

The Eliot project is explained by three main strategies: firstly, the use of passive energy a design and energy-saving building service system to maximize energy efficiency; secondly, use of artificial intelligent monitoring system for environmental control as well as energy management; thirdly, development of a website to promote environmental education on campus. (Brenda and Vale, 1991).

3.2 Air Conditioning System

In the past few years, there has been a dramatic increase in the use of under-floor air conditioning systems, especially in commercial offices; this is partly due to greater awareness in the concept of flexibility-in-use offered by the system, also because of energy saving and cost-effectiveness features (Spengler and Chen, 2000).

The Eliot Hall is the first project in the University campus which applies the under-floor air-conditioning. Since the function of the media laboratory has similar requirements as an office, the use of under-floor system is an obvious choice because it enables the accommodation of various utility lines and easy reconfiguration of services layout. But what is easy to forget is that the use of under-floor system best represents a good solution for the renovation and refurbishment nature of a heritage building such as Eliot Hall. In most cases, the ceilings of old buildings are well articulated in spatial and architectural terms. The incorporation of false ceiling to hide service pipes and ducts to accommodate air-inlet and outlets would destroy the interior ambience. Hence using an under-floor system for Eliot Hall is a sensible solution for both architectural conservation and green design.

A/C chillers are located outside the building at its rear. Chilled water is transported to the two CAMs (Conditioned Air Modules) through pipes underneath the floor. The under-floor void is divided into two zones horizontally. Whilst the under-floor void is divided into supply and return air channels using removable airtight baffles. The CAM would supply conditioned air into the supply channels in each zone. Supply air is drawn up into the occupied space by fan-assisted terminal units (FTU450), which are recessed into the floor and fed by an under-floor power source. The fan units are provided with individual controls of variable speed and temperature adjustment for user comfort. They are easily interchangeable with floor panels as they are not restricted by any duct or pipe connections. For fresh air, the FAM (Fresh Air Module) will draw air into the return side of the CAM (Fig 3)
Advantages of an under-floor air-conditioning system:

- Under-floor void as a conditioned air plenum to eliminate pipes and ducts.
- With the elimination of pipes and ducts, the initial construction time and cost is reduced.
- In a conventional system, warm air rises to high-level and condensation would occur at the cool air outlet, liable to sick building syndrome. With outlets located on the floor, such problem is overcome.
- Saves space for central plant.
- With the conventional A/c system, 600 to 800mm ceiling void is required for pipes and ducts. An additional 150mm floor void is also needed for running wires and cables. With a raised floor, only 300mm would accommodate both cables and the A/c system, a saving of 500mm of interior space is gained.
- Saves energy by eliminating wastage to cool air above human height.
- Fan speed of the floor terminal units may be adjusted according to user's comfort requirement, hence user has more control of his/her thermal comfort.
- With outlets located on the floor, users attain an optimum thermal comfort condition of warm feet and cool head without noticeable draught and mild air movement.
- The under-floor void can accommodate the services for computers.
- The FTU and return grilles can be easily relocated, as there are no pipe and duct connecting them.
- The cost of reconfiguration is reduced from HK$170-HK$200/sq.m. to HK$17-HK$20/sq.m. and the installation time is reduced from 12-16 weeks to one week.
3.3 Day Lighting Design

Implementation of energy-saving strategy in lighting design is crucial, as artificial lighting generally accounts for 20% to 25% of total energy consumption in a workplace. In the Eliot Hall, there are two main strategies - maximizing natural day-lighting by laser-cut transparent reflectors, plus an artificial lighting installation controlled by a computerized dimming system for energy saving and enhanced psychological results.

For the Eliot Hall, ample daylight available from the northwest facing orientation is directed into the interior by means of a simple and inexpensive device designed by researchers from the Queensland University of Technology, Australia in collaboration with the University of Hong Kong. The rectangular shaped transparent acrylic louvers were carefully designed and cut out by cutting-edge laser-cut technology in Australia and transported to Hong Kong. The louvers called LCP panels are to be mounted onto existing window sashes by hinged joints so that it is possible to adjust the inclinations of the louvers to capture the best daylight according to changing sun-angles. Inside the room opposite the windows, there will be corresponding reflectors, constructed of matt white finished timber panels suspended from the ceiling to receive and re-direct incident day-light into deeper interiors (Edmonds, 1993) (Fig. 5, 6) (Spiegel and Meadows, 1999)

The dimming system is an important sustainable technology incorporated to ensure the optimum performance of both lighting environment and energy efficiency. Monitored by six photo sensors, the system will activate motors controlling the opening and closing of window curtains accordingly. Readings from the same sensors would govern the intensities of the artificial lighting output by varying the energy and output levels. There is also a manual control that caters for special lighting schemes during class (Fig.7 & 8). For example, if the average readings of Sensors C & D rise above the preset level of 1,500 lux, the dimmer will reduce the current of Circuit 5, 6, 8 & 9. Once Sensor B registers a lux level reaching 2,500 lux or above, the dimmer will further reduce more than 50% of the electric current to Circuits 1-9 as shown in Fig. 7. For example, during a lecture when there is a slide show, the user may choose the desired lighting condition from the four preset light conditions by manual switches.

![Fig.5. hand-operated handle to change the inclination and the LCP panels on the northwest façade](image)

![Fig.6. establishing effective optical paths for maximum and minimum incident daylight (based on research by Edmonds)](image)

![Fig.7. Schematic diagram of the daylight dimming control system](image)
Fig. 8. Electrical lighting plan with circuit schedule for auto-dimming control

| FITTING NO. | SYMBOL | DESCRIPTION |
|-------------|--------|-------------|
| F1          | ☒      | SPOT LIGHT ON LIGHT TRACK C/W OR- CBO51 50W/12V TUNGSTEN HALOGEN LAMP AS "ERCRO 7346" OR EQUIVALENT |
| F2          |        | FLUORESCENT LIGHT FITTING ON LIGHT TRACK C/W T36 58W FLUORESCENT LAMP WITH DIMMABLE ELECTRONIC BALLAST AS "ERCRO 7777" OR EQUIVALENT |
| F3          |        | FLUORESCENT LIGHT FITTING ON LIGHT TRACK C/W 2XTCL 36W FLUORESCENT LAMP WITH DIMMABLE ELECTRONIC BALLAST AS "ERCRO 77740" OR EQUIVALENT |
| F4          |        | LIGHT TRACK - T16 54W FLUORESCENT LAMP WITH DIMMABLE ELECTRONIC BALLAST AS "ERCRO 13404" OR EQUIVALENT |
| F5          |        | WALL LIGHT FITTING ON LIGHT TRACK C/W QT12 50W/12V TUNGSTEN HALOGEN LAMP AS "ERCRO 33445" OR EQUIVALENT |
| F6          |        | RECESSED DOWNLIGHT FOR 2x36W COMPACT FLUORESCENT LAMP WHITE METAL HOUSING ALUMINIUM REFLECTOR, ALL ACCESSORIES AS "HOP SHING LOONG-ZD2225" OR EQUIVALENT (AT LOBBY AREA, DIMMABLE ELECTRONIC BALLAST SHALL BE REQUIRED) |
| F7          |        | FLUORESCENT COVE LIGHT-1200mm FLUORESCENT BATTEN LIGHT C/W 1X28W FLUORESCENT TUBE (T16/T5)8 ELECTRONIC BALLAST (EXACT NUMBER OF FLUORESCENT LAMP SHALL BE CONFIRMED ON SITE) |
| F8          | +      | LIGHTING POINT (FALSE CEILING LEVEL/WALL MOUNTED) |
| F9          | EXIT   | EXIT SIGN BOX W/18W WHITE FLUORESCENT TUBE C/W SELF-MAINTAINED TYPE EMERGENCY POWER PACK INCLUDING Ni-Cd BATTERY, INVERTER AND CHARGER FOR AT LEAST 3 HOURS EMERGENCY OPERATION AND COMPLIED WITH F.S.D. REQUIREMENT |
| F10         |        | 2X18W (LV), 3-HOUR FULLY AUTOMATIC EMERGENCY LIGHT AS "JOHNSON JES-1683" OR EQUIVALENT |
| F11         | ☼      | SURFACE MOUNTED 2X36W FLUORESCENT LIGHTING FITTING C/W ALUMINIUM LOUVRE REFLECTOR AND ELECTRONIC BALLAST AS "INTERLITE 6LC286" |
|             |        | Photo Sensors |
3.4 User-Interactive Control

With the advancement of computer technology, performance of building services system may be controlled with the click of a mouse.

The CAMs are connected to controlling modules (Hirolink) and modems which in turn are connected to a PC station in the laboratory. Data is transmitted through this path from a computer which directly controls and monitors the CAMs via a data software program (Hirovisor). The system is featured with an alarm system for specific events, for example, a high/low humidity alarm at the PC station. The PC can in turn transfer such alarms in the form of e-mail, fax and even SMS signals.

The lighting system is controlled and monitored by the same PC via the dimmer. The digital interactions between users and the systems enable remote control and status monitor through internet, automatic control and programmable functions (Fig. 9).

3.5 Electric Power Consumption Monitoring

As in an advanced building, the Eliot Hall is incorporated with an electric power consumption monitoring system for power management. Such system provides means to accessing how efficient the building behaves. In addition, it provides valuable data for researchers for development in sustainable building technology and design.

The Eliot Hall is implemented with an electric power consumption system for the aforesaid advantages. This is basically operated with digital power meters and a computer program. In total, four usages are monitored and displayed: general office appliance, lighting system, A/C system as well as the total electric power consumption in the Library adjacent to the Media Laboratory. With the assistance of computer programs, users can ask for instant readings in the past, present or statistical graph over a certain period. These statistics are useful for power management in predicting power budget, evaluating power saving strategies and circuit status monitoring with reference to space usage and occupancy (Fig. 10).

Initially, the team has carried out preliminary study to identify the percentage distribution of power consumption due to air-conditioning, lighting, and applicances. This was done with the aid of digital readings from three separated power circuits. Using data from normal work day specimen over a period of 8 months from Summer to Winter, May to December, 2003 (Figure 11a 11b and 11c). Another pilot study was carried out in Spring 2004 to measure the energy saving performance of photo-sensor operated dimming of artificial lighting installation (Figure 12). As can be seen, there is a clear indication of effectiveness with the operation of automated dimming in the measured period.

Further analysis will be carried out to measure the energy saving performance of the green features introduced for both lighting and air-conditioning system in coming months of Spring and Summer of 2004, with reference to similar occupancy status.
In June 2004, a questionnaire study of subjective response to thermal and lighting environment was carried out in Eliot Hall. A group of 9 architectural students was involved in the 25 minute test in the media laboratory, followed by a 25 minute test in an adjacent place - a library. Reference is made to similar investigation protocol reported in the “European Audit Project to Optimise Indoor Air Quality and Energy Consumption in Office Buildings” (Roulet, 1994). The test format and content aimed to detect variation in the response pattern for the media laboratory which incorporated an underfloor a/c system and auto-dimming lighting system.

The results of subjective response are tabulated in Table 14a for temperature, RH and lux level; 14b and 14c for the distribution of individual response. The overall result indicated that there is a marginal difference in the perception of brightness and coldness favoring the laboratory to the library.

### Table 1. Energy consumption in KWh of the Media Teaching Laboratory from 1 May to 29 Dec. 2003

| Total KWh | Lighting | General | A/C |
|-----------|----------|---------|-----|
| 82,059.94| 13,829.68| 10,738.46| 57,491.8 |
| 100%      | 16.9%    | 13.1%   | 70.1% |

### Table 2. Measured data during questionnaire study

| Location                  | LAB   | LIB   |
|---------------------------|-------|-------|
| Average temperature (°C)  | 23.0  | 23.6  |
| Average R.H. (%)          | 56.7  | 51.4  |
| Average illuminance (lux) | 908   | 660   |
| Time started              | 14:45 | 15:10 |
| Duration (minutes)        | 25    | 25    |

3.6 Thermal and lighting comfort study by questionnaire

In June 2004, a questionnaire study of subjective response to thermal and lighting environment was carried out in Eliot Hall. A group of 9 architectural students was involved in the 25 minute test in the media laboratory, followed by a 25 minute test in an adjacent place - a library. Reference is made to similar investigation protocol reported in the “European Audit Project to Optimise Indoor Air Quality and Energy Consumption in Office Buildings” (Roulet, 1994). The test format and content aimed to detect variation in the response pattern for the media laboratory which incorporated an underfloor a/c system and auto-dimming lighting system.

The results of subjective response are tabulated in Table 14a for temperature, RH and lux level; 14b and 14c for the distribution of individual response. The overall result indicated that there is a marginal difference in the perception of brightness and coldness favoring the laboratory to the library.

### Table 2. Measured data during questionnaire study

| Location | LAB | LIB |
|----------|-----|-----|
| Average temperature (°C) | 23.0 | 23.6 |
| Average R.H. (%) | 56.7 | 51.4 |
| Average illuminance (lux) | 908 | 660 |
| Time started | 14:45 | 15:10 |
| Duration (minutes) | 25 | 25 |

3.7 The Role to Proclaim Sustainability - Eliot Hall web site

The Eliot project has demonstrated a vision towards sustainability. A commitment is to bring out a green message, to introduce environmental awareness to the university community and the general public (Muto, 2003). Responding to this educational role, a web site on the Eliot Hall project has been created (http://www.arch.hku.hk/research/greenarch). Information on various systems, energy saving strategies, and climate data are available online. Viewers may access the a/c, lighting control and monitor electric consumption, indoor climate, weather station, camera viewing and obtain summary reports to access knowledge on green architecture (Public Technology et al., 1996).
4. CONCLUSION

Eliot Hall represents a deployment of passive technologies to bring a green concept to reality. The integrative use of relatively low cost design such as energy-saving building services system, artificial intelligent monitoring and control system optimize the use of energy resources. In simple terms, the Eliot Hall which was designed and constructed in 1912 was converted into a high performance building in 2002 (Edwards, 1998, Kobet, 1999).

It is hoped that the Eliot Hall project will promote sustainability in Hong Kong by introducing not only to the university community, but also the general public green concepts in built environment, and act as a model for sustainable design (Seal-Uncapher, 1999).

In bringing about a sustainable environment, man and nature interaction plays a major role in determining its success (Sinclair, 2001). Every action undertaken by men has an impact on the environment, directly or indirectly. Alertness to environmental protection is to be raised among the public (Woolley, 1997). This can only be achieved through intense promotion and education on green concepts.

Eliot Hall has taken the initiative in bringing userinteractive system into use. Climate control, such as indoor air conditioning, is no longer centralized. Each user is encouraged to have control over the temperature within the user’s individual work area; adjustments can be made to increase users’ comfort level, meanwhile ensuring that excess energy will not be consumed. The purpose to energy saving is achieved. Through this user interaction, it is also hoped that users will be able to build up a strong sense and understanding to sustainable development (Traugott, 1999).

The definition of sustainable development is not easy to conclude. However, as we are facing energy crisis and global warming architects, engineers and users should strive for buildings with high performance and high energy-efficiency. The Eliot Hall project is a step towards this common goal.

Acknowledgements

Thanks are to due to the following for participating, supporting and donation of hardware and software to make it possible the installation and website
Action Design Company Ltd.; AET Flexible Space (HK) Ltd.; Atelier VIII Architects Ltd.; Centre of Journalism and Media Studies; Chief Way Engineering Ltd.; Estate Office, the University of Hong Kong; JCL Consultants Ltd.; Macostar HK. Co. Ltd.; William Artists HK Co. Ltd.; and the following contributors: Chan, S.K.; Prof. Chan, Y.; Edmonds, I. R.; Li, F.M.; the late Prof. Bill Lim; Shimatsu, Y.; Tang, G.; and the HKU architectural students of Year 3, Class 2002-2003; and 9 students from Year 3 of Class 2003-2004, and finally Research Grant Council HK for its support to project no. HKU 7205/02H.

References

1) Abramson, P. (2001) School Planning & Management, 40, p54.
2) Betts, K. S. (2001) Environmental Science & Technology, 35, p198A.
3) Brenda and Vale, R. (1991) Green architecture : design for an energy-conscious future, Little, Brown, Boston.
4) Choi, L. S. (1997) The ‘green buildings’ concept in Hong Kong, University of Hong Kong, Hong Kong.
5) Crosby, M. J. (1994) Green architecture : a guide to sustainable design, Rockport Publishers, Rockport, Mass.
6) Edmonds, I. R. (1993), Performance of laser cut light deflecting panels in daylighting applications, Solar energy Materials and Solar Cells, 29, 1-26
7) Edwards, B. (1998) Green buildings pay, E & FN Spon, London.
8) Edwards, B. (Ed.) (2001) Green architecture, Wiley-Academy, London.
9) Hermannsson, J. (1997) Green building resource guide, Taunton Press, Newtown, CT.
10) International Conference Sustainable Building (October 2000) In Joint Conference of Sustainable Building 2000 and Green Building Challenge 2000(Ed, Building, I. C. S.) [Ottawa]: Natural Resources Canada, Maastricht, the Netherlands.
11) Kobet, B. (1999) Green buildings, Commonwealth of Pennsylvania : guidelines for creating high-performance green buildings, Pennsylvania Dept. of Environmental protection, Harrisburg, Pa.
12) Muto, S. (2003) Wall Street Journal - Eastern Edition, 241, pB8.
13) Public Technology, I., Council, U. S. G. B., Energy, U. S. D. o. and Agency, U. S. E. P. (1996) Sustainable building technical manual : green building design, construction and operations, Public Technology, Inc., Washington, D.C.
14) Seal-Uncapher, J. (1999) Architecture, 88, p139.
15) Sinclair, K. (2001) Engineered Systems, 18, p34.
16) Spengler, J. D. and Chen, Q. (2000) Annual Review of Energy & the Environment, 25, p567.
17) Spiegel, R. and Meadows, D. (1999) Green building materials : a guide to product selection and specification, Wiley, New York.
18) Traugott, A. (1999) Consulting-Specifying Engineer, 25, p68.
19) Woolley, T. (1997) Green building handbook : a guide to building products and their impact on the environment, E & FN Spon, London.
20) Roulet CA. European audit project to optimise indoor air quality and energy consumption in office buildings. National Report of Switzerland, 1994.
21) Bluyssen PM, de Oliveira Fernandes E, Fanger PO, Groes L, Clausen G, Roulet CA, Bernhardt CA, Valbjorn O. European audit project to optimise indoor air quality and energy consumption in office buildings. Final Report, Contract JOU-CT92-0022, TNO-Building and Construction Research, Department of Indoor Environment