

**Lighting, housing and health: contributions of the 2030 Agenda
for sustainable cities and communities**

Élgen Soares Mendes

MSc Student, Architecture and Urbanism, USJT, Brazil
elgenmendes.1852@aluno.saojudas.br

Renata Ferraz de Toledo

PhD Professor, USJT, Brazil.
renata.toledo@saojudas.br

ABSTRACT

As an important factor in the promotion of environmental comfort, lighting in houses has been increasingly analyzed in studies about health and well-being. Understanding how human exposure to light (artificial or natural) can influence health and the possible beneficial or harmful aspects can contribute to developing strategies that optimize its use and effects, both on human health and on sustainability. Thus, the objectives of this research were to analyze if, and how, lighting in houses can influence human health and determine if the lighting, housing and health topics are connected to the 2030 Agenda Sustainable Development Goals (SDGs). This is a bibliographic review carried out through searches in the Scientific Electronic Library online and EBSCO Information Services databases, based on the following descriptors: lighting, health, housing, environmental comfort and sustainable development, some of their synonyms and in different combinations, researched in Portuguese and English. Other criteria were also used to select the publications to be analyzed, which, in turn, gave rise to two thematic groups: the first addressing environmental comfort in housing, analyzing its relationship with the residents' health and listing important elements for the promotion of environmental comfort; and the second devoted to specifically analyzing the relationship between lighting and human health. When analyzed in an interdisciplinary and intersectoral way, we understand that the "lighting-housing-health" relationship can be connected to the SDGs and effectively contribute to the 2030 Agenda.

KEYWORDS: Lighting. Housing. Health.

1. INTRODUCTION

Owning a home is a Universal Human Right established by the United Nations (UN) in the 1948 Declaration of Human Rights (UN, 1948). Since then, concepts and definitions around the necessary elements for housing to achieve the objective of contributing to the promotion of citizenship, guaranteeing a dignified life for its residents, have been debated, revised, expanded and established in new international resolutions and, gradually, adopted in local legislation and public policies in UN member countries (SPINK *et al.*, 2020). In 2016, in the city of Quito, Ecuador, the United Nations Organization for Human Settlements (UN-Habitat) promoted the third edition of the United Nations Conference on Human Settlements, where the New Urban Agenda was presented, whose document argues that Adequate housing is not just about physical shelter, but must include issues such as the urban environment, socioeconomic development, health and sustainability (UN, 2016).

Since 1991, UN-Habitat adopts in its documents the concept of adequate housing published in "General Comment No. 04: The right to adequate housing" (SPINK *et al.*, 2020). Prepared by the Committee on Economic, Social and Cultural Rights, the document establishes seven basic principles for a house to be considered adequate, namely: security regarding the right to property; guarantee of access to services, equipment and infrastructure; availability at affordable prices; habitability; accessibility to all social groups; location; and cultural suitability (BRAZIL, 2013). From the habitability point of view, a house is adequate when it guarantees the residents' physical safety, not offering risks due to structural problems or facilitating the spread of disease vectors; in addition to that, the dwelling must also protect its residents against weather conditions such as rain, humidity, cold and wind (UN, 2002).

The expanded concept of housing connects it with other important elements in the promotion of citizenship, among them the right to health, also a universal human right; in this way, we understand that the urban context in which a house is inserted, its physical elements, environmental and social factors, as well as the way in which its residents perceive and interact with them, can influence their health. In 2011, a study developed by the World Health Organization (WHO), which analyzed the impacts on people's health related to housing conditions in European countries, estimated that people spent a mean of eight hours a day in their homes (WHO, 2011), a fact that reasserts the importance of considering the effects of

housing on human health, in the planning and execution of a construction or refurbishment, in the choice of construction materials and domestic infrastructure equipment, as well as in the elaboration of public policies aimed at health.

Research studies about the relationship between lighting and health almost always analyze artificial and natural lighting separately. Harms in the retina caused by the incidence of artificial light coming from fluorescent lamps, with specified characteristics, were already investigated in tests with rats in 1996 by researchers Werner K. Noell, Virgil S. Walker, Bok Soon Kang and Steven Berman (SHANG *et al.*, 2014). In turn, the effects of natural lighting, as they are almost always related to natural ventilation and sunlight and thus having the ability to promote health in internal environments, have been studied at least since 1848. At that time, the English public health legislation already stipulated that every house should comply with minimum requirements for cleanliness and provide ventilation; 110 years later, in 1939, in the United States, the “Housing Hygiene Committee” published the report entitled “Basic Principles of Healthy Housing”, with thirty principles divided into four sections linked to human needs, with the “physiological needs” section including solar lighting and artificial lighting (PASTERNAK, 2016).

Be it artificial or natural, it is known that lighting interacts with the human body beyond the visual functions. Human eyes have a class of non-visual photoreceptors that transform incoming light into nerve signals, leading them to the brain; these signals are responsible for ordering the change rhythms between the wake state (light period of the day) and the rest state (dark period of the day), contributing to regulation of the human body's physiological functions (BERSON; DUNN; TAKAO, 2002). The temporal rhythm of changes between both states contributed to the human body to develop mechanisms capable of organizing biological functions such as body temperature oscillation, hormone production and perception of the need to be on alert or to enter into rest state, in addition to cell renewal (REA *et al.*, 2008). Adequate exposure to light (considering aspects such as the light source, the amount and intensity of light and the moment and duration of exposure, in addition to its spectral composition) is important for these functions to be performed in a harmonious and orderly way and without compromising human health (TOSINI *et al.*, 2008). This orderly change between the wake and rest states takes place throughout a one-day period, approximately 24 hours, repeating itself at the next day, receiving the name of Circadian Cycle (SOARES FILHO, 2018).

Artificial lighting has undergone countless transformations since discovery of the incandescent lamp by Thomas Edison in 1879, through the emergence of electric fluorescent lamps (ROIZENBLATT, 2009), until the most recent, discovery of LEDs (Light Emitting Diodes) in early 1990s, which became widely adopted as a source of artificial light in lamps and fixtures for residential use, for offering greater energy efficiency when compared to other solutions as they provided more light while consuming less energy (SOARES FILHO, 2018).

The implications on human health due to exposure to LED light in the home environment were investigated by Soares Filho (2018), in addition to his contributions in the promotion of environmental comfort. His research analyzed 10 volunteers that lived in houses whose lighting consisted in LED light lamps and/or fixtures, specified based on a luminotechnical project. The volunteers were analyzed in different periods, lasting 3 days each, and in one period they were exposed to LED light from their homes at night and, in another period, also at night, they wore blue light blocking glasses (common in spectral composition of

light emitted by LED lamps and fixtures). In both periods, data were collected on body temperature variation, sulfatexymelatonin excretion in urine (to identify variations in the melatonin load produced during the night period), sleep quality, and the characteristics of the lighting to which the volunteers were exposed, such as light intensity and color temperature. The comparison between the data from both periods revealed that direct exposure to LED light in the home environment resulted in higher incidence values of reduction in melatonin production and changes in the body temperature variation rate, suggesting that LED lamps and fixtures used in the home environment can cause harmful impacts to its residents' health (SOARES FILHO, 2018).

A qualitative study conducted with older adults in the rural province of Saraburi, Thailand, by Somrongthong *et al.* (2014), sought to understand the effects of housing and of the physical environment on the health of these people, with a sample of 13 homes and 47 key informants and application of semi-structured interviews and an objective observation of adequacy of the homes. Data collection was organized based on four main aspects: 1) lighting and safe wires; 2) the house layout project; 3) maintenance of the house; and 4) layout of health equipment. Among some of the results of this study, it is herein highlighted that most of the houses were made of wood, which helps to keep the house above the water in floods and keep the air circulating through the house in the hottest periods, components that can promote better health and well-being. The authors also draw the attention to the fact that most local government spending on health and social assistance is still focused on combating communicable diseases and treating non-communicable diseases, contrary to the WHO guidelines, which recognize that the physical environment needs to be part of the constellation of factors that affect the policy on the social determinants of health, alongside an understanding of the psychological, social and political environments.

Regarding lighting, ten of the thirteen households analyzed had insufficient, inadequate or non-functional lighting, in addition to inadequate switches, wires and lamps; in nine of these homes, older adults could not reach the switches; in five houses, fuel-based light sources were occasionally used, a factor related in other studies to the development of respiratory infections and burn injuries; in addition, accidents, falls or risk of electric shocks were recorded, caused by the presence of electrical supply wires for the lamps, placed directly on the floor of twelve of the houses. Some of the harms related to lighting observed are connected to two other aspects analyzed, "maintenance" and "design and composition", namely: inadequacy of the amount of lighting needed at greater intensity for aged people; inaccessibility to the fixtures and their activation devices; and improvisation in the installation of the fixtures and in the arrangement of the electrical supply wires. The risks linked to non-maintenance of the house and to the use of lamps based on fuels can be related to the fact that these homes are located in rural areas and, therefore, where the residents often have "limited resources" (SOMRONGTHONG *et al.*, 2014).

Regardless of the home environment structure, whether it had a lighting project for the execution of artificial lighting, or if it did not even have an architectural project for its construction, are some of the many factors that must be considered when trying to understand how lighting can influence its residents' health, whether considering the biomedical concept of health related to diagnosis and treatment of diseases or its expanded concept, proposed by the Health Promotion field, which integrates physical, environmental, emotional and social aspects (COHEN *et al.*, 2007). For being directly linked to decisions about

the production of physical spaces, which demands consumption of construction materials, products and devices, a connection is established with issues linked to sustainability, in addition to energy consumption efficiency. Therefore, it proves to be necessary to better understand the lighting-housing-health relationship and interpret how it is connected to the 2030 Agenda SDGs.

2. OBJECTIVES

The objective of this paper was to analyze if, and how, lighting in houses can influence human health and determine if the lighting, housing and health topics are connected to the 2030 Agenda Sustainable Development Goals (SDGs).

3. METHODOLOGY

For this study, of a theoretical and conceptual nature and with a qualitative approach, the bibliographic review is supported on the lighting, housing and health topics. For Severino (2017), this process evaluates the already existing production on the subject matter, establishing from that starting point the possible contribution of the research to knowledge about the study object.

The Scientific Electronic Library Online (SciELO) and the EBSCO Information Services (EBSCO) were the two databases where the searches were conducted, based on the following descriptors: “lighting” and “health”, “lighting” and “housing”, “housing” and “health”, “housing” and “environmental comfort”, “lighting” and “environmental comfort”, and “lighting” and “sustainable development”, researching them in the Portuguese and English languages. The inclusion criteria defined to select the publications that would be analyzed were the following: articles published from 2016 onwards, as this research aims at investigating the connection of these topics with each other and with the 2030 Agenda SDGs; articles published in any language, available in full; and, from reading their titles and abstracts, articles that best responded to the objectives of this research.

The organization, presentation and analysis of the publications selected were descriptive, allowing for the elaboration of analysis categories that gathered all the knowledge produced from this bibliographic review.

4. RESULTS

Based on the descriptors and on the period defined, the research initially yielded 238 articles. Of these, based on the analysis of their titles and abstracts, 18 articles were read in full and 6 were selected for the analysis because they were better related to the objectives of this research. Chart 1 below indicates the specifications of these articles.

Chart 1 - Articles selected for analysis in this bibliographic review.

Database	Title	Authorship and year	Journal	Theme
SciELO	A pilot study in a climatic chamber: The effect of natural light on health and well-being aspects not related to sight	TAMURA, Cintia Akemi; KRÜGER, Eduardo Leite. (2016)	<i>Ambiente Construído</i>	A methodology to analyze the effects of natural lighting on human health
SciELO	Housing and health	PASTERNAK, Suzana. (2016)	<i>Estudos Avançados</i>	Environmental comfort in housing and health
SciELO	Healthy housing and biosafety	COHEN, Simone Cynamon <i>et al.</i> (2019)	<i>Saúde em Debate</i>	Criteria for healthy housing
EBSCO	Natural lighting in historic houses during times of pandemic. The case of housing in the Mediterranean climate	MUÑOZ-GONZÁLEZ, Carmen <i>et al.</i> (2021)	<i>International Journal of Environmental Research and Public Health</i>	An analysis of lighting in historical houses and the ability to solve the demands created by confinement during the COVID-19 pandemic
EBSCO	Thermal and Lighting Housing Environments and Circadian Blood Pressure Variability: Findings from the HEIJO-KYO Cohort	OBAYASHI, Kenji; SAEKI, Keigo. (2018)	<i>Nippon Eiseigaku Zasshi</i>	Internal factors capable of influencing health, with artificial lighting among them
EBSCO	Lighting in the Home and Health: A Systematic Review	OSIBONA, Oluwapelumi <i>et al.</i> (2021)	<i>International Journal of Environmental Research and Public Health</i>	Internal factors capable of influencing health, with natural and artificial lighting among them

Source: The authors, 2022.

Of the articles selected for analysis, 4 were published in journals in the Health area and 2 in the Architecture and Urbanism area, showing the complexity and interdisciplinary nature of the lighting-housing-health relationship, a fact supported by the survey conducted by Soares Filho (2018), who presented studies already carried out and in progress in areas such as Medicine, Physiology, Biology, Public Health, Psychology, Engineering and Architecture, in order to investigate some physiological changes caused by exposure to LED light.

After reading and analyzing the articles selected, we were able to classify them into two thematic groups: the first addresses environmental comfort in housing, analyzing its relationship with its residents' health and listing important elements for the promotion of environmental comfort; and the second devoted to specifically analyzing the relationship between lighting and human health.

4.1. Environmental comfort, housing and health

Thinking about how the built space, be it a city or a house, can influence the health of its inhabitants and residents, started to have room in the public discussion in the middle of the first half of the 19th century in some European countries and it spread gradually around the world, starting with the sanitary vision that conditioned emergence and proliferation of some diseases to the absence of urban infrastructure and the living conditions of people in the city.

Gradually, this global view started to be more targeted at individuals, especially with the emergence of vaccines; however, it was later perceived that it was necessary to focus the attention on structural and collective issues again, so that it achieved effective results. Pasternak (2016) presents this evolution in the discussion about the housing-health relationship and indicates that this relationship started to be advocated and disseminated by the WHO from the second half of the 20th century, supported by the idea of expanding the concept of health beyond the treatment of diseases to the concept of Health Promotion, where several determinants might influence human beings' quality of life, among them the housing conditions, which also started to be understood beyond the physical space, now including the emotional or subjective dimension, the immediate surroundings or neighborhood, and the community or city.

The author suggests an analysis of the “housing-health” relationship, which divides housing needs into four groups: 1) the house and communicable diseases - physical characteristics of the house or even absence and/or deficiency of some services that can contribute to proliferation of diseases, such as water supply, sewage collection, adequate toilets, ventilation, sunlight, food preservation, bedroom space and densification, among others; 2) the house and physiological needs - the house must have conditions that meet human beings' physiological needs, such as adequate temperature, pure and fresh air, natural and artificial lighting, acoustic well-being and an adequate design; 3) the house and domestic accidents - material safety, fire and flood protection, protection against shock, burns, falls, gas poisoning, and automobile protection; and 4) the house and mental health - it involves elements such as privacy, family life, community life, ease of maintenance and performance of household activities, aesthetic satisfaction and compliance with the local standards.

In Brazil, the concept of adequate housing is measured in a backward manner, the characteristics of the houses that can render them inadequate for living are assessed, as well as whether they should be requalified or not. Due to the large number of houses in the outskirts and *favelas*, the João Pinheiro Foundation (*Fundação João Pinheiro*, FJP) suggests adopting different criteria to consider a house as adequate or inadequate, according to its residents' income range, allowing for the classification of houses located in *favelas* and urban outskirts as adequate or susceptible to adaptations. In the city of São Paulo, although there has been certain evolution in the access to urbanization public services and improvements in the housing conditions in the first two decades of the 21st century and, consequently, a reduction in infant mortality and in proliferation of some diseases, as a tool of health promotion, adequate housing still faces challenges such as excessive density of self-built houses in *favelas* and outskirts of the city (which hinders having sunlight and ventilation inside the houses) and excessive internal density in the homes, associated with precariousness of the buildings in the central regions where low-income people live (PASTERNAK, 2016).

It is in order to understand the residents' needs regarding the use of a built space and, thus, to propose effective interventions or new spaces in the sense of providing environmental comfort and contribute to promoting its residents' health that Cohen *et al.* (2019) suggest articulating the healthy housing and biosafety strategies. For the authors, both strategies together can contribute to promote environmental quality in the space built, when used as diagnosis tools. In common, they aim at guaranteeing safe, healthy and good quality environments and depend on a checklist for monitoring the internal and external risk factors to the built environment that exert impacts on human and environmental

health, in order to take the necessary short-, medium- and long-term intervention measures, according to their severity level. Biosafety is a set of actions related to prevention, control and reduction and elimination of risks that may affect human, animal or environmental health. The healthy housing strategy assesses the existing risks in the internal and external environment that can compromise human and environmental health. Therefore, they are complementary strategies aimed at promoting habitability and safety of a building.

The physical space must make the elements related to the building compatible with the methods that seek to maintain environmental quality, aiming at reducing or eliminating the occurrence of adverse effects of the agents causing environmental imbalances or the risk that they may exert impacts on health or the environment (COHEN *et al.* 2019, p. 1198).

The risks associated to the home space are classified as follows: 1) physical risks - radiation, ventilation, noise, vibration, lighting and heat stroke; 2) chemical risks - they involve environmental or human contamination by chemical products; 3) ergonomic risks - inadequate posture, intense physical efforts and lifting and carrying heavy objects; 4) psychosocial risks - related to the social context in which the house is inserted and to the predominant external factors; 5) biological risks - fungi, bacteria, viruses and vectors, among others; 6) accident risks - use of defective tools, electrical overload, probability of fire and inadequate physical arrangements; 7) sanitary risks - absence or irregularity in the water and electricity supply and in sewage garbage collection; and 8) socioeconomic risks - linked to the family purchasing power and to issues related to income, employment and schooling level, among others (COHEN *et al.*, 2019).

Joint action of both strategies should be adopted when planning or preparing the project, be it an intervention in an already existing house or in a new building. It involves the following criteria: 1) location of the building - it must take into account not only the risks and physical characteristics of the place, but also the social integration and the possibility of interaction; 2) sizing - it must consider the functionality of each space with human needs; 3) functional organization - it must promote social interactions, through pleasant environments for the coexistence of all residents, regardless of age group and physical condition, and flexibility and communication characteristics; 4) architectural characteristics - when possible to adopt modular projects with the possibility of dividing the module into smaller units, the project must provide for the sizing of internal circulations, furniture and equipment, location of the building networks of electricity, water, gas and others engineering systems, the characteristics of the proposed or existing construction and finishing materials and other elements that may interfere with the housing space; 5) constructive and environmental characteristics - to provide adequate salubrity and environmental comfort conditions (thermal, acoustic, visual, ventilation and sunlight incidence conditions); and 6) infrastructure - hydraulic, sanitary, electrical, electronic and natural gas distribution facilities (COHEN *et al.*, 2019).

The publications analyzed in this category, 'environmental comfort, housing and health', introduce us to the main concepts of comfort in the built environment and offer ways to identify deficiencies and solve them; in addition to that, they list the main factors to be considered in order to achieve health through quality of the house, considering its physical, environmental and subjective aspects. Lighting is included among these factors, mostly natural lighting, almost always associated with factors such as sunlight and ventilation.

4.2. Lighting and human health

With the objective of examining internal lighting in home environments and its association with the effects on the residents' health, Osibona *et al.* (2021) developed a systematic literature review entitled "Home lighting and health", which sought articles on the topic published until 2020. The survey resulted in 4,043 publications, of which 28 were chosen for a detailed analysis. The type of lighting was categorized as follows: 1) natural light, produced by the Sun; 2) artificial light, based on fuel or electricity; and 3) night light, natural and/or artificial. In turn, the results referring to health were categorized as follows: a) physical health; b) mental health; and c) sleep health. The survey result reveals that one of the least studied factors of housing quality is domestic lighting, with an evidence base in the period under study limited to a reduced number of studies in different light and health domains.

Although limited in numbers, the studies available assessed a wide variety of lighting types (natural light, artificial light and night light) in twenty-two specific health results. Twenty five of the twenty-eight studies included in the review observed an association between exposure to light in at least one health result. The studies included showed positive associations between exposure to natural light and health improvements in all domains (physical, mental and sleep health). Adequate natural light in a house protects human health from several complications, such as tuberculosis, leprosy, depression, mood changes, falls and sleep. Regarding artificial light, the use of fuel-based light sources exerts negative health impacts linked to respiratory infections and injuries and/or burns, mainly in children, as fuel burning releases harmful particles and pollutants which, when inhaled, result in respiratory diseases and lung cancer, especially in poorly ventilated houses (in the developing world, 860 million people do not have access to electricity, as fuel-based lighting is a common method for the house); and in deterioration of sleep quality due to exposure to electric light (fluorescent or LED) in cold color temperature. Regarding exposure to night light, chronic exposure to the night can negatively impact sleep and other physiological functions. The researchers found positive and negative effects linked to human exposure and home lighting, in addition to a gap since, for them, house lighting and the specific health results were not well studied, despite strong hypotheses for such connections. For the problems identified, they suggest adopting individual actions in the house, which can mitigate the negative effects, such as: keeping the curtains open during the day to allow natural light to enter the house, improving insufficient lighting (especially around the stairs), sleeping in a dark room or with an eye mask, and replacing fuel-burning light fixtures with off-grid electrical systems (e.g., solar power) (OSIBONA; SOLOMON; FECHT, 2021).

Investigating specific health effects caused by internal housing conditions, Obayashi and Saeki (2018) propose a descriptive analysis of blood pressure variation and changes in the circadian rhythm influenced by temperature and lighting; this relationship had been pointed out in a research study initiated in 2010, in the city of Heijo-Kyo, Japan. In the home environment of 1,127 individuals aged at least 60 years old, the houses' environmental aspects and the changes in the residents' biological and physiological indicators were measured simultaneously. The research sought to understand the increase in excessive mortality due to cardiovascular diseases in the winter, verified in several countries of the world, backing on previous studies that showed occurrence of higher blood pressure (BP) during winter. The

relationship between exposure to low temperatures in closed environments and BP variability, linked to the circadian rhythm, remained unknown.

In 146 individuals (healthy, aged 32 years old and randomly divided into two groups), the researchers investigated the effects of changes based on the comparison between exposure to external temperature and the internal temperature of their home environments, not discarding the diverse evidence associated with the increased intake of food products rich in sodium during the winter, for the analysis of the test results. For the purposes of our research, it is worth noting the evaluation regarding exposure to lighting. Physiologically, exposure to light is the most important environmental factor for the circadian cycle and melatonin production, with an increase in nighttime exposure to shortwave light (from 460 to 500 nm, i.e. blue light) and a reduction in daytime exposure significantly associated with lower melatonin production, which, at lower levels, is significantly related to higher nighttime BP values and to the development of atherosclerosis (an inflammation with formation of fatty plaques, calcium and other elements in the artery walls of the heart and other parts of the human body, characterized by narrowing and hardening of the arteries due to fat accumulation in their walls, known as atheroma); these two factors can evolve to affect the development of cardiovascular diseases (OBAYASHI; SAEKI, 2018).

Few epidemiological studies investigate the effects of exposure to temperature and domestic light on the incidence of diseases. The existing studies that investigate the effects of nighttime exposure to artificial light indicate that this exposure can contribute to problems such as hypertension, sleep disorders, depression, obesity, diabetes and dyslipidemia (a disease characterized by abnormalities in the blood lipid levels, mainly of total cholesterol and triglycerides), and these problems can contribute to the development of various diseases. As a direct effect of inadequate exposure to lighting, most of the research studies point to a reduction in the production of melatonin, a hormone directly related to regulation of the biological rhythms and to sleep quality, as well as to blood vessel dilation and to antioxidant effects (OBAYASHI; SAEKI, 2018).

In 2014, Tamura and Krüger (2016) conducted a pilot study that sought to test a methodology to measure the effects of natural light on health and well-being aspects not related to the visual function, and such research was performed in a climatic chamber in Karlsruhe, Germany. The climatic chamber had controlled thermal comfort conditions and the lighting conditions were adjusted to simulate situations with natural lighting alone, artificial lighting alone, or artificial and natural lighting combined. Four volunteers were divided into two pairs and subjected to simulations that also alternated the facade's geographical orientation. The tests took place for seven days, the variations in the incidence and luminous flux and the volunteers' subjective perception were measured through questionnaires, seeking to understand if lighting exerted any effect on the volunteers' chronotype (change rhythms between the activity and rest moments), daytime sleepiness, sleep quality, Seasonal Emotional Disorder (depression episodes linked to variation in exposure to natural light in different seasons), anxiety and stress.

Aspects of health and comfort in the built environment are only some of the contributions of natural lighting, and it is also important to consider its effects on the user's health and its influence on human biological rhythms, as hormones such as melatonin and cortisol are directly linked to regulation of these rhythms and exposure to light can influence the production of these hormones. The experiment was not dedicated to biomedical

measurements to quantify physiological and health issues, focusing on analyzing comfort and well-being conditions, and it was not possible to objectively quantify data that related these aspects in the volunteers with the lighting conditions; however, a tendency was detected for an increase in the stress symptoms, under the influence of artificial light, in individuals with preexisting symptoms for this condition. For the researchers, this shows the complexity and interdisciplinary nature of human emotions and perceptions, results of their interaction with the environment, therefore requiring a reassessment of the methodology employed and an analysis in a larger sample (TAMURA; KRÜGER, 2016).

A survey conducted by Muñoz-González *et al.* (2021) in the city of Málaga, Spain, analyzed physical aspects of natural lighting in two historical buildings, a multifamily house and a single-family one, analyzing 838 questionnaires that were answered online. The survey was conducted between April and June 2020, period which corresponded to the COVID-19 transmission peak in Spain and to the recommendation of social isolation as a strategy to reduce contagion by the SARS-COV-2 virus. The objective of the research was to understand how the lighting conditions of the historical buildings might influence the health of the people who needed to adapt work activities to the home environment during the confinement period. The questionnaires surveyed data such as age and size of the houses, number of windows and the residents' perception about health-related changes noticed since confinement. The physical survey and the simulations performed in both houses measured the following: 1) circadian stimulation - measured through the lighting levels during working hours to verify if the spaces have natural lighting in the amount necessary for the production of the serotonin and melatonin hormones at adequate levels for the correct functioning of the circadian cycle, responsible for the changes between the of activity and rest moments; 2) daytime autonomy - it considers the percentage of working hours per year in which the minimum amount of lighting for the performance of work activities, 300 lux, reaches the work plan; and 3) annual exposure to the sun - which measures how much of the home space received direct solar radiation: this data is important to determine whether there is risk of glare when using natural lighting to perform work activities.

Headaches, pain in the eyes, tiredness and lack of concentration were the health disorders perceived during the confinement period and reported by the volunteers who answered the online questionnaires. The analysis of the results revealed that these disorders were less common in residents of single-family homes that had a garden and in residents of homes built before 1950; patios, gardens, balconies, facades with a greater number of windows and horizontal windows were more identified in homes built up to 1950, showing the importance of access to natural light for the reduction of health disorders caused by staying in the home environment for extended periods of time. The analysis of both houses also revealed the following: in the summer, both had spaces where the natural lighting levels were adequate to maintain the circadian rhythm and carry out professional activities without any risk of glare; and in winter, natural lighting was insufficient at some hours of the day, demanding the combined use of natural and artificial lighting. As a result, it is noted that, for the best possible leverage of the benefits of natural lighting for human health, it is necessary for architects and designers to guide the layout of the houses, taking into account natural lighting aspects specific to each project, related to the new demands of the home environment imposed by the pandemic and, when specifying lamps and fixtures to make up for the insufficiency of natural

light, when necessary, considering not only factors related to energy efficiency but also the residents' comfort, well-being and health (MUÑOZ-GONZÁLEZ *et al.*, 2021).

4.3. Lighting-housing-health in the 2030 Agenda SDGs

In a research study that evaluated the city-health-sustainability relationship, Mendes, Sígolo and Toledo (2021) highlight the need to reflect on the “health of housing” and the “health of cities” through an expanded, interdisciplinary and intersectoral look that takes into account environmental, social, cultural, economic, political conditions and determinants, and their connections with sustainability, also considering health as cross-sectional to all 17 SDGs (MENDES; SÍGOLO; TOLEDO, 2021). As shown in the articles analyzed, artificial and natural lighting in the home environment are important so that they are able to contribute to promoting their residents' health; we can therefore assert the existence of a direct connection with “Goal 3 – Health and well-being” from the 2030 Agenda, which sets the target of ensuring a healthy life and promoting well-being for all, at all ages (UN, 2016).

Considering the complexity inherent to the lighting-housing-health relationship, its interdisciplinary character and the cross-sectionality of health across all SDGs, it becomes necessary to investigate other connections in the articles analyzed. When associated with sunlight and natural ventilation, natural lighting can contribute to lighting comfort and, consequently, to the promotion of thermal comfort in home environments (COHEN *et al.*, 2019; PASTERNAK, 2016), contributing to electrical systems for cooling or heating the house to be less demanded, thus consuming less energy (HEYWOOD, 2015); in this sense, well-designed projects that consider the activities to be carried out in the home environment during the day and according to the availability of natural light in the environments can also contribute to reducing energy consumption by artificial lighting systems (MUÑOZ-GONZÁLEZ *et al.*, 2021). These aspects indicate a connection with the following goals: “11 – Sustainable cities and communities”, “12 – Responsible consumption and production”, and “13 – Action against global climate change” (UN, 2016).

Following the recommendation proposed by Mendes, Sígolo and Toledo (2021) and with an expanded and interdisciplinary perspective towards this analysis, we highlight the observation by Muñoz-González *et al.* (2021) who, in their research and when analyzing the effects of residential lighting on health during the confinement period of the COVID-19 Pandemic, suggested that, if lighting of the home environment is able to comfortably house work activities and not compromising the health conditions of people who have the possibility of opting for the home-office practice will be contributing to reducing the number of home-work commutes, which many times depend on the use of vehicles that predominantly run on the basis of burning fossil fuels and contribute to the release of carbon dioxide into the atmosphere. Thus, it is concluded that home-office work can be considered a safe option, even without the compulsory character of confinement. In this way, we note that, indirectly, the conditions of health and well-being, both physical and emotional, provided by the lighting conditions of the home environment can contribute to the construction of communities and cities with less air pollution (which can contribute to other health problems), as they indirectly favor the reduction of CO₂ release into the atmosphere, with its importance not being reduced only to energy consumption due to the choices of certain types of lamps and fixtures and projects that consider the most efficient use of natural light (MUÑOZ-GONZÁLEZ *et al.*, 2021).

This analysis indicated an important connection between the lighting-housing-health relationship and the aforementioned SDGs, in addition to alignment with the 2030 Agenda core goal of contributing to Global Sustainable Development.

5. CONCLUSION

Through a bibliographic review, this paper proposed an analysis of the relationship between lighting, housing and health, as well as a reflection to analyze if, and how, this relationship in the selected articles is connected with the Sustainable Development Goals (SDGs) proposed by the UN in the 2030 Agenda, as well as the contributions they can bring to the construction of sustainable cities and communities. It becomes necessary to recognize the scope limits of this analysis, which precludes generalizations for being a study of a qualitative nature. On the other hand, the importance and contributions of the reflections herein proposed should be noted.

The analysis reinforced the understanding of the interdisciplinary character of the lighting, housing and health topics, as well as the complex nature of the connection between them. The nature of the approaches analyzed about the implications of lighting in houses on their residents' health, either through a traditional and hegemonic perspective of the biomedical concept of health or through the expanded perspective of the concept of Health Promotion, which integrates environmental, social, cultural, economic and political conditions and determinants conditions and determinants, leads us to understanding that the health implications can be beneficial or harmful and depend on a combination of decisions about the countless aspects related to the process of construction, renovation or adaptation of a house, such as: design of the project; distribution of the internal layout; choice of building materials; and specification of products and equipment for artificial lighting systems.

The articles devoted to the analysis of existing buildings do not make it clear whether these houses were designed by specialized professionals; however, the aforementioned aspects related to planning and execution of a house demand specific technical knowledge so that the implications of the exposure to light in the home environment are not harmful to its residents' health, and act in the opposite direction of contributing to the factors necessary for the promotion of human health. Consequently, it becomes necessary to try to understand if measures in this respect are analyzed and if they can be realized in houses that lacked the support of specialized professionals and technicians when they were built; in other words, self-built homes. Present in many Brazilian metropolis, the *favelas* and urban outskirts almost entirely consist of self-built houses. A research study conducted in 2015 by the Architecture and Urbanism Council (*Conselho de Arquitetura e Urbanismo*, CAU) shows that 85% of the people who already built or refurbished their houses lacked professional support from architects or engineers (CAU, 2015).

The analysis allowed verifying a broad connection between the lighting-housing-health relationship with the 2030 Agenda SDGs, the reflections imposed by the COVID-19 Pandemic on the physical conditions of housing and its ability to contribute to promoting the residents' health and the cross-sectional nature of the health issue made it possible to identify connections beyond the contributions linked to the energy efficiency of houses; therefore, it is possible to assert that, in fact, this relationship can contribute to the core objective of the

2030 Agenda: to achieve Sustainable Development by 2030 and provide for the construction of sustainable cities and communities.

6. REFERENCES

- BERSON, D. M.; DUNN, F. A.; TAKAO, M. Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock. *Science*, [s. l.], v. 295, n. 5557, p. 1070–1073, 2002. Disponível em: <https://www.science.org/doi/10.1126/science.1067262>. Acesso em: 16 ago. 2022.
- BRASIL. Direito à moradia adequada. *In*: , 2013, Brasília, Brasil. (Secretaria de Direitos Humanos da Presidência da República, Org.) **Anais [...]**. Brasília, Brasil: Coordenação Geral de Educação em SDH/PR, Direitos Humanos, Secretaria Nacional de Promoção e Defesa dos Direitos Humanos, 2013. p. 76. Disponível em: https://urbanismo.mppr.mp.br/arquivos/File/DH_moradia_final_internet.pdf. Acesso em: 16 ago. 2022.
- CONSELHO NACIONAL DE ARQUITETURA E URBANISMO DO BRASIL - CAU. Percepções da sociedade sobre Arquitetura e Urbanismo. 2015. Disponível em: <https://www.cau.br/pesquisa2015/>. Acesso em: 12 ago. 2022.
- COHEN, S. C.; BODSTEIN, R.; KLIGERMAN, D. C.; MARCONDES, W. B.. Habitação saudável e ambientes favoráveis à saúde como estratégia de promoção da saúde. *Ciência e Saúde Coletiva*, [s. l.], v. 12, p. 191–198, 2007. Disponível em: <https://www.scielo.br/j/csc/a/kjksLCBLLvb8qPbLfjBqz5p/abstract/?lang=pt>. Acesso em: 15 ago. 2022.
- COHEN, S. C.; CARDOSO, T. A. de O.; NAVARRO, M. B. M. de A.; KLIGERMAN, D. C. Habitação saudável e biossegurança: estratégias de análise dos fatores de risco em ambientes construídos. *Saúde em Debate*, [s. l.], v. 43, n. 123, p. 1194–1204, 2019. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-11042019000401194&tlng=pt. Acesso em: 09 ago. 2022.
- HEYWOOD, Huw. 101 regras básicas para uma arquitetura de baixo consumo energético. 1. ed. São Paulo: Gustavo Gili, 2015.
- MENDES, É. S.; SÍGOLO, L. M.; TOLEDO, R. F. de. Healthy housing, sustainable city and interlocation between science and society. *Periódico Eletrônico Fórum Ambiental da Alta Paulista*, [s. l.], v. 17, n. 2, p. 363–376, 2021. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/forum_ambiental/article/view/2972. Acesso em: 09 ago. 2022.
- MUÑOZ-GONZÁLEZ, C.; RUIZ-JARAMILLO, J.; CUERDO-VILCHES, T.; JOYANES-DÍAZ, M. D.; MONTIEL VEGA, L.; CANO-MARTOS, V.; NAVAS-MARTÍN, M. A. Natural Lighting in Historic Houses during Times of Pandemic. The Case of Housing in the Mediterranean Climate. *International Journal of Environmental Research and Public Health*, [s. l.], v. 18, n. 14, p. 7264, 2021. Disponível em: <https://www.mdpi.com/1660-4601/18/14/7264>. Acesso em: 17 ago. 2022.
- OBAYASHI, K.; SAEKI, K. Thermal and Lighting Housing Environments and Circadian Blood Pressure Variability: Findings from the HEIJO-KYO Cohort. *Nippon Eiseigaku Zasshi (Japanese Journal of Hygiene)*, [s. l.], v. 73, n. 2, p. 138–142, 2018. Disponível em: https://www.jstage.jst.go.jp/article/jjh/73/2/73_138/_article/-char/ja/. Acesso em: 17 ago. 2022.
- ONU, Organização das Nações Unidas. **Declaração Universal dos Direitos Humanos**. 1948. Disponível em: <https://www.oas.org/dil/port/1948%20Declara%C3%A7%C3%A3o%20Universal%20dos%20Direitos%20Humanos.pdf>. Acesso em: 15 ago. 2022.
- ONU, Organização das Nações Unidas. **Ficha Informativa Nº 21: O Direito Humano a uma Habitação Condigna**. [S. l.: s. n.], 2002. Disponível em: https://gddc.ministeriopublico.pt/sites/default/files/documentos/pdf/ficha_informativa_21_direito_habitacao_condigna.pdf. Acesso em: 27 jul. 2022.
- ONU, Organização das Nações Unidas. Objetivos do Desenvolvimento Sustentável. **Agenda 2030**: 2016. Disponível em: <https://brasil.un.org/pt-br/sdgs>. Acesso em: 15 ago. 2022.
- OSIBONA, O.; SOLOMON, B. D.; FECHT, D. Lighting in the Home and Health: A Systematic Review. *International Journal of Environmental Research and Public Health*, [s. l.], v. 18, n. 2, p. 609, 2021. Disponível em: <https://www.mdpi.com/1660-4601/18/2/609>. Acesso em: 27 jul. 2022.
- PASTERNAK, Suzana. Habitação e saúde. *Estudos Avancados*, [s. l.], v. 30, n. 86, p. 51–66, 2016. Disponível em: <https://www.scielo.br/j/ea/a/CHFxZBNt7kyDWRtSfXQFF/?lang=pt>. Acesso em: 22 jul. 2022.

REA, M. S.; BIERMAN, A.; FIGUEIRO, M. G.; BULLOUGH, J. D. A new approach to understanding the impact of circadian disruption on human health. **Journal of Circadian Rhythms**, [s. l.], v. 6, p. 7, 2008. Disponível em: <https://www.jcircadianrhythms.com/article/10.1186/1740-3391-6-7/>. Acesso em: 16 ago. 2022.

ROIZENBLATT, Isac. **Crerios da iluminao eltrica urbana**. 196 f. Tese (Doutorado em Arquitetura e Urbanismo). Universidade Presbiteriana Mackenzie, 2009. Disponível em: <http://livros01.livrosgratis.com.br/cp112654.pdf>. Acesso em: 09 ago. 2022.

SHANG, Y.-M.; WANG, G.-S.; SLINEY, D.; YANG, C.-H.; LEE, L.-L. White Light-Emitting Diodes (LEDs) at Domestic Lighting Levels and Retinal Injury in a Rat Model. **Environmental Health Perspectives**, [s. l.], v. 122, n. 3, p. 269–276, 2014. Disponível em: <https://ehp.niehs.nih.gov/doi/10.1289/ehp.1307294>. Acesso em: 09 ago. 2022.

SOARES FILHO, Ruy Barbosa. **Resposta humana à luz**: alteraes no visuais e o projeto luminotcnico residencial com LEDs. 152 f. Dissertao (Mestrado em Arquitetura e Urbanismo). Universidade de So Paulo, 2018. Disponível em: <http://www.teses.usp.br/teses/disponiveis/16/16132/tde-09102018-161925/>. Acesso em: 03 ago. 2022.

SOMRONGTHONG, R.; DULLYAPERADIS, S.; WULFF, A. L.; WARD, P. R. The Effects of Housing on Health and Health Risks in an Aging Population: A Qualitative Study in Rural Thailand. **BioMed Research International**, [s. l.], v. 2014, p. 1–7, 2014. Disponível em: <http://www.hindawi.com/journals/bmri/2014/289731/>. Acesso em: 16 ago. 2022.

SPINK, M. J. P.; MARTINS, M. H. M.; SILVA, S. L. A.; SILVA, S. B. da. O Direito à Moradia: Reflexões sobre Habitabilidade e Dignidade. **Psicologia: Cincia e Profisso**, [s. l.], v. 40, p. e207501–e207501, 2020. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1414-98932020000100139. Acesso em: 03 ago. 2022.

TAMURA, C. A.; KRÜGER, E. L. Estudo piloto em câmara climática: efeito da luz natural em aspectos de saúde e bem-estar no relacionados à viso. **Ambiente Construído**, [s. l.], v. 16, n. 2, p. 149–168, 2016. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-86212016000200149&lng=pt&tlng=pt. Acesso em: 16 ago. 2022.

TOSINI, G.; POZDEYEV, N.; SAKAMOTO, K.; IUVONE, P. M. The circadian clock system in the mammalian retina. **BioEssays**, [s. l.], v. 30, n. 7, p. 624–633, 2008. Disponível em: <https://onlinelibrary.wiley.com/doi/10.1002/bies.20777>. Acesso em: 16 ago. 2022.

WHO, World Health Organization. **Environmental burden of disease associated with inadequate housing**. 2011. [s. l.], 2011. Disponível em: https://www.euro.who.int/__data/assets/pdf_file/0003/142077/e95004.pdf. Acesso em: 20 ago. 2022.