Journal of Renewable Energies
Revue des Energies Renouvelables
journal home page : https://revue.cder.dz/index.php/rer

Indoor Lighting Study: case of UDES’ Solar Smart House Bou-Ismail-Algeria

Aissa Meflah [a], Fathia Chekired [a,*], Fethi Akel [a], Yousria Yasmine Bouhouche [b]

[a] *Unité de Développement des Equipements Solaires, UDES, Centre de Développement des Energies Renouvelables, CDER, 42004, Tipaza, Algérie*

[b] *Institute of Electrical and Electronic Engineering. Department of Control and Power. M’Hmed Bouguara University, Boumerdes, Algeria.*

* *Corresponding author, E-mail address: chekiredfathya@yahoo.fr*

Abstract

In the residential sector, the energy consumed for lighting represents an important amount of the total energy consumption in a typical house. In this paper, a lighting system in a solar smart house prototype in Bou-Ismail, Algeria, has been studied. This study focuses on the optimization of lighting and the energy consumption in the house, where the experimental and the simulation of the light distribution in the house was carried out using DIALux software. The purpose is to find the most suitable devices that are able to reduce lighting energy consumption and still ensure an optimal visual comfort inside the house. The obtained results show the efficiency of the proposed lighting system, where a reduction in energy consumption of 55.87% has been achieved.

Keywords: Lighting optimization, LED, Dialux, Energy saving.

1. Introduction

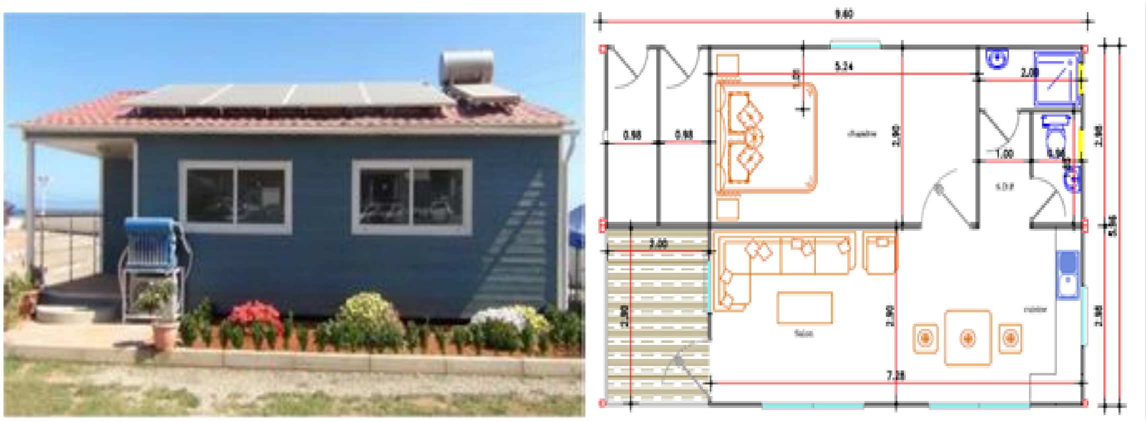
Analysis and studies show that the residential sector represents 43% of the global energy consumption [1]. A reduction in this sector represents a significant amount and results in an important impact on global energy consumption. Hence homes appear to be the cornerstone for reducing energy consumption in this sector; several works are particularly focused on optimization of the energy houses. Beside considering some architectural aspects in order to improve the thermal insulation of the houses, the installation of renewable energy sources on houses roof top along with an effective Home Energy Management System (HEMS) [2-5], which monitors and controls the energy consumed, can help in minimizing the energy consumption from the grid and increase the renewable energy consumption. In addition to the renewable energy sources and to go further in the reduction of the energy consumption in a house; optimization methods should be applied, such as: the use of low-consumption lamps and appliances[6-7], the integration of smart sockets that control the energy consumption of all home appliances[8] and the choice of the adequate lighting system[9].Home automation is also a modern way to associate the optimization of power consumption, the comfort and the security of the inhabitants[10, 11].According to [12,13], lighting is a significant feature in the energy consumption of residential sector, a deep study of the light distribution in a surface is able to give the optimal choice of lighting devices and system architecture. Integrated lighting controls for request side energy organization in building can improve its global performance [14–16], increase energy efficiency, and improve resident comfort [17] and approval with the built environment [18]. Consequently, all these studies have been directed to "smart homes" [11, 19]. As a result, researchers around the world aim to create a smart house that satisfies the following features:

- Provide low energy consumption.
- Powered by renewable energy sources.
- Ensure comfort and security for inhabitants.

In this context, the present paper focuses on the study of optimization of lighting energy consumption of the “Low Consumption Solar Smart House” prototype of the UDES (Unité de Développement des Equipements Solaires) situated in the coastal region of Algeria in Bousmail, Tipaza. The present work is organized as follows: Section 2 presents the description of UDES solar smart house. In section 3, the lighting system of the house is exposed and the aim is to find most suitable devices that consume less power but still ensure visual comfort. To achieve this, a light distribution study will be described.

2. UDES’ Solar Smart House

The solar house with 57m2 area is situated in the coastal region of Bou-Ismaîl, Tipaza, Algeria (Latitude: 36°38′33″ North and Longitude: 2°41′24″ East). It was assumed that a family of three members occupied it. The home energy demand depends on the number of appliances, the electrical power used by each appliance and the amount of use of appliances, which was determined by the behaviour of the occupants in the house.



(a) (b)

Fig 1. Solar smart house of UDES-Bou-Ismail, (a): Outside view, (b): house plan

This house has a photovoltaic system composed by a PV generator, an inverter and a battery bank. The sizing of the PV system was determined by considering the mean electricity consumption of a typical house. The energy needs of the house are met by the direct local PV power generation, then by the battery bank and as a last resort by the grid. In case of excess production, this is injected into the network. The PV system was included to the proposed solar home prototype in order to reduce the power grid dependence.

3. Study of the lighting system of Solar Smart House

Saving energy in house induces the optimization of the lighting energy consumption, which involve studying firstly the lighting distribution. A comparison between different Luminaires (lighting devices) was also performed to find the more suitable to be applied in the house. Some important features have been taken into account in this study when choosing the right lighting device (bulb or tube):

- Color rendering index (CRI): it is a measure of the ability of the light to illuminate colors accurately. The higher the better.
- Efficiency (or efficacy, as it is called in the lighting industry): Lighting efficacy is measured in lumens (light output) per watt (electricity use). The higher the better.
- Flux: is the measure of the perceived power of light. It is measured in Lumen.

In UDES' solar smart house, Linear and Compact fluorescent lights are installed as described in figure 2. Table 1 presents the lighting system distribution.

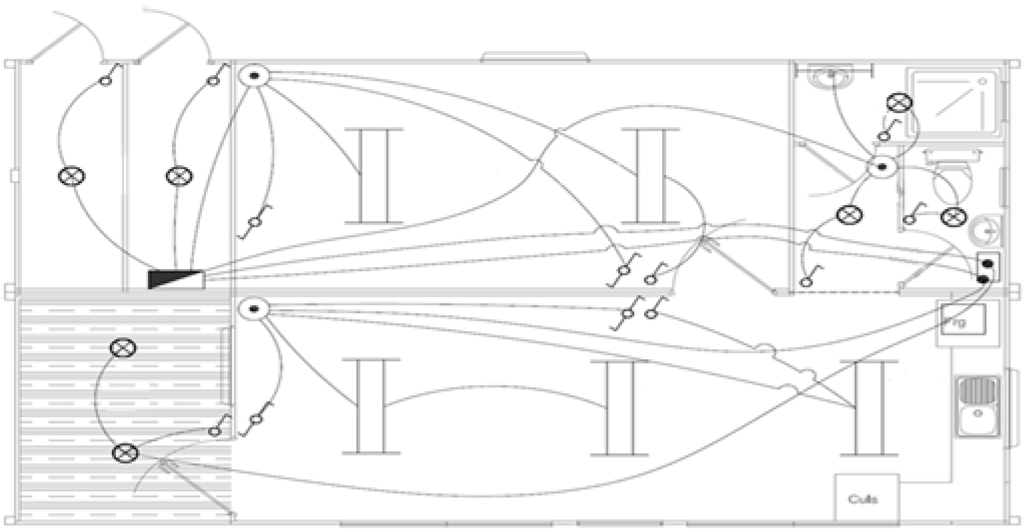


Fig 2. Lighting system of UDES' smart house: ⊗ Represents CFL bulb, / Represents 2 LFL tubes in same position

Table 1. Distribution of the lighting system of UDES' smart house.

ZONE		Type of Lighting Device	Power Consumption of the device (Watt)	Number of devices used
Zone 1	Living room	Linear Fluorescent	36	4
	Kitchen	LFL (tube)	36	2
Zone 2	Sleeping room	LFL (tube)	36	4
Zone 3	Hall	Compact Fluorescent	60	1
	Bathroom	CFL (bulb)	60	1
	Restroom	CFL (bulb)	60	1
Zone 4	Entry	CFL (bulb)	60	1
Zone 5	Work room	CFL (bulb)	60	1

3.1 Lighting distribution study

As mentioned in Table 1, Linear and Compact fluorescent lamps (LFL/CFL) were installed in the house without any technical study because this step is often neglected in the residential sector. As a result, visual comfort is not achieved, light is not uniformly distributed in the surface, and a lot of energy is wasted. In our case study, the total energy consumed in house is around of 15.197 kWh and that consumed by lighting is about 3.51 kWh. Lighting represents 23.09%of the total energy. Therefore, a real light distribution study should be done, following the above objectives:

a. Consume a lower amount of energy.

b. Ensure a visual comfort adapted to each room, that is:

- 250 to 300 lux for the living room,
- 300 to 350 lux for the kitchen,
- 250 to 300 lux for the sleeping room.

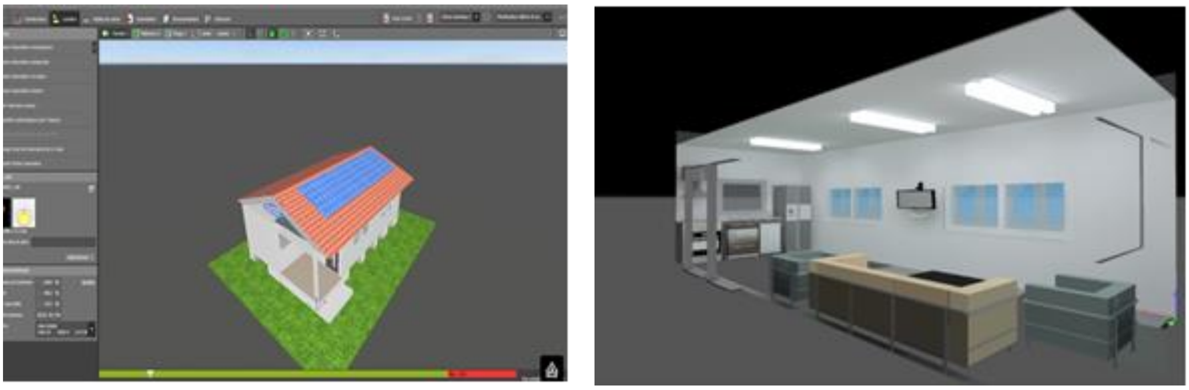
c. Avoid harmful components as the mercury for fluorescent technology.

d. Match an optimal cost.

A comparative study between the LFL technology previously installed in the house and the LED technology is established. It is shown that, the LED technology can meet most of objectives. The obtained light distributions were measured using a lux-meter in a specific zone of the house.

3.2 Comparative study of light distribution in the house

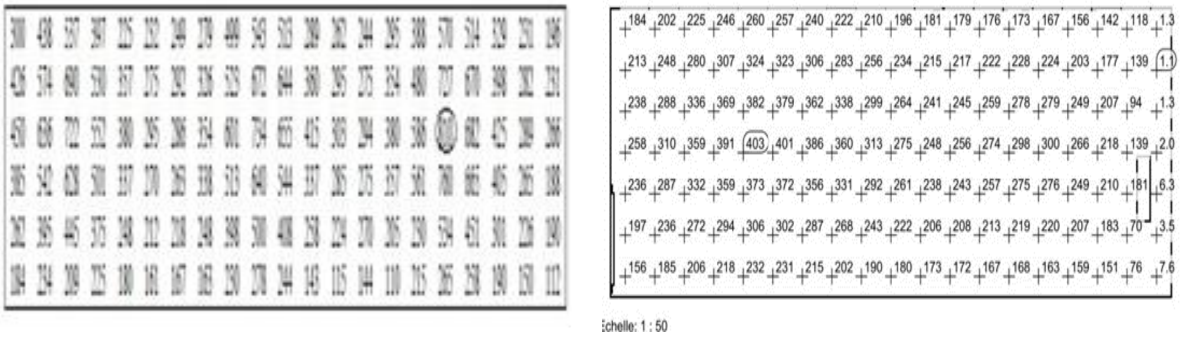
In order to choose the more suitable technology for the lighting system of the solar smart house and to meet the appropriate properties, the comfort of inhabitants and the cost, a distribution study using the LFL technology lamp and the LED technology lamp is used. This section interests to perform a light intensity measurement using a lux-meter (adevice that is able to measure the intensity of light in Lux) for the Zone 1 of the smart house: open surface of the living room and the kitchen. Then, to compare experimental and simulation values, DIALux software has been used (free complete software created by DIAL used for planning, calculation and visualization of indoor and outdoor lighting). The software makes professional lighting design easier and accessible. We were able to have a 3D visualization of the house using DIALux as shown in Fig. 3.



(a) (b)

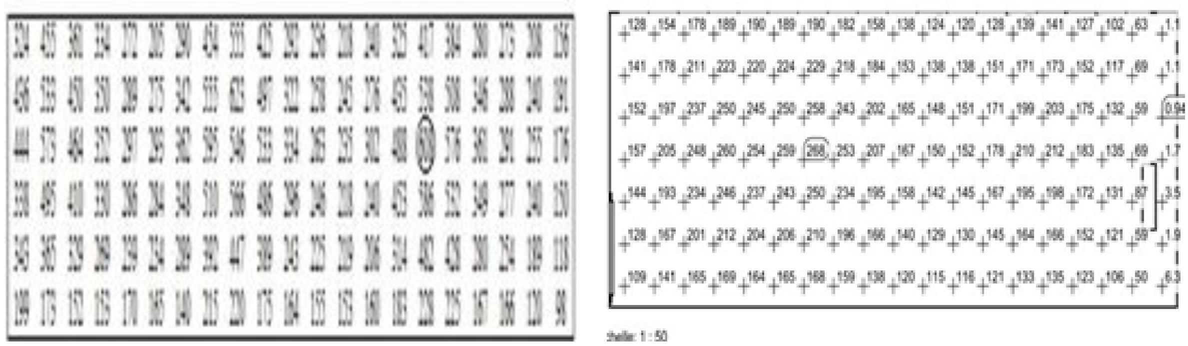
Fig 3. 3D visualization of UDES' solar smart house using DIALux, (a) Exterior visualization of the solar house.(b) Zone1: living room and kitchen.

The light distribution study is conducted by two steps: the light distribution measure in lux using LFL Lamps and then using the Led Lamps. Simulation and experimental results for light distribution in zone 1 of the house are presented in Fig. 4 and Fig. 5 respectively.



(a) (b)

Fig 4. Light distribution of LFL tubes in zone 1 of the house: (a) Experimental, (b) Simulation.



(a) (b)

Fig 5. Light distribution of LED tubes in zone 1 of the house:(a) Experimental, (b) Simulation.

As observed in Fig.4 and Fig.5, the luminance is uniformly distributed using LEDs and non-uniformly distributed using LFLs. Medium and maximum values obtained using excel software are shown in Table 2.

Table 2. Medium and maximum values of light intensity using LFLs and LEDs

Medium value observed in LFL	Maximum value observed in LFL	Medium value observed in LED	Maximum value observed in LED
406 lux	810 lux	350 lux	608 lux

From the Table 2, the medium value obtained by the LFL light distribution is 406 LUX. This value exceeds the standard 300 to 350Lux needed in a living room, thus, the visual comfort is not achieved using the LFLs. The moreover, the medium value obtained using the LED light distribution is 352 lux. The value matches the standard value 300 to 350 lux needed in a living room, according to the Illuminating Engineering Society of North America report [18], the standard illumination for a living room and kitchen is to be between 300lux to 500lux.This study is extended to the useful plan of the kitchen with the same steps. We conclude that, 6 LED tubes distributed as shown in figure 06 ensure an optimal visual comfort and a homogenous light distribution in Zone 1 of the house. Table 3 shows the specifications of both lighting devices.

Table 3. Characteristics and specifications of LFLs and LEDs.

Type of lighting Device	**Power consumption (Watt)**	**Flux**	**IRC**	**Life time Hours**	**Time to turn on**
Linear Fluorescent Lighting (LFL)	36	2400	90	8.000	500 to 1500 mS
Light Emitting Diode (LED)	16	1600	94	20.000	Instantaneous

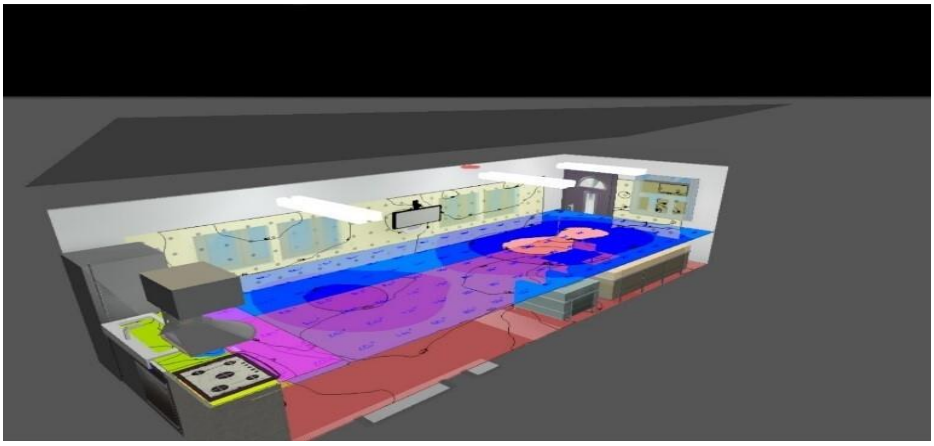


Fig 6. Light distribution in Zone1 with LEDs using DIALux software in the useful plan "0.85m".

From Table 4, it can be seen that LEDs offer many advantages compared with LFLs: lower power consumption, higher color rendering index, much higher life time and higher time to turn on. As below advantages concluded from this study:

• Low energy consumption: 16 W. High color rendering index (CRI): 94 %. Long Life time: 20.000 hours.

• Optimal visual comfort.

As described previously, there are 6 tubes used in zone1. Table 4 shows technical parameters for that zone.

Table 4. Technical comparison between LFLs and LEDs in zone 1

Type of lighting Device	Number of devices	Total Power consumption(W)	Total Energy consumption (Watt/hour) for 3h/day
Linear Fluorescent Lighting (LFL)	6	216	648
Light Emitting Diode (LED)	6	96	288

Table 4 and Table 5, we conclude that LED technology is more suitable for our case study and shows many advantages. Assuming that lights are turned ON for about 3hours a day in summer, the energy consumed by LFLs is 648Wh where the energy consumed by LEDs is 288 Wh. It represents an optimization of 55.55% in the lighting energy consumption in zone1. For these reasons, this work has been extended to all house zones and we replaced all Linear and Compact fluorescent lamps (LFL/CFL) lamps by LEDs. Table V describes the new lighting system using LEDs lamps. The lighting energy consumed using Led technology is around 1.55 kWh instead 3.5KWh using LFL technology. It represents an optimization of lighting energy consumption of 55.87% in all house zones. The total house energy consumption is than 13.247kWh using LED technology instead of 15.197kWh using LFL, which represents a total energy saving in the house of 12.85%.

Table 5. Lighting system of UDES solar smart house after performing light distribution study.

ZONE		Type of Lighting Device	Power Consumption of the device (W)	Number of devices used	Energy consumption (Wh)	Total Energy consumed by lighting (Wh)
01	Living room	LED tubes	16	4	1360	1549
	Kitchen	LED tubes	16	2		
02	Sleeping room	LED tubes	16	4		
03	Hall	LED spots	18	1	189	
	Bathroom	LED spots	18	2		
	Restroom	LED spots	18	1		
04	Entry	LED spots	18	1		
05	Work room	LED spots	18	2		

4. Conclusion

In this paper, first, a comparative study on light intensity distribution in UDES' solar smart house has been presented for two different types of devices used in the lighting system. The results show that LEDs are more suitable for residential use since they reduce considerably the power consumption. The light distribution can ensure an optimization of 55.87% of the energy consumption thus, an optimization of 12.85% of total energy consumption of the selected house. This method is then highly efficient for the optimization of power consumption and for the improvement of inhabitant's comfort. To summary, this work leads to understand that the preliminary study of the lighting system is essential to achieve visual comfort, optimization of the energy consumption and optimal cost.

5. Acknowledgements

This work was supported by Directorate General for Scientific Research and Technological Development DGRST/ Ministry of Higher Education & Scientific Research (Algiers), MESRS under contract N° 185 DGRSDT -UDES/CDER.

6. References

[1] OECD/IEA, Transition to sustainable buildings.Strategies and opportunities to 2050, 2013.

[2] F. Chekired, L. Canale, S. Tadjer, A. Louni, C. A. Bouroussis and A. Tilmatine, "Low-Cost House Automation System based on Arduino Microcontroller," 2021 IEEE Industry Applications Society Annual Meeting (IAS), 2021, pp. 1-6, doi: 10.1109/IAS48185.2021.9677162.

[3] S. A. Shinde, Home Energy Management System for Demand Response Applications. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol 4 Issue 06, June-2015.

[4] F. Chekired, S. Houtti, C. A. Bouroussis, A. Rahmani, A. Tilmatine and L. Canale, "Low-Cost Automation System for Smart Houses based on PIC Microcontrollers," 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Madrid, Spain, 2020, pp. 1-5, doi: 10.1109/EEEIC/ICPSEurope49358.2020.9160808.

[5] A. Gonçalves, Á. Gomes, C. HenggelerAntunes. Optimizing the management of smart home energy resources under different power cost scenarios, Applied Energy, 15 May 2019, (242), pp. 351-363.

[6] S.P.Borg, N.J.Kelly. The effect of appliance energy efficiency improvements on domestic electric loads in European households, Energy and Buildings, September 2011, Volume 43, Issue 9, pp.2240-2250.
[7] N. Luewarasirikul, A Study of Electrical Energy Saving in Office, Procedia - Social and Behavioral Sciences. 2015, (197), pp. 1203–1208.
[8] C. Keles, A. Karabiber, M. Akcin, A. Kaygusuz, B. BaykantAlagoz, O. Gul, A smart building power management concept: Smart socket applications with DC distribution. Electrical Power and Energy Systems 2015, (64), pp. 679–688.
[9] C. K. Lee, S. N. Li, and S. Y. Hui, "A design methodology for smart LED lighting systems powered by weakly regulated renewable power grids," IEEE Trans. 2011, Smart Grid, vol. 2, no. 3, pp. 548554.
[10] G. Hoseinia, N. D. Dahlana, U. Berardib, N. Makaremia. The essence of future smart houses: from embedding ICT to adapting to sustainability principles. Renew Sust Energy Rev 2013; 24:593–607.
[11] L.C. DeSilva, C. Morikawa, I.M. Petra. State of the art of smart homes.Eng. Appl. Artif. Intell. 2012;25(7), pp.1313–21.
[12] J. Cao, C. Hun Choi, F. Zhao, Agent-based modeling of the adoption of high-efficiency lighting in the residential sector, Sustainable Energy Technologies and Assessments, February 2017, (19), pp. 70-78.
[13] A. Shady, M. Hamdy, S. Ezzeldin, Twenty-year tracking of lighting savings and power density in the residential sector, Energy and Buildings, 1 November 2017, (154), pp. 113-126.
[14] F. Rubinstein, J. Jennings, D. Avery, and S. Blanc, "Preliminary resultsfrom an advanced lighting controls testbed," J. Illuminating Eng. Soc,vol. 28, no. 1, pp. 130–141, 1999.
[15] B. Roisin, M. Bodart, A. Deneyer, and P. D'Herdt, "Lighting energysavings in offices using different control systems and their real con-sumption," Energy Buildings, vol. 40, pp. 514–523, 2008.
[16] D. H. W. Li, K. L. Cheung, S. L. Wong, and T. N. T. Lam, "An analysisof energy-efficient light fittings and lighting controls," Applied Energy, 2010,(87), pp. 558–567,.
[17] Y.-J. Wen and A. M. Agogino, "Personalized dynamic design of networked lighting for energy-efficiency in open-plan offices," EnergyBuildings, 2011, (43), pp. 1919–1924.
[18] F. Rubinstein, S. Treado, and P. Pettler, "Standardizing communicationbetween lighting control devices," in Proc. 38th Annu. Meet. IEEE Ind.Appl. Soc., 2003.

[19] D. Marikyan, S. Papagiannidis, E. Alamanos, A systematic review of the smart home literature: A user perspectiveTechnological Forecasting and Social Change, January 2019, (138), Pages 139-154.