# INNOVATIVE OFFICE BUILDING – LIGHTING, PRODUCTIVITY AND ENERGY

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## ABSTRACT:

In December 2000, a new demonstration building for lighting research "Valotalo" (Light House) was inaugurated at Helsinki University of Technology. The newest experimental technologies for integration of artificial and daylight were applied in order to validate their efficiency and peoples' acceptance. Photovoltaic panels of 7 kW maximum power were integrated in the south façade. A 30 $m^2$ solar heating system mounted on the roof of "Light House" produces warm service water. A daylighting test room is also built on the roof for further daylight research. Inside the building, all of the Lighting Laboratory's rooms have different lighting control systems: two types of LON-control systems, and the newest digital lighting control with DALI protocol. The south facing windows of the 3rd floor have motorised venetian blinds in their lower half and laser-cut panels in the upper half of the window frame. At present, the performance of the installed technologies is being studied. Data are collected from energy availability, luminance measurements and analysis, and users interviews. In offices, perception of glare is measured, and luminance distribution is analysed at different seasons and time of the day using a digital photometric image analysis system.

## KEYWORDS

Lighting control, daylighting, photovoltaic panel, solar heating, laser-cut panel

## "LIGHT HOUSE"

The new building extension of the Department of Electrical and Communications Engineering, inaugurated in December 2000 at the Helsinki University of Technology, was specifically designed to create the optimum environment for lighting research. Its name is "Valotalo" – "Light House". The objective was to apply the newest experimental technologies for the integration of artificial and natural lighting, and to validate the efficiency and peoples' acceptance of these technologies.

The building is structured on four floors. On the ground and the first floor are a net café, respective the department's library and reference library. On the second and third floors are Lighting Laboratory's rooms and two computer classrooms. Thermal solar panels and an experimental, completely glass-built room, which create a multi purpose bed for daylighting research, are placed on the roof of the building. The photovoltaic panels are architecturally and aesthetically integrated on the south façade of the building. The panels are serving also as sunshade elements. The south facing windows of the third floor have built-in motorised venetian blinds in their lower half and laser-cut panels in the upper half of the window frame. The purpose of the panels is to eliminate direct glare from daylight, and to redirect the sunlight to the ceiling and deeper into the room. In this way the light reaching the ceiling is spread around the room. All of the Lighting Laboratory's rooms have different integrated lighting control systems.

## SOLAR ENERGY

### Solar Thermal System

The solar heating system mounted on the roof of "Light House" is based on the production of domestic hot water. The consumption of hot water is high due to the presence of the department's cafeteria. The total area of the roof-mounted glass-coated high temperature collector is 30 $m^2$, and the estimated average power is 13 kW. The produced thermal energy is stored in the hot water storage tank of 2400 litres and distributed in the internal installation of hot water supply.

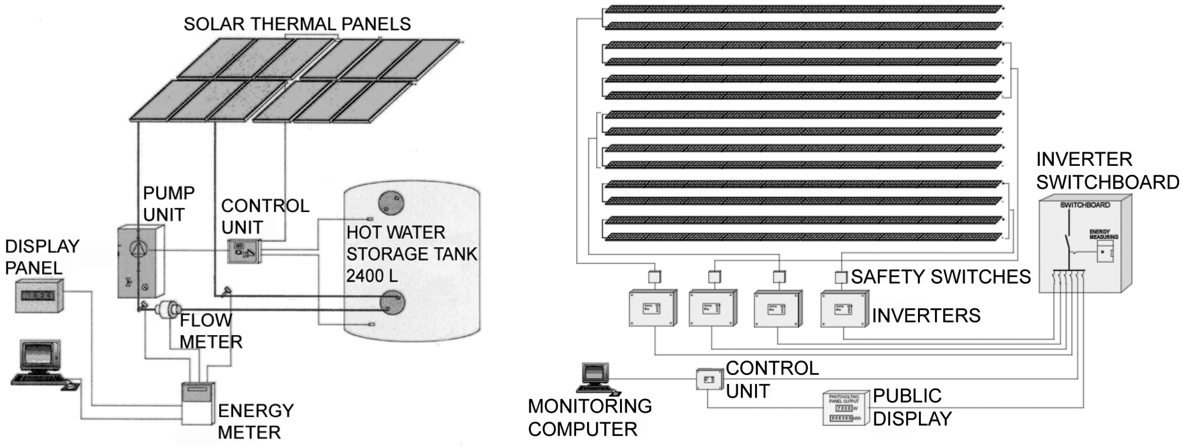

Figure 1: The solar energy installations of solar thermal system (a) and photovoltaic panels (b)

After 12 548 surveillance hours, the solar heating system has produced a total amount of energy of 15.868 MWh for a volume of 3 885.34 $m^3$ hot water. The maximum recorded power of the system was $P_{max}$ = 18.6 kW for a flow rate of 0.94 $m^3/h$ and a delivered temperature of 48 ºC.

### Photovoltaic Panels

On the surface of the south façade of the building, an integrated system of photovoltaic panels is mounted between the ground and third floors. The panel system serves also as sunshades. The maximum power gained by the panels is 7 kW. The photovoltaic grid contains 140 high efficiency polycrystalline silicon photovoltaic modules of 50 Watts each. The total area of the panels is 60 $m^2$. The modules are designed to be able to withstand harsh conditions and still continue to perform efficiently. The direct current produced by the panels is converted to alternating current by four string inverters with an efficiency of 96% in optimal conditions (the efficiency is 94% already at 0,25 $P_{ACnom}$), and supplied to the distribution mains. The inverters transmit data through the mains using power-line communication, making the data of the single components accessible at nearly any point of the building. The acquired parameters for diagnosis and control are: (1) PV-voltage and current; (2) grid voltage and frequency; (3) output current and power; (4) total operation hours; (5) total accumulated energy [kWh]; and (5) the system status. The control unit connected to the AC line collect the data provided by the inverters and then processes, visualizes and transmits it according to the user's requirements. The control unit is a central data acquisition and diagnosis system for up to 50 inverters, which allows a flexible system management with remote control of the plant components and transmission of system relevant data to PCs.

The amount of electric energy gained over one year by PV system is 4 421 kWh. The low amount of energy gained (~12 kWh daily) is due to the dust coming from nearby construction site. A new wing was built to the department very near the "Light House" during last year, and the construction phase affected the performance of panels.

## GLASS "CUBE"

The glass "cube" is located on the roof of the building. The total floor area of the cube is 4 x 4 m and the height is 2,7 m. The walls (cardinal directions oriented) consist of 1 m wide glass elements. The wall elements and the ceiling have a single glazing. The cube is equipped with darkening curtains and venetian blinds. The size and orientation of the windows can be freely chosen.

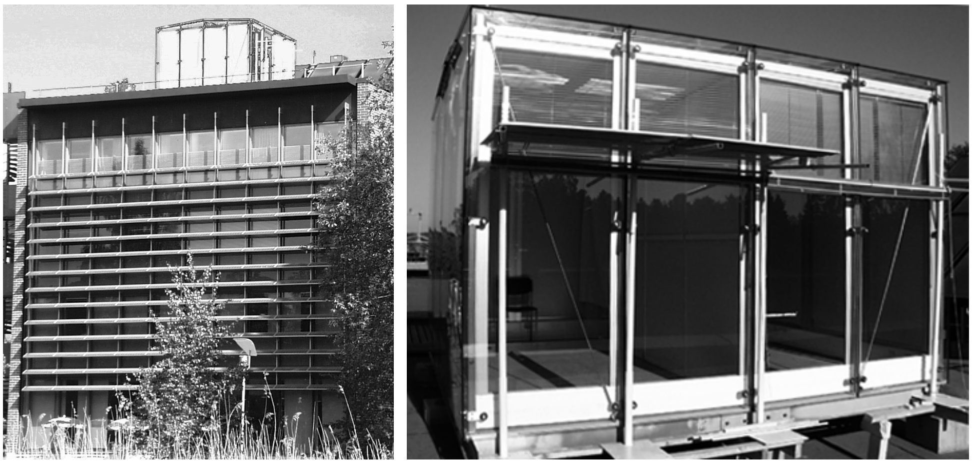

Figure 2: The south façade of "Light House" and the roof mounted "Glass Cube"

For lighting measurements inside the room the cube is equipped with a 10 channel data acquisition system. Daylight data is gathered with one horizontal and four vertical sensors on the roof of the building near the glass cube.

The Productive Office 2005 research project includes laboratory studies in the areas of artificial lighting and daylighting. The visual characteristics of display units, the quantity and quality parameters of modern workplace lighting and the effects of daylight glare on productivity will be studied. Productivity and visual performance tests with observers will be carried out in the glass cube. Results of the laboratory studies will be linked to the productivity model development. The project is a part of the Healthy Building Technology Program of Tekes, the National Technology Agency. The program aims to improve the current lifecycle of buildings and extend their service life.

## LIGHTING CONTROL

In the “Light House” the lighting control systems are different in different rooms: there are two LON control systems (pure LON and Helvar-Mimo LON system) and the new Helvar’s Digidim lighting control system, based on DALI protocol. The pure LON system has only manual up/down light control. Mimo LON system has a constant light control with a photosensor, rotary control switch and occupancy sensor. DALI system consists of a wall-mounted panel with 4 pre-programmed lighting scenes, occupancy and constant light control with multi-sensor and IR-remote control.

### Performance test of a constant light system

The objective of the test was to measure the performance of daylight responsive lighting control system Helvar-Mimo LON and to establish the energy savings provided by the system. The test of the control system was carried out during one week in May 2001 daily from 8 am to 5 pm.

The test room was one office room (size 4.8 m x 3 m x 3 m) situated on the 3rd floor of the building. The vertical window with double-glazing faced to the west. The position of the venetian blinds was open during the test period.

### Measuring instruments

The room was equipped with three horizontal photosensors (front sensor near the window, middle sensor in the middle of the room and rear sensor in the back of the room) at the height of the workplane. The locations of the photosensors were chosen according to the IEA monitoring protocol. The outdoor horizontal and vertical west-oriented photocells were located on the roof of building. The readings of the photosensors and the control signal voltage to the ballasts were recorded every 1 minute.

### Energy savings

The power consumed by the luminaires, for the evaluation of energy savings, was calculated from the recorded control signal values and measurements carried out in an integrating sphere. In the integrating sphere the lumen output and the power consumption over the whole control signal range (0…10V) was measured.

The energy savings were calculated between 8 a.m. to 5 p.m. The reference power was the maximum power of the lighting system during the night-time.

The recorded illuminances and the calculated power consumption on a semi-cloudy day (19th of May 2001) are presented in Fig.3. The daylight data of that day is presented in Fig. 4. The energy saving for this observed day was 61%. During the test period the daily energy savings were between 49…63% and the average value was 58%.

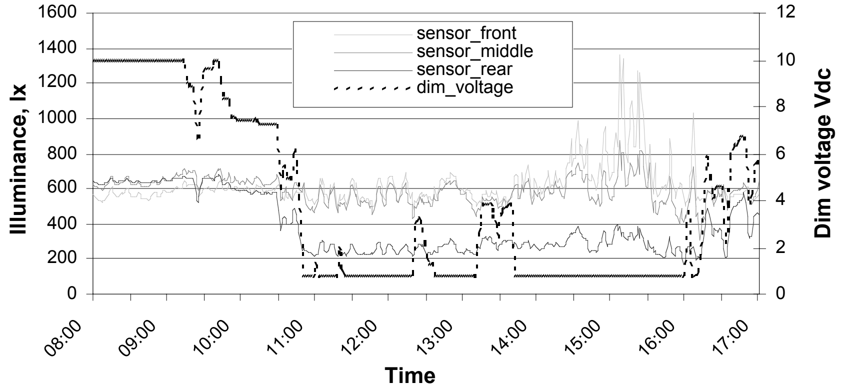

Figure 3: Performance of constant light system on semi-cloudy day

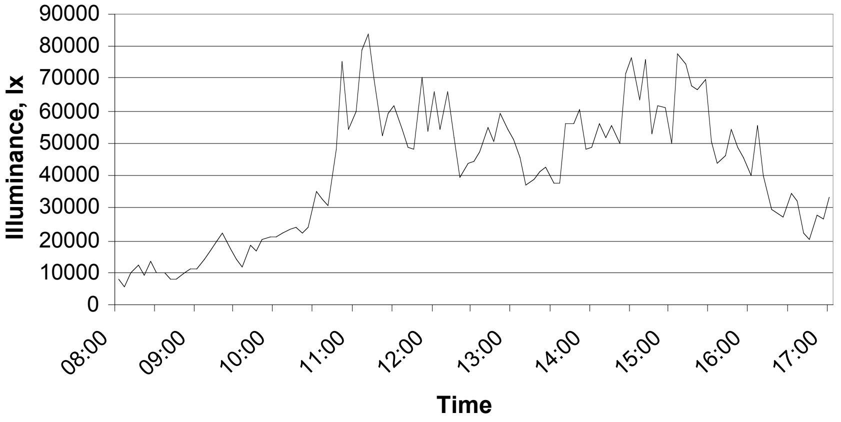

Figure 4: Outdoor horizontal illuminance

## LASER-CUT PANELS

On the 3rd floor, the south-facing windows of two office rooms and a coffee-break hall are equipped with built-in motorised venetian blinds and laser-cut panels. The venetian blinds occupy the lower half of the windows and are controlled by the users. The laser-cut panels occupy the interior upper half of the window frame. There are four types of panels: (1) fixed panels – normal cut; (2) middle tilted panels – normal cut; (3) side tilted panels – normal cut, and (4) fixed panels – 10º cut. The cut spacing ratio for all panels is $D/W = 4/6 = 0.666$, where $D$ is the cut spacing and $W$ is the cut depth (and thickness of the panel).

The fixed panels with normal cut behave as follows:

- In summer time nearly all sunlight is admitted and deflected to the ceiling;
- About half of near equinox light is deflected to the ceiling;
- Winter light passes through without deflection or with minor deflections;
- Diffuse light from overcast sky is strongly deflected towards the ceiling.

For fixed panels with laser cuts at 10º inclination the high elevation light is deflected considerably more deeply into the room.

The tilt of the mobile laser-cut panels can be continuously adjusted to obtain optimum penetration of the sunlight into the room.

The purpose of the laser-cut panels is to eliminate direct sunlight glare, and to redirect the sunlight to the ceiling and back end of the room. This has been achieved but in some circumstances the panels themselves are a new source of glare as can be seen in fig.5-b for the adjustable panels (middle window).

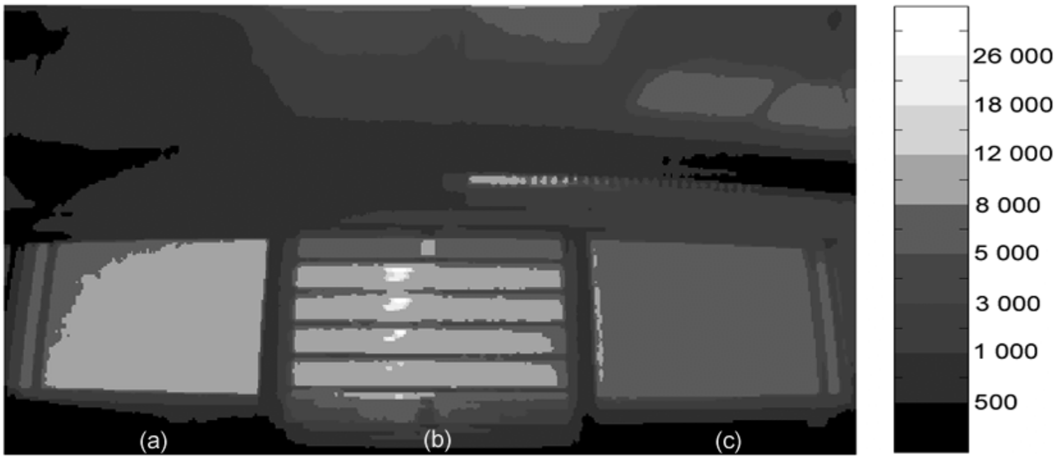

Figure 5: Windows without panels (a), with slat-type adjustable panels (b) and fixed panels – normal cut (c): Luminances [cd/m$^2$] and luminance distribution in a clearly sunny day at noon

## CONCLUSIONS

The amount of solar energy gained is expected to increase after the cleaning and maintenance program has been adopted. However, because of architectural reasons, it was not possible to give the optimum slope to the PV panels, thus the power of the system is always lower than the nominal one.

The expected energy savings with constant light systems are high even in Finland between March and October. This requires however, that glare problems caused by daylight can be solved with an advanced daylight redirecting blind systems. With traditional manually controllable blinds the frequent daily controls by the occupant are necessary to gain remarkable savings. Digital lighting controls give new possibilities to make and store individual pre-programmed lighting scenes for the user’s needs. The occupancy sensor is a useful and inexpensive device to save lighting energy in office buildings assuming that its placement is carefully designed to guarantee the desired action.

Vertical laser-cut panels (with fixed or 10º-inclination angle) are performing properly with high solar altitudes, but with adjustable slat-type panel it is possible to improve daylight penetration and glare control in all seasons.

After one year of use, the demonstration building “Light House” has attained one of its goals: to offer to the Helsinki University of Technology’s students and lighting researchers an optimal environment for a better understanding, usability and discovery of new meanings of the fact of light. The present and future investigations developed here are establishing proper ways to integrate these new technologies in ordinary buildings, for helping people to feel and perform better in better environments.