THE ENERGY ASSESMENT OF THE BUILDING SERVICES FACULTY OF CLUJ-NAPOCA

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Abstract: *Lighting Engineering Laboratory – LEL - is one of the major lighting independent consultants in the north-west side of Romania. The laboratory is affiliated to the Building Services Faculty of the Technical University of Cluj-Napoca. Over the past few years, the Lighting Engineering Laboratory carefully mapped the university's energy use. To estimate the actual level of energy efficiency at our faculty we compared previous consumption data to obtain the trends of energy consumption. The paper presents the energy consumptions recorded for the Building Services Faculty of Cluj-Napoca. This should be the very first step to achieve the most appropriate energy efficiency solutions for the university's buildings. Some lighting refurbishments were also tested as case studies. A new design for an active educational building that will produce more energy that it consumes - was proposed. The present paper tries to determine the detailed aspects of the building energy consumption, proposing at the same time some energy efficiency solutions economically viable for the most educational buildings in the Eastern Europe.*

1. INTRODUCTION

The European Commission released in 14.07.2021 a proposal for a Directive of the European Parliament and of the Council on Energy Efficiency (recast). With the adoption of the European Green Deal in December 2019, the Commission set out "a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in

2050 and where economic growth is decoupled from resource use [1]. In March 2020, the Commission tabled a proposal for a European Climate Law to decarbonize Europe by 2050.

In its Climate Target Plan (CTP) [2], the Commission proposed to raise the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, which is a substantial increase compared to the existing 40% target.

Energy efficiency is a key area of action, without which the full decarbonization of the Union economy cannot be achieved [3]. The Energy Efficiency Directive has led to the Union's current energy efficiency policy to capture the cost-effective energy saving opportunities. In December 2018, the Energy Efficiency Directive was amended as part of the 'Clean Energy for All Europeans package', in particular to include a new headline 2030 Union energy efficiency target of at least 32,5% (compared to projected energy use in 2030), and to extend and strengthen the energy savings obligation beyond 2020.

In the same context Romania adopted in April 2020 the Integrated National Plan for Energy and Climate Change 2021-2030. The main energy and climate targets for the year 2030, are as follows [4]:

- Target on reducing domestic greenhouse gas emissions by at least 40% by 2030 compared to 1990;
- The target for renewable energy consumption of 32% in 2030;
- The target for improving energy efficiency by 32.5% in 2030;
- The objective of interconnecting the electricity market at a level of 15% up to 2030.

Therefore, Romania targets a primary energy consumption of 32.3 Mtoe, respectively one final energy consumption of 25.7 Mtoe, thus obtaining energy savings of 45.1%, compared to the primary consumption for 2030, respectively 40.4% for final consumption compared to the PRIMES 2007 baseline scenario.

For the educational buildings, the Romanian Integrated National Plan for Energy and Climate Change 2021-2030 reveal the next scenario – Table 1.

Table 1. Detailed refurbishment scenario – educational buildings

Building type	Total Surface	Buildings	Investment	Energy reduction	CO_2 reduction
	[MM sq m]	[No]	[MM EUR]	[MM toe]	[MM t]
Education	4.24	4361	874.84	0.03	0.14

For the total number of 4361 of educational Buildings in Romania the proposed refurbishment scenario leads to a total 0.03 MM toe energy reduction and 0.14 [MM t CO_2].

2. UNIVERSITY ENERGY CONSUMPTION

The Technical University of Cluj-Napoca (UTC-N) financed for the year 2012-2013 - [5] and 2014 - [6] an internal lighting efficiency project aiming to determine the actual energy consumption of the university buildings as well as to identify the best techno-economical energy efficiency lighting solution.

A detailed measurement of the current consumption of the Faculty of Building Services – UTC-N, with a total area of 4775.98 sq. m was performed. The electricity and natural gas bills for the year 2012 were analyzed - Table 2.

Table 2. Current annual energy consumption 2012 – UTC-N – Faculty of Building Services

Building Services Energy Consumption 4776 sq. m				
	[euro/month]	[euro/year]	[kWh/month]	[kWh/year]
ELECTRIC CONSUMPTION 0.155 [euro/kWh]	1 064	12 770	6 865	82 385
NATURAL GAS CONSUMPTION 0.0382 [euro/kWh]	1 752	21 020	45 856	550 262
TOTAL	**2 816**	**33 790**	**52 721**	**632 647**

A total energy (electrical and natural gas) consumption of 132.46 [kWh / (sq. m*year)] was identified for the year 2012, based on the utility bills [7].

The main energy consumers of the building can be spited in two main categories, using: electricity or natural gas. The heating central system is the only gas consumer. Meanwhile electricity is used for - lighting, general use sockets, air ventilation / cooling systems. The building is geared with HVAC installations for just two rooms and the main building 300 persons amphitheater. Even if the AC installations are main electricity users – their share in the general electricity consumption is very small due to the university reduced activity during summer. The main consumers are the old conventional T8 fluorescent luminaires. Unfortunately, the old electric installations didn't give us the opportunity to individually monitor the lighting vs socket electricity consumption.

In the last years LEL installed different lighting retrofit solutions. The starting point was in 2013 - the lighting refurbishment success of the greatest lecture hall by replacing the old 4*18 W fluorescent luminaires by new LED ones and a new DALI lighting control system, get 70% savings in lighting electricity consumption. For 2014 the hallways existing 2*36 W fluorescent luminaires were geared with electronic ballasts and motion sensors. In the same year the faculty outdoor lighting LED system controlled by daylight/time sensors was installed. In 2015 the classic fluorescent recessed 4*18 W fluorescent luminaires were retrofitted using 4*14.4 W LED modules. The overall luminous efficacy of the retrofitted luminaires was around 55 lm/W. In the last year a new emergency lighting system powered from a smart central battery unit was installed. In another class 2*36 W fluorescent lighting system was completely replaced with 37 W LEDs and a modern PLC dimmable control system able to maintain a certain user defined lighting level on the desk working area. In 2020 two main lighting manufacturers equipped experimentally tow student classrooms with the state-of-the-art lighting equipment's.

The electricity consumption of the building was evaluated based on the readings recorded by an electronic meter. The hourly readings were recorded over a period of 3 years, namely 2014, 2015 and 2016 [8]. The total annual consumption was different over the years. Due to the installation of a new cooling system in the faculty main amphitheater an increase of 11237 kWh/year, from 82375 kWh/year in 2012 to 93612 kWh/year.

Afterwards, a decrease from 93612 kWh/year in 2014 to 86190 kWh/year in 2015 and 68901 kWh/year in 2016 was recorded (*fig. 1*), due to the new LED lighting system installed, which meant a general reduction of more than 25%, from 2014 to 2016.

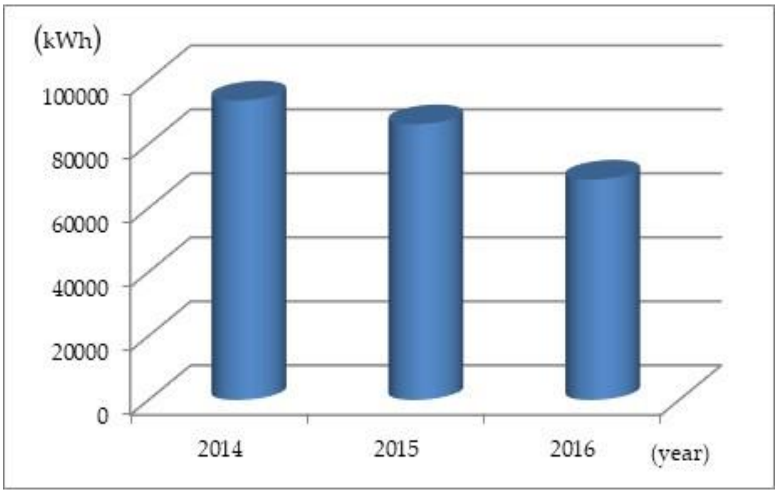

Fig.1. UTC-N Faculty of Building Services yearly electricity consumptions

The recorded monthly average electricity consumption is detailed in Table III. Mainly the 2015 values are lower than the values recorded in 2014. The reason for this might be the energy efficiency lighting retrofits implemented for some classrooms. The existing fluorescent T8 luminaires were replaced by LED luminaires / sources. The exception from May to July are not relevant while the university auditorium is also used by other faculties from the Technical University of Cluj-Napoca, so the running ours are different from one year to another. Also, in those months the installed chiller is used for cooling the amphitheater indoor air.

Using the university adopted lighting retrofit solutions as case studies, circular economy aspects were identified [9]. For a LED retrofitted recessed luminaire T8 4 × 18 W, the previous study [10], showed a major reduction of the installed power, a correct lighting distribution, but also revealed some issues: lack of certification of the retrofit luminaire, necessity of qualified personnel, high workforce costs, etc.

A consumption pattern was also identified for the year 2014 electrical consumption. *Figure 2* shows the daily electricity consumption in the first eight months of the year 2014. The graph shows the consumption variations after classes/semesters. All the measurements were made in the same day of the week (Thursday) in order to compare theoretically the same class schedule. For the first four months, the electricity consumption is higher (over 20 kWh) from 6.00 AM to noon. For the next three months, the electricity consumption is more constant during the day (over 10 kWh) from 6.00 AM to 2.00 PM. August readings show constantly low electricity consumption (3 kWh) for the holydays, when usually the university building is close.

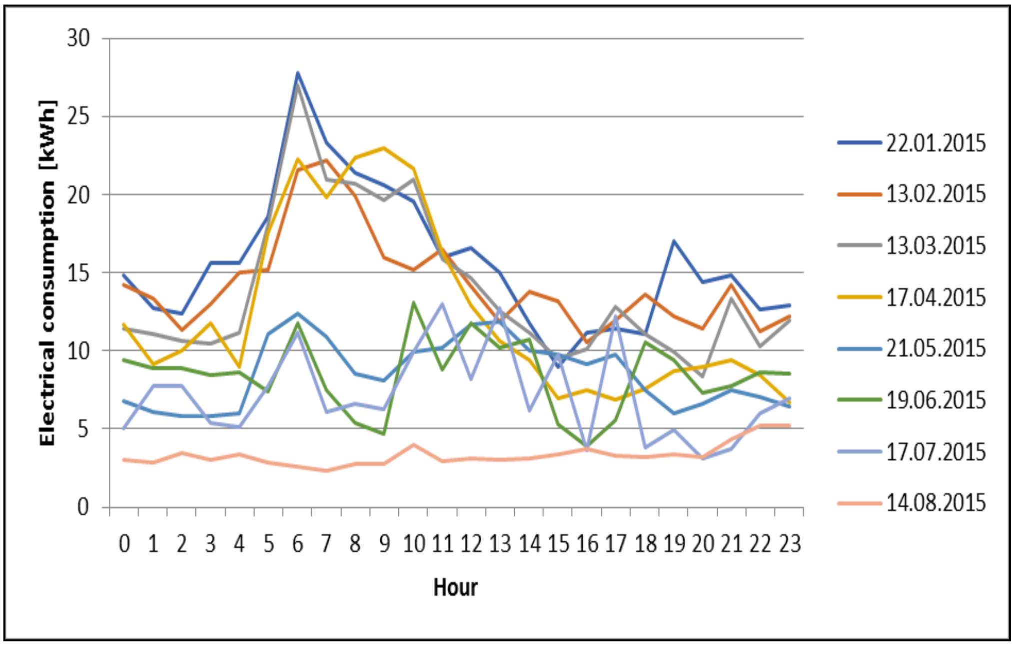

Fig. 2. UTC-N Faculty of Building Services daily electricity consumption in the first eight months (first semester) of the year 2014

The recorded monthly average electricity consumption is detailed in Table 3. Mainly the 2015 values are lower than the values recorded in 2014. The reason for this might be the energy efficiency lighting retrofits implemented for some classrooms. The existing fluorescent T8 luminaires were replaced by LED luminaires / sources. The exception from May to July are not relevant while the university auditorium is also used by other faculties from the Technical University of Cluj-Napoca, so the running ours are different from one year to another. Also, in those months the installed chiller is used for cooling the amphitheater indoor air.

Table 3. Monthly average electricity consumption UTC-N – Faculty of Building Services – 2014, 2015

Electricity Consumption [kWh]		
Month	**2014**	**2015**
1	12317.68	12162.93
2	10042.38	8973.10
3	9655.28	9952.89
4	7504.10	7427.34
5	6358.32	5342.16
6	6372.00	3269.86
7	5510.50	2710.12
8	2686.86	2135.34
9	3461.92	3416.39
10	8340.45	9093.93
11	11469.51	10534.71
12	11362.39	11173.46
Total	**95081.38**	**86192.23**

The faculty building recorded electricity consumption recorded for the years 2014 and 2015 is showed in *fig. 3* and *fig. 4*. The daily average consumption values are indicated in *fig. 3*. The lowest consumption is in August for bought 2014 and 2015, when usually the building access is restricted to few people due to the holydays.

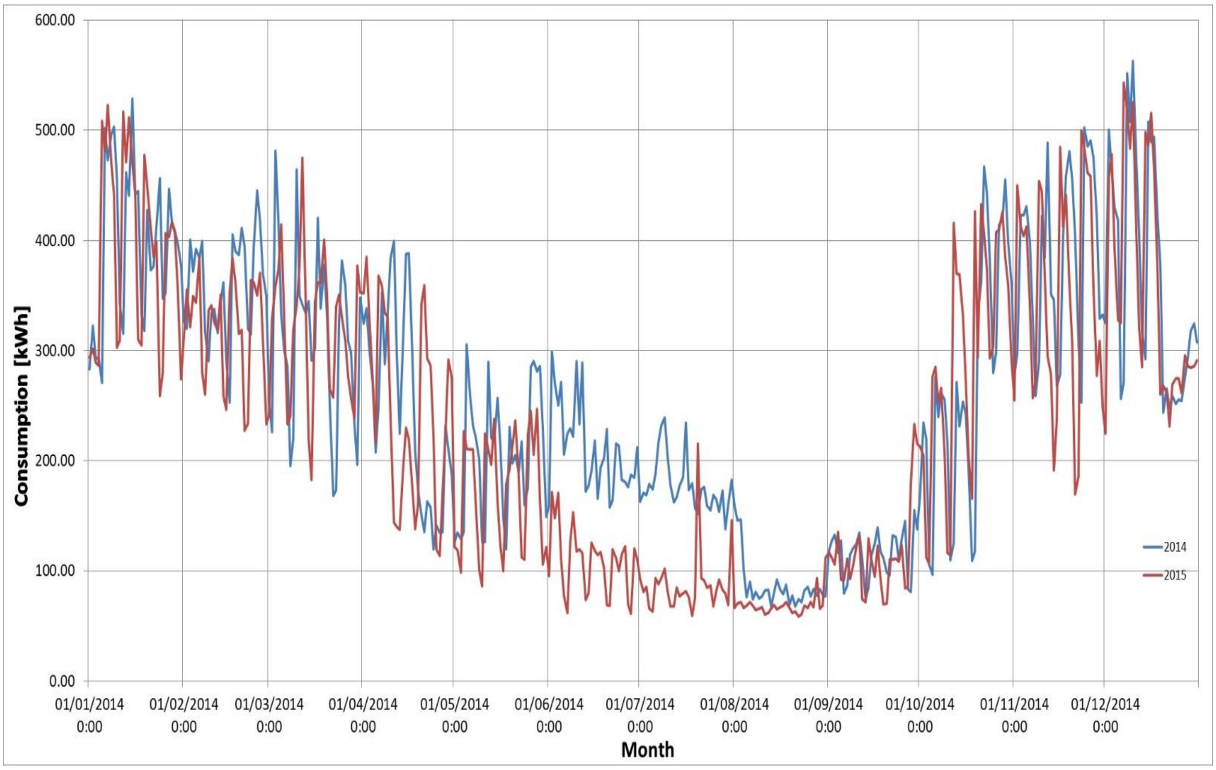

Fig. 3. UTC-N Faculty of Building Services daily electricity consumptions, 2014, 2015

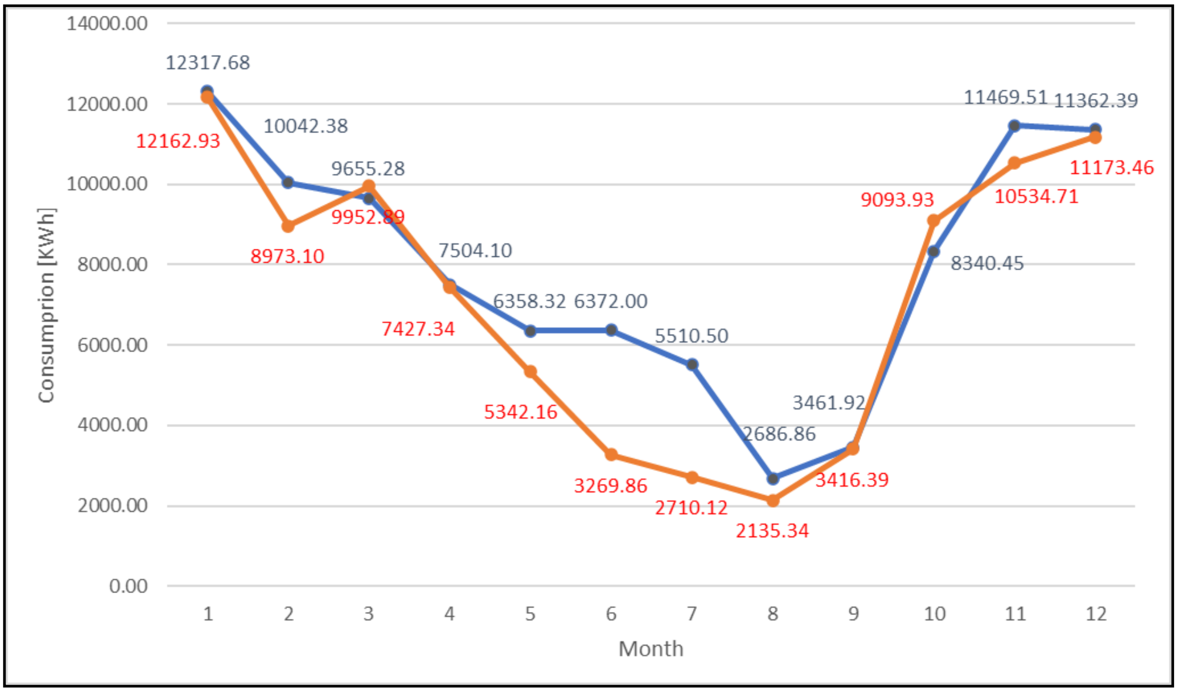

Fig. 4. UTC-N Faculty of Building Services monthly average electricity consumptions, 2014, 2015

3. LIVING BUILDING LAB - CASE STUDY

The Living Building Lab Project (LBL) presumes a holistic approach and includes young architects, constructors and building services engineers, starting with vernacular architecture (traditional), passing through traditional materials (straw, wool, hemp) and reaching modern technologies. Without these technologies the user's comfort cannot be achieved, nor a small energy consumption or the transformation into active buildings (Buildings Management Systems - BMS). Among the practical results of this project the most important will be to build the first Romanian green building (Living Building Lab), using traditional materials combined with the latest technologies, educational - purpose space, where these solutions are to be tested in real conditions. The building process will be supported by volunteers (project members, PhD researchers and students). The private/public sector interest will be involved by new sponsorships contracts (specialized services, materials, equipment) and only partially for some uncovered costs, the university funds. The present achievements of the project are presented. The project member's main goal is to achieve an active building and a very low carbon footprint. Up to this point a draft architectural design was finalized and waits for feedback from the structural/building services team specialists, *fig. 5*. To obtain a low carbon footprint and achieve a practical low-cost building example, simple, bio and locally available construction materials are needed. Building structure will be made from wood having a metal pylon foundation to avoid the Portland cement use. The thermal isolation will be made of bales of straw and wool. As for the exterior building envelope, wood and clay plasters will be used. The proposed building has two floors and a total area of 220 sq m. The southeast side of the building will have vertical green walls. For the roof area an isolation study was performed, considering the LBL location and the surrounding buildings. To get the largest photovoltaic roof exposition, the final solution was half terrace and half pitched roof, facing south. A total photovoltaic area of 71 sq. m was reached.

Fig. 5. Living Building Lab architectural design

The photovoltaic system will be designed to power the building facilities and the old faculty building consumers. Natural and heat recovery ventilation systems will be used as well as a Canadian well and a heating pump. The interior lighting system will use besides the traditional windows, tubular daylight guidance systems [11] and LED luminaires. The rainwater will be used for the water supply of the building and the plants irrigation system. To ensure a minimal ecological impact, an eco-water purification plant will be installed. An advanced building management system – BMS will be used to achieve the best energy efficiency and to constantly monitories the building's consumptions.

The Living Building Lab Project – UTC-N should be an example of how to change the annual energy requirement of the old university buildings (135 [kWh / (sq. m*year)] to a close to zero energy consumption green facility.

The present paper is just the beginning of the first Romanian green building model for educational/exhibition proposes. Just the first design steps are presented to discus and get feedback from the scientific society and previous experiences. The Living Building Lab Project aims to develop a green model for an active house built up using eco, locally available and low-cost construction materials with a very low carbon footprint. The public should see that everyone can afford those eco building technologies (straw, wool, clay etc.) that combined with the latest energy efficient technologies can actually consume close to zero energy and have a minimal impact on the environment.

4. CONCLUSIONS

The ongoing lighting refurbishment solutions already prove their economic viability and the conclusions are clear and detailed. Starting from those case studies, The Technical University of Cluj-Napoca financed the Living Building Laboratory Project – meant to be an example of how to change the annual energy requirement of the old university buildings (132 [kWh/sq. m/year] to a close to zero energy consumption green facility – *fig. 6*.

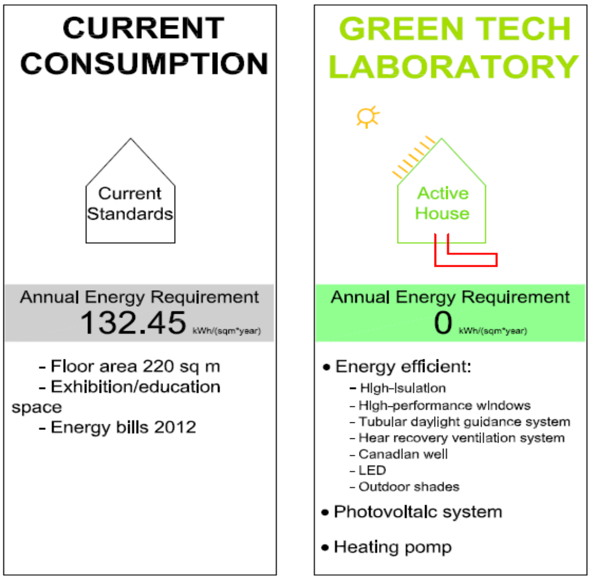

Fig. 6. Living Building Lab goal

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The Living Building Laboratory Project presumes a holistic approach and includes young architects, constructors and building services engineers, starting with vernacular architecture (traditional), passing through traditional materials (straw, wool, hemp) and reaching modern technologies. Without these technologies, the user’s comfort cannot be achieved, nor a small energy consumption or the transformation into active buildings that will produce more energy that it will consume.

REFERENCES

[1] European Comission - *Proposal for a Directive of te European Parliament and of the Council on Energy Efficiency (recast) 14.07.2021*, https://ec.europa.eu/info/sites/default/files/ proposal_for_a_directive_on_energy_efficiency_recast.pdf.

[2] Communication from the Commision to the European Parliament, the Council, the European Economic and Social Comettee and the Committee of the Regions, *Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people*, COM/2020/562 final.

[3] Communication: *A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* (COM/2018/773 final), *where the role of energy efficiency as a condition sine qua non for all decarbonisation scenarios is assessed.*

[4] *The Romania Integrated National Plan for Energy and Climate Change* 2021-2030, april 2020, https://ec.europa.eu/energy/sites/default/files /documents/ro_final_necp_main_ro.pdf.

[5] A. Ceclan, *Innovative Research Tools for an Efficient Energy University*. UTC-N Project, Cluj-Napoca, 2013.

[6] C. Ciugudeanu, *Energy - Efficient Technologies for a Green University*. UTC-N Project no. 29223/2014, Cluj-Napoca, 2014.

[7] Beu, D.; Ciugudeanu, C.; Ceclan, A. *Energy Efficient Lighting in University Buildings*. Lux Europa, pp. 142-146, Ljubljana, September 18-20, 2017.

[8] C. Ciugudeanu, M. Buzdugan, D. Beu, A. Campianu, and C. D. Galatanu, *Sustainable Lighting-Retrofit Versus Dedicated Luminaires-Light Versus Power Quality*, Sustainability, vol. 11, no. 24, pp. 7125, 2019.

[9] Scottish Engineering Hall of Fame. Available online: http://www.engineeringhalloffame.org /profile- young.html (accessed on 15 July 2018).

[10] D. Beu, C. Ciugudeanu, M. Buzdugan, *Circular Economy Aspects Regarding LED Lighting Retrofit—from Case Studies to Vision*. Sustainability, vol. 10, pp. 3674, 2018.

[11] Ciugudeanu C, Pop F. *Passive tubular daylight guidance systems, design methodology*. The 6th International Conference EEDAL - Energy Efficiency in Domestic Appliances and Lighting, 2011.