Strategies for increasing energy efficiency in commercial buildings

ALBU Horaţiu Călin, Ph.D. student[1]
GROSULEAC Dan Lucian[2]
BEU Dorin, reader[3]
POP Florin, professor[4]
[1, 3, 4] Technical University of Cluj-Napoca, Romania
[2] Philips Romania

Commercial lighting systems consume around 43% of the total electrical energy use by lighting, accounting for 30% of the total energy consumption in commercial buildings. [1]

Personal computers and monitors account for approximately 40% of all energy consumed by office and telecommunications equipment in U.S. commercial buildings. [2] Annual energy use by personal computers is expected to grow 3% per year, while energy use due to other types of office equipment is expected to grow 4.2%, caused by the continuous penetration of new technologies and greater use of office equipments. [3]

The EU has committed to its new energy policy to improve energy efficiency by 20% until 2020. [4]

Office lighting systems

The light output provided in the commercial buildings in 2005 was due to linear fluorescent lamps (76.5%), incandescent lamps (7.2%), halogen lamps (2.2%), compact fluorescent lamps (7%) and high intensity discharge lamps (7.2%). From the total light delivered, only 7.7% is provided by efficient lighting technologies. [1]

The factors that have a positive impact on the reduction of lighting energy consumption are [6]:

- sensible control of lighting;
- use of daylight;
- use of presence detectors;
- intelligent consideration of hours of use;
- energy-efficient lamps;
- need-based use of luminaires and lighting solutions, specified for the respective application;
- constant lighting control (maintenance control).

Office equipments

The full energy saving potentials for office equipments can be achieved by:

- reducing the power consumption in every mode (idle, sleep and turned-off);
- decreasing the total operating hours.

Intelligent office equipment with high efficient power management can support the rational use of energy in buildings, but the direct interaction between the user and the office equipment has a great impact to all user specific measures. [13]

Power management is most successful among monitors and laser printers, and least successful among desktop computers, inkjet printers, copiers, and fax machines. Turn-off rates are highest (≥ 40%) among integrated computer systems, copiers, scanners, and lowest (≤ 20%) among laser printers and LCD monitors. [3]

The reduction of the electrical energy consumption in the commercial sector should consider the application of Best Available Techniques and Sustainable Development Strategies.

The potential for energy savings in the field of lighting is indicated by:

- rooms or areas with long operating hours;
- absence of control systems;
- intermittent occupancy pattern;
- low-efficiency lighting technologies;
- no maintenance plan.

Two factors are important in increasing the energy savings for office equipment:

- users who leave the equipment on during night;
- equipment with power management features that fail to engage their attributes.

The building energy efficiency is related not only to electrical systems and equipment but also to human, climate and architectural variables. With these variables the built space is adapted to the environment where it is located, providing comfort, electrical energy consumption reduction and environment negative impacts reduction. [20]

Implementing new energy efficient solutions will require clients to be prepared for higher installation costs and users to be open minded to new lighting solutions including their operation. To achieve this will require the attention of the research and development community, particularly those dealing with lighting equipment, light and lighting measurements and lighting design. It will also require investigations by behavioural scientists who specialise in human factors relating to light and lighting. [21]

An office building of 6450 m^2, divided in 10 floors was selected for a case study. Each floor is composed of three identical office rooms with a surface equal to 57 m^2, four identical office rooms that have a surface equal to 38 m^2, two lobbies, bathrooms and utility rooms.

The case study analyzes the available strategies of refurbishment the existing lighting installation using modern light sources.

The technical requirements imposed by the building characteristics consist of: the room surfaces reflection factors were set to 0.20/0.50/0.70, the work-plane was established at 0.80 m for the office rooms and at 0.10 m for the lobbies; the illuminance value at working plane was selected equal to 500 lx for the office rooms, and 100 lx for the lobbies.

Case Study 1: Lighting systems in office buildings

Table 1. The lighting characteristics of the light sources

Lighting solution	**Lamp type**	**Lamp**			**Units**
		Power	Luminous flux	Luminous efficacy	
		W	lm	lm/W	
Existing installation	2xTL8-36 W MB	85	5700	67.06	620
Solution 1	2xTL5-28 W HF	62	5200	83.87	640
Solution 2	2xTL5-28 W HF	62	5200	83.87	510
	37 W LED	37	2000	54.05	180
Solution 3	62 W LED	62	3750	60.48	720
	37 W LED	37	2000	54.05	180

UNIVERSITATEA TEHNICĂ DIN CLUJ - NAPOCA

Table 2. The lighting characteristics of the office building

Lighting solution	**Office building**		
	Luminous flux	Power	Specific installed power
	lm	W	W/m^2
Existing installation	4,154,000	52,700	8.17
Solution 1	3,328,000	39,680	6.15
Solution 2	3,012,000	38,280	5.93
Solution 3	3,060,000	51,300	7.95

Table 3. DIALux simulation illuminance levels at work-plane level for an office room

Lamp type	E_{av}, lx	E_{max}, lx	E_{min}, lx	E_{min}/E_{av}
2xTL8-36 W MB	503	734	256	0.508
2xTL5-28 W HF	509	825	261	0.513
62 W LED	501	624	295	0.588

A financial analysis is performed, considering a reporting period of 20 years, the inflation equal to 3%, and the energy costs equal to 0.08 Euro/kWh. The initial cost, the operational costs, the energy costs for the entire period and the return of investment for all the lighting solutions are presented in Table 4.

Table 4. Total costs for the lighting solutions

Lighting solution	Initial cost, Euro	Operational cost, Euro	Energy costs, Euro	Return of investment
Existing installation	105,503	403,370	298,610	-
Solution 1	175,466	311,711	217,937	1.31
Solution 2	241,075	308,137	214,577	0.70
Solution 3	1,184,250	396,256	303,256	0.01

Case Study 1: Lighting systems in office buildings

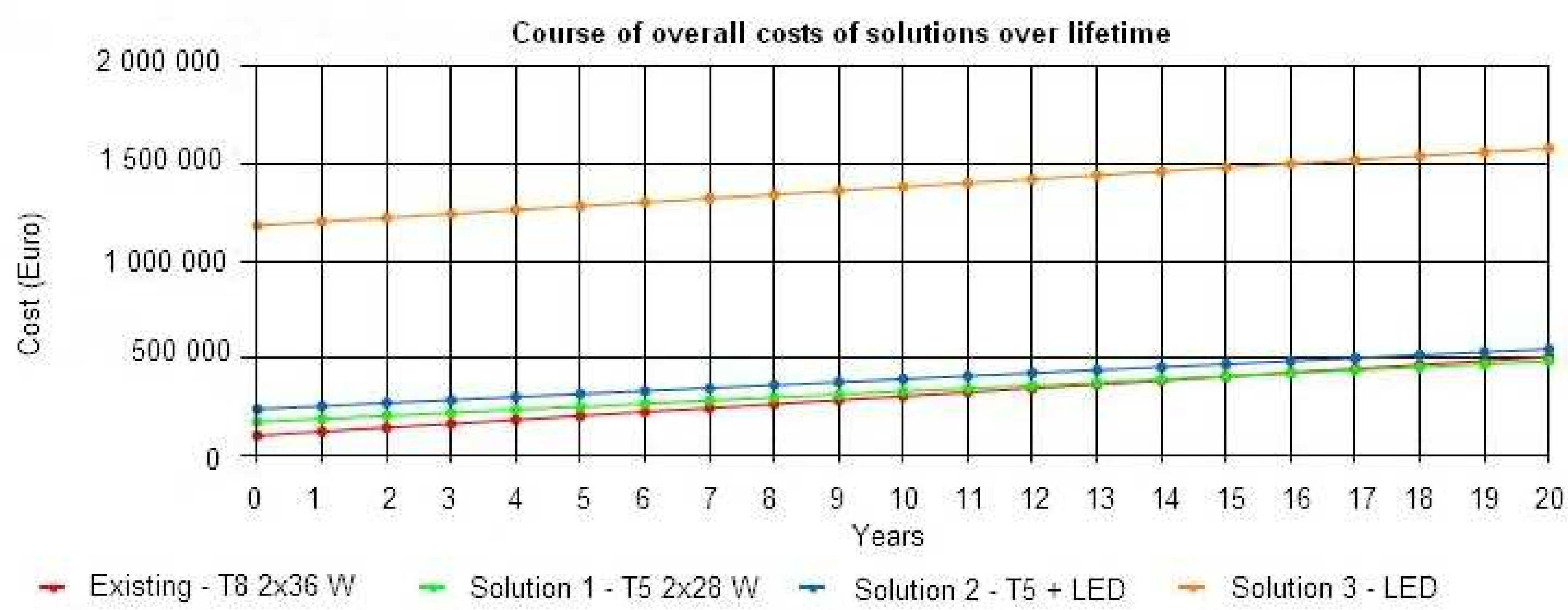

Figure 1. The cumulative costs throughout the reporting period

The information presented in Table 1 and Table 2 indicates that Solution 3 is the adequate solution to be used for the replacement of the existing installation, due to the lower power consumption. However, the financial analysis from Table 4 and Figure 1 shows that, due to the smaller initial cost, the Solution 2 is the best solution to replace the existing installation.

The financial impact of daily feasible electric energy gains due to the use of energy-saving methods was investigated for the same office building. The following assumptions were taking into account:

- Each office room with a surface equal to 38 m^2 has a 6 m^2/person working space, and each office room with a surface equal to 57 m^2 has a 5 m^2/person working space. [23]
- The office working hours were selected from 8:00 to 17:00, with lunch break hours in the interval 11:00 ÷ 13:00 (one hour/person). It was considered also a 20 minutes break at each two hour period.
- Each office worker was assumed to have access to computer systems: 30% have access to computer systems composed of desktop computers, monitors and inkjet printers, 45% to computer systems composed of desktop computers and monitors and 25% to laptops.
- The period until the desktop computer, monitor and printer enter in sleep mode was assumed at 10 minutes; the period until the laptop enters in sleep mode was assumed at 5 minutes.

Case Study 2: Office equipment in office buildings

The power consumption for each computer systems was determined by measurements at MicroDERLab Laboratory, Polytechnic University of Bucharest, with the use of a Fluke 43 measurement equipment [24].

Table 6. Measured office equipment characteristics

Equipment	Characteristics
Desktop	CPU: Intel Pentium 4 2.8 GHz, RAM: 512 MB, Hard Drive: 80GB 7200 rpm, Video Card: NVIDIA GeForce 6200
Laptop	CPU: 1.6 GHz Pentium M 715, RAM: 512 MB, Hard Drive: 80 GB 4200 rpm, Video Card: NVIDIA GeForce FX GO 5200, Monitor: 15.4” WXGA screen
Monitor	Horizon 17” LCD, Model: 7005L
Printer	HP DeskJet, Model: 5150

Table 7. Active power for the computer systems at different operation states

Computer system	Operation state			
	Off	Sleep	Idle	Active
	W	W	W	W
Desktop+Monitor	3.79	5.17	83.05	129.17
Desktop+Monitor+Printer	7.41	8.79	87.88	134.00
Laptop	0.85	1.60	44.15	64.84

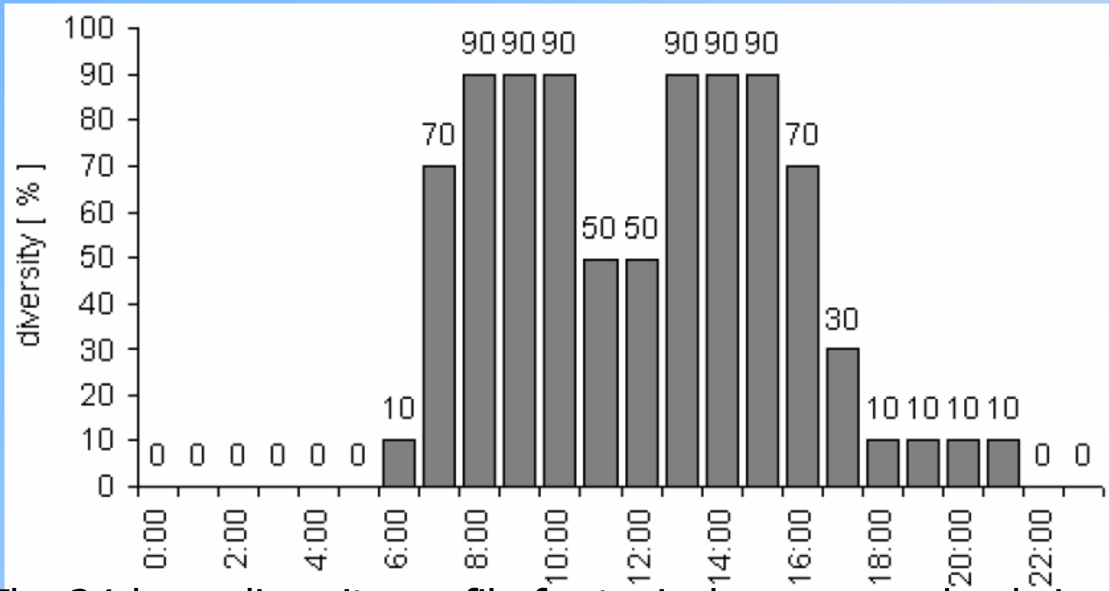

Figure 2. The 24-hour diversity profile for typical occupancy loads in office environments [26]

Case Study 2: Office equipment in office buildings

Taking all the previous assumptions into consideration, for the existent office building of 6450 m^2, a number of 570 working persons have been presumed.

Five scenarios have been considered:

- Scenario 1: idle + active operation during the working hours for all equipments, idle operation for one third of computer systems in rest of the time, while the remaining percent is in sleep mode operation (worst case scenario);
- Scenario 2: idle + active operation during the working hours and sleep operation rest of the time;
- Scenario 3: idle + active operation during the working hours and off operation rest of the time;
- Scenario 4: idle + active operation during the working hours, sleep operation during lunch and break times and off operation rest of the time;
- Scenario 5: idle + active operation during the working hours, sleep operation during lunch and break times and disconnected from the power network rest of the time (best case scenario).

Table 8 shows the daily and monthly energy savings that can be achieved by employing different power manager features. It can be seen that significant energy savings (up to 49%) can be achieved for the office equipment electrical energy consumption with power management functions and responsible user behaviours.

Table 8. Daily and monthly potential energy savings for all five scenarios

Scenarios	**Daily energy consumption**		**Monthly energy consumption**		**Monthly savings**
	kWh	Euro	kWh	Euro	%
Scenario 1	310.722	24.85	6835.891	546.87	-
Scenario 2	236.435	18.92	5201.583	416.13	23.91
Scenario 3	221.902	17.75	4881.857	390.55	28.59
Scenario 4	208.136	16.65	4579.004	366.32	33.02
Scenario 5	158.737	12.70	3492.230	279.38	48.91

Case Study 2: Office equipment in office buildings

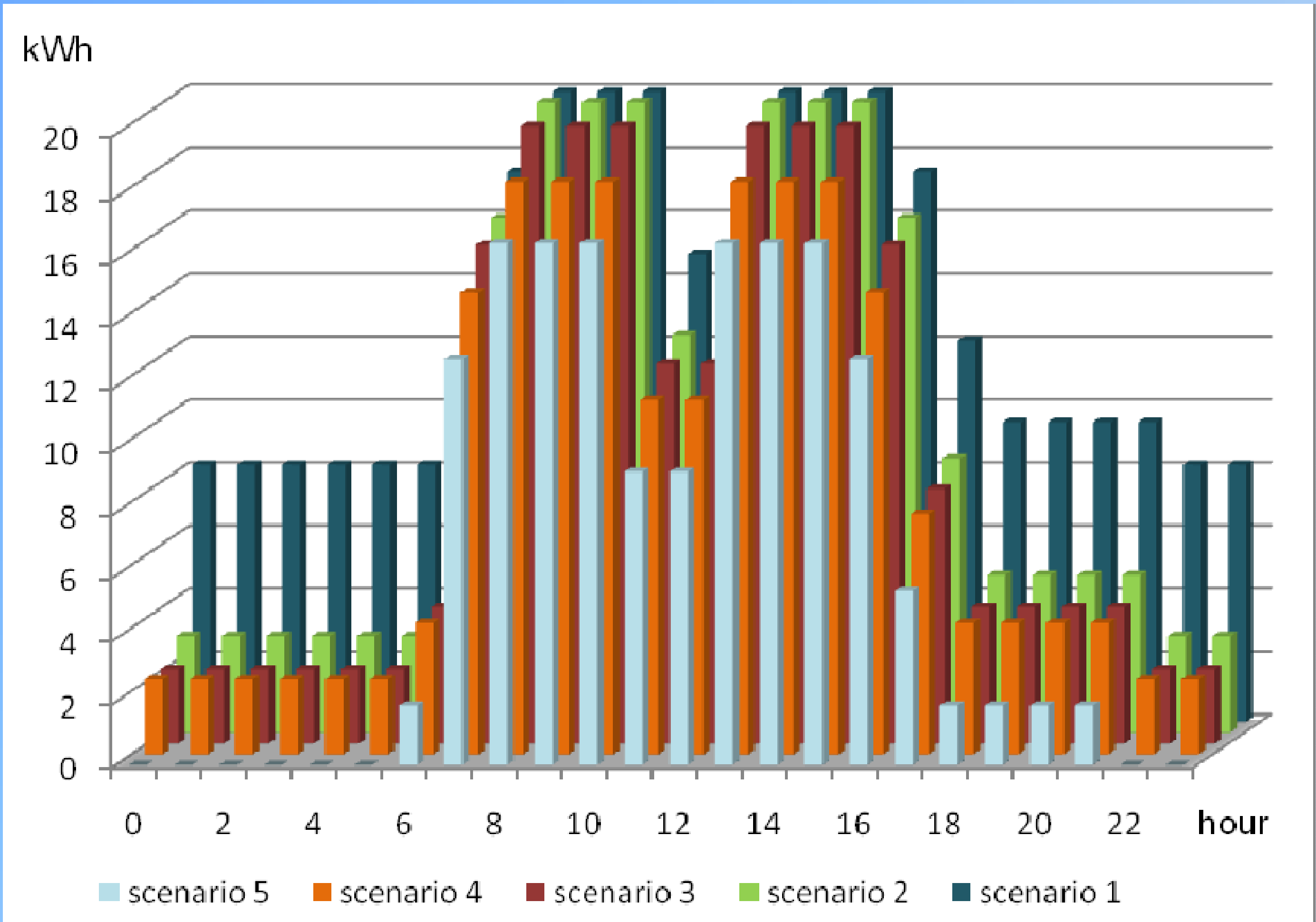

Figure 3. The 24-hour energy consumption for all five scenarios

Conclusions

The paper analyses the problem of energy efficiency in office buildings, focusing on lighting systems and office equipments. Literature study conclusions are presented to emphasize the availability and successfulness of the existing energy efficiency techniques.

In the first case study, the feasibility of upgrading the lighting system from an office building is analysed. From the proposed lighting solutions, the Solution 2 (luminaires equipped with TL5 fluorescent lamps and electronic ballasts) is the most adequate to replace the existing one. Besides the energy economy and user satisfaction, the luminaires equipped with T5 fluorescent lamps and electronic ballast present the opportunity of employing different light controls, and therefore, the possibility of increasing the energy savings.

The second case compares different scenarios involving the use of power management function of office equipments. The study is based on electric energy consumption measurements done on different types of office equipments that are still used in office buildings. Calculating the monthly energy consumption, it is showed that savings of up to 49% can be achieved by power management functions and responsible user behaviours.

References

[1] International Energy Agency. *Light's Labour's Lost – Policies for Energy-efficient Lighting*, OECD/IEA, 2006.

[2] Judy A. Roberson et. al. *Energy Use and Power Levels in New Monitors and Personal Computers*, July 2002. LBNL-48581. Can be downloaded from: http://enduse.lbl.gov/info/lbnl-48581.pdf.

[3] Judy A. Roberson et. al. *After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment,* January 2004. LBNL-53729.

[4] http://ec.europa.eu/energy/energy_policy/doc/01_energy_policy_for_europe_en.pdf.

[6] http://www.zumtobel.co.uk/download/ilr_cp_TheLightingHandbook.pdf.

[13] http://www.eu-greenbuilding.org/fileadmin/Greenbuilding/gb_redaktion/modules/GreenBuilding_Office_Equipment_Module_V2.pdf.

[20] Batista N.N. and Rovere E. L. *Energy Building Performance and Energy Efficency Level Evaluation*. RIO 9 - World Climate & Energy Event (Rio de Janeiro, Brazil, March 17-19, 2009).

[21] Loe DL. *Energy efficiency in lighting - considerations and possibilities*, Lighting Res. Technol. pp: 209–218, 2009.

[23] http://www.ccohs.ca/oshanswers/ergonomics/office/working_space.html

[24] Albu H. and Pop F. Research Report PRODOC UTC-N. Report on the research traineeship at Polytechnic University of Bucharest, Romania, between November 29 – December 10, 2010.

[26] Bourgeois D., Detailed occupancy prediction, occupancy-sensing control and advanced behavioural modelling within whole-building energy simulation, Doctoral Thesis, Faculté Des Études Supérieures Université Laval (Québec, Juin, 2005).

THANK YOU FOR YOUR ATTENTION!

The presented study is co-financed by the European Social Fund - FSE - through the development Project of doctoral studies in advanced technologies – "PRODOC" POSDRU/6/1.5/S/5 ID 7676, Technical University of Cluj-Napoca, Romania.

ALBU Horaţiu Călin
horatiu.albu@insta.utcluj.ro
GROSULEAC Dan Lucian
dan.grosuleac@philips.com

Dr. BEU Dorin, Reader
dorin.beu@insta.utcluj.ro
Dr. **POP Florin**, Professor
florin@florinrpop.ro