

Lighting Consumption Analysis in Retail Industry: Comparative Study

Elena C. Tamaş, Grațiela M. Tărlea, Gianni Flamaropol, Dragoş Hera

Abstract—This article is referring to a comparative study regarding the electrical energy consumption for lighting on diverse types of big sizes commercial buildings built in Romania after 2007, having 3, 4, 5 versus 8, 9, 10 operational years. Some buildings have installed building management systems (BMS) to monitor also the lighting performances starting with the opening days till the present days but some have chosen only local meters to implement. Firstly, for each analyzed building, the total required energy power and the energy power consumption for lighting were calculated depending on the lamps number, the unit power and the average daily running hours. All objects and installations were chosen depending on the destination/location of the lighting (exterior parking or access, interior or covering parking, building interior and building perimeter). Secondly, to all lighting objects and installations, mechanical counters were installed, and to the ones linked to BMS there were installed the digital meters as well for a better monitoring. Some efficient solutions are proposed to improve the power consumption, for example the 1/3 lighting functioning for the covered and exterior parking lighting to those buildings if can be done. This type of lighting share can be performed on each level, especially on the night shifts. Another example is to use the dimmers to reduce the light level, depending on the executed work in the respective area, and a 30% power energy saving can be achieved. Using the right BMS to monitor, the energy consumption depending on the average operational daily hours and changing the non-performant unit lights with the ones having LED technology or economical ones might increase significantly the energy performances and reduce the energy consumption of the buildings.

Keywords—Lighting consumption, commercial buildings, maintenance, energy performances.

I. INTRODUCTION

IN Romania, the existing buildings, built between 1950 and 1990, were having a poor registered energy performance compared to the energy performances regulations appeared after 1973, when the design requirement changed due to the energy crisis, and the building envelope and its thermal protection design were asked to be calculated and taken into the consideration for the energy performances of the buildings. In 2013, when we accessed the site of National Institute of Statistic [1], there was a percentage of 86% corresponding to the residential buildings from the total built area. The final energy consumption for such buildings varies between 150 and 350 kWh/m²*year [2]. Those buildings erected around the 1990s have a low energy performance, between 150 and 250

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kWh/m²*year, and the ones built after 2000 have the energy performance, between 120 and 230 kWh/m²*year [2]. At the beginning of March 2017 [3], European Commission released a report about Romania updates and showed that, from the entire Romanian built area, in non-residential sector, 956.000 m² is corresponding to the retail, logistic and offices spaces. And from this total area, 380.000 m² was delivered in the industrial and logistic real estate segment. In case of non-residential buildings, the energy performance is between 120 and 400 kWh/m²*year [2], depending on the type of building.

Non-residential building stock, according to the National Institute of Statistics, INCD URBAN – INCERC [4], has the following structure: 27% retail buildings, 17% educational facilities, 14% health facilities, 12% office buildings, 9% culture buildings, 8% hotels and restaurants buildings, 7% sport facilities, 4% public administration buildings and 2% others (industry/logistics buildings).

The main laws regarding the construction works in Romania are [5]: Law on Building Permits (50/1991; 125/1996; 453/2001), Law on Construction Quality (10/1995), Housing Law (114/1996 and Ordinance 44/1998), Government Decision on General Urban Regulation (525/1996), Law on Territorial Planning and Urbanism (350/2001), Law on Protection of the National Cultural Heritage (1998). But, for the energy efficiency and sustainable construction strategies in Romania, there are in force Law no. 121/2014 on energy efficiency [6], implementing Directive 2012/27/EU [7] on energy efficiency, Law 159/2013 [8], which transposes the provisions of Directive 2010/31/EC into national legislation, by amending Law 372/2005 [9] regarding the energy performance of buildings (e.g. nZEB, EPCs, etc.). The Romanian government approved in January 2016 a further amendment to Law no. 372/2005 on the energy performance of buildings. Moreover, in line with the requirements of the Energy Efficiency Directive (2012/27/EU), the Romanian government approved the National Energy Efficiency Action Plan (NEEAP) [10] for 2014-2020, setting out the estimated energy consumption and planned energy efficiency measures to meet the 2020 energy efficiency targets, such as: the thermal insulation improvement of the building envelope; the use of renewable energy sources (RES) to cover needs for heating and domestic hot water (DHW) preparation; implementing energy management systems aimed at improving energy efficiency and monitoring energy consumption; the replacement of fluorescent and incandescent lighting luminaires with high energy efficiency and long life ones; rehabilitation and modernization of the technical building systems for heat and DHW preparation and transport,

ventilation and air-conditioning (AC), including passive cooling systems, as well as related equipment acquisition and installation, followed by its connection to the central heating systems as appropriate; other activities that lead to fulfilling the objectives of energy efficiency.

In our paper, for ten different commercial buildings, the shares of the electrical energy consumptions were analyzed for lighting in function of the lighting destination needs and of its operational years.

The most recent ones are energy efficient buildings that have been audited and received national certifications. Their investors announced that, for these buildings, new applications for international BREEAM [11] or LEED [12] certifications started.

II. THE ANALYZED SITUATION

A. Comparative Analysis on the Buildings General Status

Our study is following the electrical energy consumption

evolution for outdoor parking lighting, indoor parking lighting, building perimeter lighting, indoor building lighting starting with the opening year till the present day, during all operational period of buildings analyzed. In our study there are: 1 building (no.10) with 3 years, 2 buildings (no.1 and no.5) with 4 years, 1 building (no.7) with 5 years, 1 building (no.9) with 8 years, 3 buildings (no.2, no.3, no.4) with 9 years, 2 buildings (no.6, no.8) with 10 operational years (see Fig. 1 for the operational years status) [13].

In Fig. 2, we have operational hours' status for buildings depending on the destination of the electrical energy for lighting as follows: Fig. 2 (a) situation of the buildings having 3, 4, 5 years versus Fig. 2 (b) for the buildings having 8, 9, 10 years in operation.

There are buildings which do not have outdoor parking (building no. 2), or indoor parking (buildings nos. 3, 5, 7, 8, 9, 10), and so, there are no consumptions related.

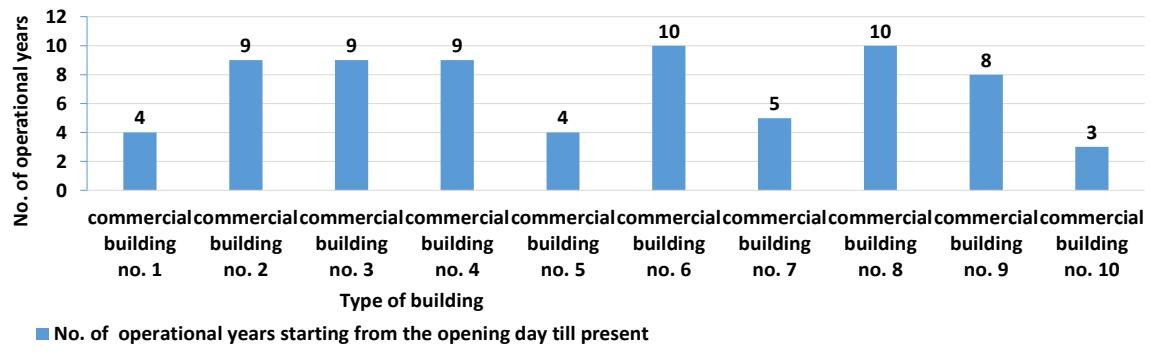


Fig. 1 Operational years' status for buildings from the opening day till present

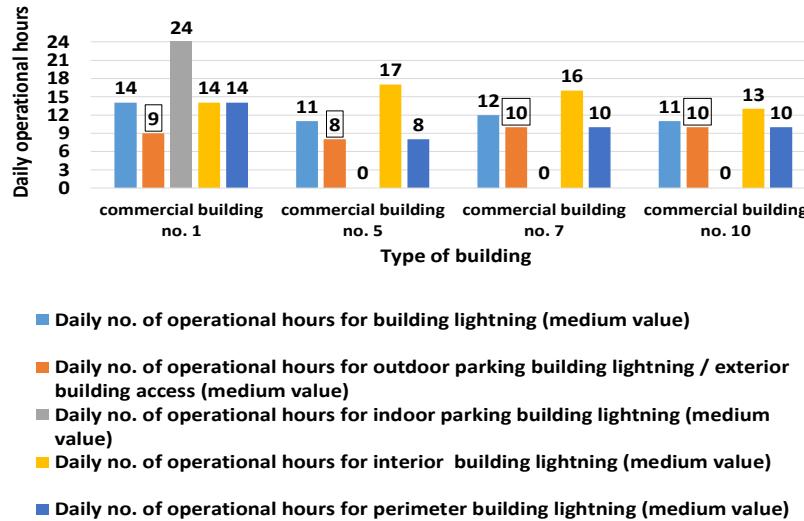


Fig. 2 (a) Daily operational hours number for buildings depending on electrical energy for lighting destination - status for buildings with 3, 4, 5 operational years

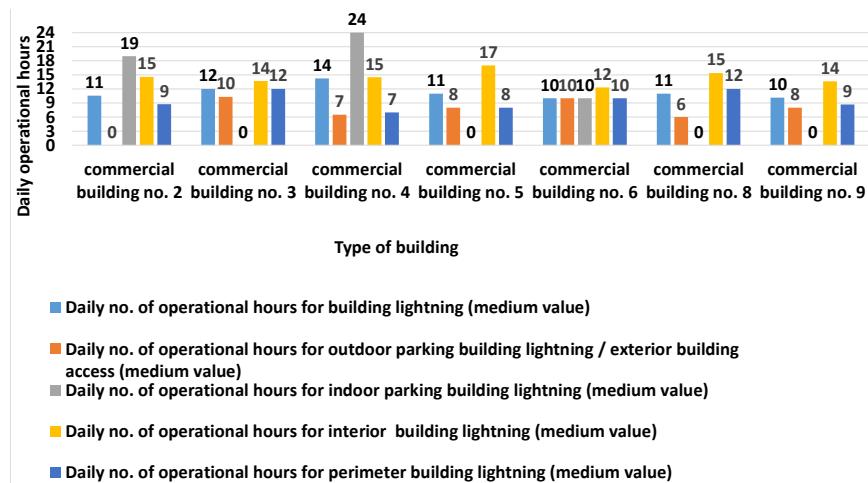


Fig. 2 (b) Daily operational hours number for buildings depending on electrical energy for lighting destination - status for buildings with 8, 9, 10 operational years

TABLE I
TOTAL ELECTRICAL POWER FOR BUILDINGS LIGHTING DEPENDING ON DESTINATION

Building type	Total electrical power for building lighting (no shops) [kW]	Total electrical power for outdoor parking lighting [kW]	Total electrical power for indoor parking lighting [kW]	Total electrical power for interior building lighting [kW]	Total electrical power for perimeter building lighting [kW]
Commercial building no. 1	367	3	83	276	5
Commercial building no. 2	64	0	11	45	8
Commercial building no. 3	475	297	0	94	84
Commercial building no. 4	150	15	9	113	13
Commercial building no. 5	43	20	0	18	5
Commercial building no. 6	96	38	9	47	2
Commercial building no. 7	134	54	0	70	9
Commercial building no. 8	44	21	0	17	6
Commercial building no. 9	80	52	0	22	6
Commercial building no. 10	40	21	0	10	9

For some buildings depending on:

- 1) the building importance on the market,
 - 2) the position of the outside parking,
 - 3) the exterior access for public,
 - 4) the supplying areas for the shops,
- the lighting schedule was chosen to be as 6 hours (building no. 8), 7 hours (building no. 4), 8 hours (building no. 5), 9 hours (building no. 1) and 10 hours (buildings nos. 3,6,7,10).

The buildings having 24/24 commercial activities, such as building no. 1 and 4, have bigger electrical energy consumptions for lighting against the others, including those for indoor parking. Similar is the situation for the building no. 2 with 19/24 hours of use for indoor parking lighting.

B. Comparative Analysis on the Buildings Energy Consumption

We calculated, functioning on the type of installations (type of lighting objects, quantities and unit power), the total electrical energy for lighting for each type of destination and each building and we present in Table I the values found for the analyzed buildings [13]. Tables II and III are showing the total daily and respectively total monthly electrical energy consumption for analyzed buildings depending on the lighting

destination (outdoor parking, indoor parking, interior building, perimeter building, entire building) [13]. As example, for the building no. 1, we have a total electrical power for building lighting as of 367 kW from which:

- 1) At outdoor parking there are considered 60 lighting pillars having LED connection with a unit power of 0.02 kW and five lighting pillars having pins connection with metal iodine bulb with a unit power of 0.4 kW, and a total electrical power of 3.2 kW;
- 2) At the indoor parking, we have considered 1431 fluorescent lighting objects with a unit power of 0.06 kW and a total electrical power of 83 kW;
- 3) Inside the building there are 3593 fluorescent lighting objects with a unit power of 0.058 kW and respectively 1622 LED connection with a unit power of 0.035 kW, with a total electrical power of 276 kW;
- 4) At the perimeter of the building there are considered 33 lighting objects with metal halides with unit power of 0.15 kW, 11 fluorescent lighting objects with a unit power of 0.04 kW, one lighting object with LED connection having a unit power of 0.05 kW, with a total electrical power of 5 kW.

TABLE II
TOTAL DAILY ELECTRICAL ENERGY CONSUMPTION FOR BUILDINGS LIGHTING DEPENDING ON DESTINATION

Building type	Total daily electrical energy consumption for building lighting (no shops) [kWh]	Total daily electrical energy consumption for outdoor parking lighting/exterior access building [kWh]	Total daily electrical energy consumption for indoor parking lighting [kWh]	Total daily electrical power consumption for interior building lighting [kWh]	Total daily electrical power consumption for building perimeter lighting [kW]
Commercial building no. 1	5953	28	1992	3857	76
Commercial building no. 2	946	0	209	647	90
Commercial building no. 3	5185	3146	0	1037	1003
Commercial building no. 4	3069	96	218	1752	81
Commercial building no. 5	508	158	0	309	41
Commercial building no. 6	1086	376	93	595	23
Commercial building no. 7	1758	544	0	1126	88
Commercial building no. 8	438	126	0	236	76
Commercial building no. 9	832	416	0	370	45
Commercial building no. 10	437	208	0	139	90

TABLE III
TOTAL MONTHLY ELECTRICAL ENERGY CONSUMPTION FOR BUILDINGS LIGHTING DEPENDING ON DESTINATION

Building type	Total daily electrical energy consumption for building lighting (no shops) [kWh]	Total daily electrical energy consumption for outdoor parking lighting/exterior access building [kWh]	Total daily electrical energy consumption for indoor parking lighting [kWh]	Total daily electrical power consumption for interior building lighting [kWh]	Total daily electrical power consumption for building perimeter lighting [kW]
Commercial building no. 1	178591	837	59759	115713	2283
Commercial building no. 2	27421	0	5308	19406	2708
Commercial building no. 3	155548	94365	0	31096	30087
Commercial building no. 4	64407	2888	6532	52551	2436
Commercial building no. 5	15253	4752	0	9277	1224
Commercial building no. 6	32582	11280	2784	17841	677
Commercial building no. 7	52736	16320	0	33780	2635
Commercial building no. 8	13213	3851	0	7076	2286
Commercial building no. 9	24951	12480	0	11108	1363
Commercial building no. 10	13106	6246	0	4160	2700

Such constructed buildings having 3, 4, 5 operational years in comparison with the ones having 8, 9, 10 operational years, are using mainly lighting objects with LED technology according to the technical specifications given by the landlords and have installed as well BMS (electronic meters and automated management for buildings).

So that, below, in Fig. 3 (a) (for buildings having 3, 4, 5 operational years) and Fig. 3 (b) (for buildings having 8, 9, 10 operational years), there are presented for the analyzed buildings, in percentages, how much represents, monthly, the total electrical energy consumption for building lighting (with no shops included in the calculation), in conformity with the schedule hours previewed for operation, total electrical power, building age and lighting destination (considered for outdoor parking, indoor lighting, interior building, perimeter building).

In Fig. 3 (a), there is shown for the buildings having 3, 4, 5 operational years, the following data regarding the total monthly electrical energy consumption for building lighting depending on the lighting destination:

- 1) For building no.1 we have obtained 0.47% for outdoor parking lighting, 33.46% for indoor parking lighting, 64.79% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 1.28% for perimeter lighting;
- 2) For building no.5, we have obtained 31.15% for outdoor parking lighting, 0.00% for indoor parking lighting,

60.82% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 8.02% for perimeter lighting;

- 3) For building no.7, we have obtained 30.95% for outdoor parking lighting, 0.00% for indoor parking lighting, 31.74% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 5.00% for perimeter lighting;
- 4) For building no.10, we have obtained 47.66% for outdoor parking lighting, 0.00% for indoor parking lighting, 60.82% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 20.60% for perimeter lighting.

In Fig. 3 (b), there is shown for the buildings having 8, 9, 10 operational years, the following data regarding the total monthly electrical energy consumption for building lighting depending on the lighting destination:

- 1) For building no.2, we have obtained 0.00% for outdoor parking lighting, 19.36% for indoor parking lighting, 70.77% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 9.88% for perimeter lighting;
- 2) For building no.3, we have obtained 60.67% for outdoor parking lighting, 0.00% for indoor parking lighting, 19.99% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas,

- etc.) and 19.34% for perimeter lighting;
- 3) For building no.4, we have obtained 4.48% for outdoor parking lighting, 10.14% for indoor parking lighting, 81.59% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 3.78% for perimeter lighting;
 - 4) For building no.6, we have obtained 34.62% for outdoor parking lighting, 8.54% for indoor parking lighting, 54.76% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 2.08% for perimeter lighting;

- 5) For building no.8, we have obtained 29.15% for outdoor parking lighting, 0.00% for indoor parking lighting, 53.55% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 17.30% for perimeter lighting;
- 6) For building no.9, we have obtained 50.02% for outdoor parking lighting, 0.00% for indoor parking lighting, 44.52% for interior building lighting (with no shops, only corridors, technical areas, staircases, administrative areas, etc.) and 5.46% for perimeter lighting.

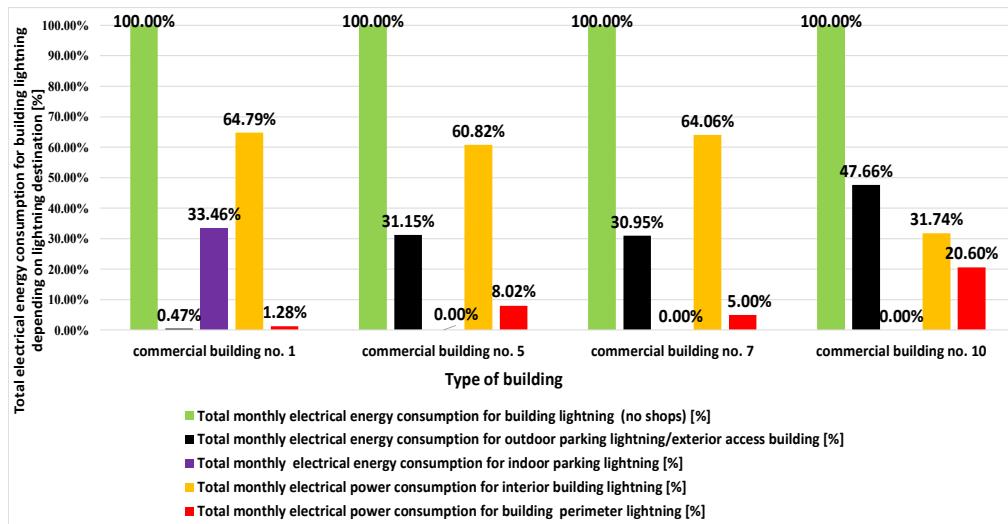


Fig. 3 (a) Total monthly electrical energy consumption for buildings lighting depending on lighting destination [%] - status for buildings with 3, 4, 5 operational years

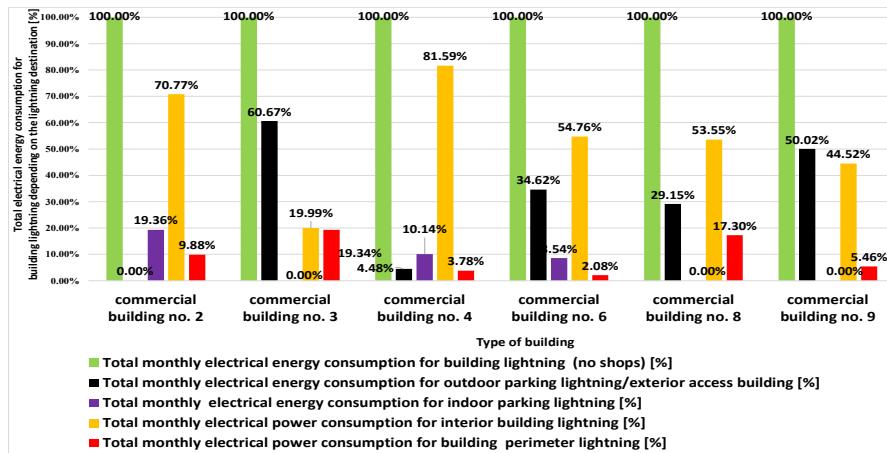


Fig. 3 (b) Total monthly electrical energy consumption for buildings lighting depending on lighting destination [%] - status for buildings with 8, 9, 10 operational years

Of course, the biggest values from the total electrical energy consumption for lighting per analyzed building represent interior lighting building consumption with values between 19.99% and 81.59%, followed by the one for outdoor parking lighting with values between 0.47% and 60.67%.

In comparison with the buildings having 8 (building no. 9),

9 (buildings nos. 2, 3, 4), 10 (buildings nos. 6 and 8) operational years, the buildings with 3 (building no. 10), 4 (buildings nos. 1 and 5), 5 (building no. 7) operational years have a significant improvement of the energy performances, considering a reduced energy consumption for interior lighting and for indoor parking, which are important values from the

total electrical energy consumption for buildings lighting.

The newest constructed, which have instead a lot in the lighting objects to expose better the interior design and the furniture and to offer a better interior comfort for its clients, have higher values of the electrical energy consumption. These values are explained also by the operating lighting schedule hours which is around 14 hours for interior lighting and 24 hours for indoor parking. For all of these, the schedule counting systems and the use of presence sensors, the use of voltage changers, mean important measures to be followed all the time during the operational hours.

For some buildings (e.g. building no.1), where there are installed ice rinks during the winter time [14], which have separate lighting installation systems, the electrical energy consumption is insignificant as percentage from the total electrical energy consumption of the building and does not affect in any way the general lighting installation systems of the building, simply because it is a seasonal use and is a separate installation, which can be monitored alone and switch on / off as it is requested.

III. IMPROVEMENT SOLUTIONS FOR BUILDINGS ENERGY PERFORMANCES

The buildings, which have shared the use of the lighting objects in such a way to function as 1/3 from the daily schedule hours, depending on the area from which is belonging, succeed to reduce accordingly the electrical energy consumption for lighting and those buildings were the buildings having 3, 4, 5 operational years.

The 1/3 functioning of the lighting objects was recommended to be performed for the indoor parking and for the outdoor parking where it was possible (and not to hinder in any way the security and surveillance of the buildings) and it can be done as well in the interior of the building on each level, considering the hourly nights. This can be achieved also for the buildings with more operational years (8, 9, 10) if it will be done manually, anytime is needed, locally, which it can be more difficult from operational point of view (people available to be involved in) and this is happening because there are not so many such buildings with a performant BMS installation. For these buildings, with more than 8 operational years, it is harder to install a BMS system after construction when the building is fully operational, but is not impossible, it takes only time to execute and a major investment, which is very justified for both investors and clients. This solution is considered to be an efficient measure to improve the energy performances of the buildings also because is involving much more, like teaching the users and clients to protect and use in a more efficient way the resources inside the buildings, to replace those non performant lighting objects with the ones having LED technology, to install presence sensors in areas designated for public and corridors, technical rooms, sanitation areas, staircases, everywhere is applicable.

Another solution to improve energy performances of the building from the lighting consumption point of view is to use programmable clocks to command the lighting installations according to the desired operational schedule.

During the night, it is necessary to have lights on the staircases, toilets, some locations to allow an optimal circulation and security. The dimmers are recommended to be used to reduce the lighting level depending on the activity to be done in the respective areas, and thus, it can be reached 30% energy savings.

It was calculated that, if such improvements shall be implemented in the analyzed buildings older than 8 operational years, there could be reached 20-30% energy savings for lighting and for the analyzed buildings with 3, 4, 5 operational years can be reached 40-50% energy savings.

Currently, the buildings with 3, 4, 5 operational years, have already obtained, due to their own systems (including BMS), the energy savings values for lighting consumption between 31% and 43% from the total buildings energy consumption.

IV. CONCLUSION

This paper is referring to the electrical energy consumption for the commercial buildings with big sizes, built after 2010 versus the ones constructed after 2007.

The preventive maintenance, daily operation, making on time the technical maintenance required by the producers, designers and constructors for all equipment and installations and all improvements adopted for each type of building accordingly to their needs, all that are a necessity for the administrators and investors starting with the construction year which can be for most the first operational year of the building erected.

The increase of the energy performances of the buildings appear also due to several aspects like: timed lighting; the replacement of the non-performant lighting objects with the ones having LED technology; installing presence sensors in all areas not designated to the public areas or in the toilets rooms to command the lighting installations depending on the requested operational schedule.

Using dimmers to reduce the lighting level depending on the unfolded activity in the respective areas can reach energy saving by 30%.

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REFERENCES

- [1] National Institute of Statistic www.insse.ro, accessed on March 13, 2018.
- [2] D. Tenea, C. Stamatia, A. Simion, M. Bontea, Implementation of the EPBD in Romania. Status in July 2015, www.mdrap.ro, accessed also on March 13, 2018: <https://www.dropbox.com/s/vaq0h8if64ypmlh/CA3-BOOK-2016-web.pdf?dl=0>.
- [3] European Commission, European Construction Sector Observatory Country Profile: Romania, March 2017, accessed on March 13, 2018: <https://ec.europa.eu/docsroom/documents/23751/attachments/1/translations/en/renditions/pdf>.
- [4] National Institute of Statistics, INCD URBAN INCERC www.incd.ro, private publication for.
- [5] Musat&Asociatii, <http://www.musat.ro/knowledge-2016/>- see chapter

- 28-Property-and-Construction.pdf 72 accessed on March 13, 2018.
- [6] Romanian Law no. 121/2014 on energy efficiency.
 - [7] Directive 2012/27/EU Energy Efficiency Directive.
 - [8] Romanian Law no. 159/2013 transposes the provisions of Directive 2010/31/EC into legislation.
 - [9] Romanian Law no. 372/2005 on the energy performances.
 - [10] National Energy Efficiency Action Plan (NEEAP) for 2014-2020, Romania, accessed on March 13, 2018 <https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans>.
 - [11] BREEAM, www.breecam.com.
 - [12] LEED, <https://new.usgbc.org/leed>.
 - [13] E.C. Tamaş, G. M. Tărlea, D. Hera, G. Flamaropol, "Status of the energy efficiency in retail industry," www.sgem.org, 17th International Multidisciplinary Scientific Geo Conference SGEM 2017, Green Buildings Technologies and Materials.
 - [14] G. Flamaropol, G. M. Tărlea, E. C. Tamaş (Papuc), D. Hera: "Analysis of energy consumption for a seasonal ice rink – Case study" in: Conference for building services, energy, efficiency, comfort, Brasov, Romania, 2017.