

Sustainable Energy Design Study in Esmeraldas, Ecuador

Ruiz Lourdes¹, Garcia Damarys²

¹Ext. La Concordia, Universidad Técnica de Esmeraldas Luis Vargas Torres, Ecuador.

²Vicerrectorado, Universidad Técnica de Esmeraldas Luis Vargas Torres, Ecuador.

Received: 3 Oct 2020; Received in revised form: 18 Nov 2020; Accepted: 20 Nov 2020; Available online: 27 Nov 2020

©2020 The Author(s). Published by AI Publications. This is an open access article under the CC BY license

(<https://creativecommons.org/licenses/by/4.0/>)

Abstract— Sustainable energy design is particularly challenging in equatorial climates with large tourist populations because of demands on fossil fuels for comfortable indoor temperatures. This study analyzed the relationship between windows buildings, design variables usage during hot tourist periods by life cycle analysis in buildings. A study was conducted in buildings of Esmeraldas, Ecuador. A database was used to reconstruct the local microclimatic variations in MERRA 2 coastal areas, on-site observations were made, and a life cycle analysis using SIMAPRO software was used to process the data. The results revealed that window size and exterior protections from solar energy were important features. These findings contribute to the study of buildings in hot coastal areas that require air conditioning, which could be reduced if bioclimatic designs were used on the exterior walls that are most exposed to solar radiation, implying an adverse internal heat gain. Effective bioclimatic design parameters could be used regarding unprotected buildings on beaches to reduce their energy consumption for air conditioning.

Keywords—Energy, sustainable design, Esmeraldas, Ecuador.

I. INTRODUCTION

The energy consumption mostly is for artificial air conditioning, which contributes to air pollution and greenhouse gas (GHG) emissions, and much of the usage relates to the building's designs. To address these problems, it is necessary to investigate and quantitatively assess the environmental impacts of buildings in various climatic regions to provide designers with information they can apply to effect preventive measures. These measures are urgent for coastal cities that rely on tourism and for residents who might seriously be affected by rising sea levels and temperatures related to global climate change. The city of Esmeraldas, Ecuador, is an example of this global problem, and this study performed a comparative life cycle analysis (LCA) between modern and traditional designs in the Esmeraldas region.

The effects of climate change on buildings located in warm microclimates indicate the need to conduct research on sustainable energy design. Achieving energy sustainability in response to climate change might be most important in the world's coastal areas. Galindo, Samaniego, Alatorre, and Ferrer argued that Latin America

could reduce its exposure to climate change and adaptation costs using a regional integration process by considering, for example, food and energy security issues in the regional context [1]. Economic Commission for Latin American and the Caribbean indicated that climate change demands adjustments in current production and consumption patterns and establishing a new style of sustainable development [2]. The International Panel on Climate Change issued a warning more than a decade ago about the negative effects of climate change on economies, population well-being, and ecosystems [3] According to Stern, the evidence in 2007 suggested that a temperature increase of 2° C and accompanying planetary impacts during the first half of the 21st century is practically was almost inevitable [4]. Others have warned us that Latin America needs to recognize the importance of adapting to new climatic conditions during this century if it hopes to reduce the effects of climate change, and the region should simultaneously seek a sustainable development path [1]. They highlighted the importance of implementing effective adaptive measures to reduce the negative impacts [1].

Latin America and the Caribbean might be particularly sensitive to climate change because of their diverse geographical, social, economic, and environmental features [5]. Climate-sensitive activities, such as agriculture, livestock ranching, fisheries, tourism, population density in coastal and other vulnerable areas, high levels of biodiversity, and the historically hot temperatures point to the need to integrate climate change response measures into municipal and national policies [1]. According to climate indicators, energy use emissions comprise more than 40% of the total emissions by Latin America and the Caribbean [6]. Consequently, effective measures are needed to reduce energy consumption in residential areas and by various economic activities, such as tourism. The Ministry of Environment of Ecuador recently proposed measures to mitigate climate change effects caused by energy consumption, which included strengthening the implementation of existing measures to promote energy efficiency and sovereignty and a gradual transition in the energy consumption matrix to increase the proportion of renewable energy uses [7].

Because climate change implies consistent increases in average daily temperatures and greenhouse gas concentrations in the atmosphere, buildings will need more energy to control interior climates and more mechanical air conditioning systems to cool them. Many climate change response measures have eco-designs or green buildings designs that apply the principles of energy efficiency through bioclimatic designs based on efficient uses of resources and materials, as well as support human well-being and provide optimal indoor climatic comfort [8, 9]. Bioclimatic principles form the foundation of this sustainable energy design in architecture [10], and the microclimate and individual well-being define the comfortable conditions [11]. The negative effects of climate change on equatorial microclimates and indoor temperature of buildings are numerous and complex. Some studies have described these implications [12], [13], [14], [15] [16].

The climate is arguably the most important factor in bioclimatic design because it encompasses temperature, structural type, and atmospheric factors, such as wind, relative humidity, urban weather factors, and vegetation factors. Implementing sustainable architecture criteria in cities should be economically beneficial for the real estate market because building performance, operating costs, and energy savings are enhanced [16].

A definition by the US Environmental Protection Agency (EPA) [17] is as follows: "Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient

throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction." Indoor Air Quality refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants [17].

Green building certification for different types of buildings and some programs such as include the Building Research Establishment Environmental Assessment Methodology (BREEAM) [18]. and Leadership in Energy and Environmental Design (LEED) [19], are used in many countries. Green buildings are implemented by various programs and criteria around the world. The impact of ambient temperature on the total electricity consumption showed that the actual increase of the electricity demand per degree of temperature increase varies between 0.5% and 8.5%. They emphasize efficient use of energy and resources and, to lesser extent, healthy indoor air quality [20] [21].

Many studies have investigated the association between ventilation and energy design in buildings includes the effect of the design on the outdoor environment, [22], [23], [24], [25], and [26]. The relation between wind effects, wind comfort, wind danger and wind climate is outlined Air temperature surrounding the building significantly increases due to the multiple reflections of the radiation heat flux, leading to an increase in the cooling demand A number of studies have investigated the efficiency improvement of building cooling systems with the implementation of an air-side economizer. Applying energy storage building materials that can efficiently use thermal energy to a building can reduce the peak load of building energy use and reduce the heating and cooling load by efficient use of thermal energy and, furthermore, increase the thermal comfort time [26], [27], [28], [29], [30]

The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased reaching figures between 20% and 40% in developed countries [31], like Ecuador. Few studies have been done regarding other aspects of air distribution. Amongst existing types of ventilation systems, the performance of each ventilation methods varies from one case to another due to different usages of the ventilation system in different buildings [31], [32], especially on equatorial microclimate zoning, and temporary adjustments to zone temperature set points is one approach for implementing demand response measures during peak cooling periods [33].

The coastal areas hot and dry characteristics usually require cooling of building interiors, which consumes large amounts of energy, and the energy conservation strategies based on bioclimatic and sustainable designs should be implemented there. Criteria for Assessing Sustainable Buildings in Developing Countries: The Case of Esmeraldas, reported on the studies on climate zoning in Ecuador [34]. It used geographic information systems to map the climatic zone extending from the southern Manabí coast to Ecuador's coastal provinces of Esmeraldas which have hot and extremely dry conditions with continuous airstreams from the sea [35], [36].

A bibliographic review was conducted on the life cycle analysis (LCA) applied to energy management in buildings [37], [38], [39], [40]. Life cycle analysis and multi-criteria decision-making techniques when used in combination within the same methodological framework have been shown to be the best tool for sustainable evaluation [39]. Time differentiation along the framework could have a significant impact on the LCA results and on decision support], [40].

II. MATERIALS AND METHODS

The current study collected primary data to reliably perform an LCA, which was conducted in accordance with the current international standards. Energy demands, GHG emissions, and environmental impact categories were assessed to obtain an integrated sustainability analysis for windows in building's façade with high level of energy consumer in Esmeraldas, Ecuador. A life cycle approach to design has the potential to reveal the balance between projected operational energy savings and inverted incorporated energy.

However, some authors [41], [42], [43] point out limitations in these methodologies but for the purposes of the present investigation if it is feasible to use for the windows of existing buildings and robust primary data measured [37], [38], [39], [40], in each place at different times have been collected.

2.1 Study Site.

Esmeraldas is the province of the northernmost Ecuadorian coast, that is, the one in the north of the country. The territory is flat, with small hills of a maximum of 30 meters above sea level. Small existing elevations. The climate of Esmeraldas varies from tropical subhumid, subtropical humid and subtropical very humid, with an average temperature of 23 ° C.

The Province of Esmeraldas is made up of 7 cantons, with their respective urban and rural parishes. According

to the latest territorial ordinance, the province of Esmeraldas will belong to a region also included by the provinces of Carchi, Imbabura and Sucumbíos, although it is not officially formed, called North. Esmeraldas occupies a territory of about 14,893 km², being the seventh province of the country by extension. It limits to the east with Carchi and Imbabura, to the south with Santo Domingo de los Tsáchilas and Manabí, to the southeast with Pichincha, to the north with the Province of Tumaco-Barbacoas, of the department of Nariño belonging to Colombia, and to the west and north with the ocean Pacific along a maritime strip of about 230 kilometers. According to the demographic projection of the INEC for 2020, being the eighth most populated province in the country with 643,654 people live in the Emerald territory.

The province of Esmeraldas is known for its beautiful beaches, its exuberant landscapes and its hot and humid climate, for being traditionally the Afro-Ecuadorian territory par excellence. Its main attraction is its coasts - especially the beaches of the southern sector- as well as its ecological reserves -such as the Cayapas Mataje ecological reserve, to the north. All this makes the province one of the most visited tourist destinations in the country, with most of the provincial territory enjoying a favorable temperature throughout the year (21 and 25 ° C); [48], [49], [50], [51].

Esmeraldas has the mangrove forests that are among the highest in the world, the Majagual Mangroves, located in the Cayapas-Mataje Ecological Reserve, these are located in the north of the province (San Lorenzo) near the border with Colombia. Likewise, the Emerald jungles are the cradle of 3 of the 4 indigenous nationalities of the Litoral Region of Ecuador: the cayapas, the épera and the awá. The area of the province was the cradle of cultures such as the Atacames, Tolas, Cayapas, [52], [53], [54].

2.2 Study design

The study was conducted in three stages: data collection, analysis, and synthesis and discussion of results. First, the main design variables regarding solar influences on buildings were identified: window height, the projection of shadows with solar heat gain, and electricity consumption for cooling purposes.

The hypothesized: (1) more solar energy filtered into the buildings and more electricity was used for air conditioning by larger windows and (2) shadow projection negatively related to solar gain and electricity consumption for air conditioning.

The weather data files investigated are the experimental data from the reference station of Esmeraldas airport and other data were obtained from the global databases of the

Modern-Era Retrospective Analysis for Research and Applications model, version 2 (MERRA-2), using the U. S. National Aeronautics and Space Administration documentation as a reference. MERRA-2 is a large database relevant to reconstructing variations of microclimates on any place on earth [20], particularly in coastal areas and small islands. MERRA-2 data were publicly available from the Data and Information Services Center of Goddard Earth Sciences [44], [45].

2.2 Analytical Methods

The following five variables were considered the most important to solar heat gain:

1. Relative solar heat gain (GCSRI), defined as the heat gained through opaque and transparent parts of a building's south facade.
2. Orientation of a building as facing south, measured by the solar radiation density of the south orientation because it occurs almost all year and all day.
3. Concrete block wall area on the south wall.
4. Aluminum profile, fixed transparency of four-mm thick glass window area of the south wall.
5. Width of the eaves that projected over the windows for solar protection (awnings).

The life cycle analysis (LCA) method was used to assess the influences of the architectural design variables on electricity consumption for comparison in case studies. LCA reveals the energy and resources consumed and the environmental impacts of a device during its useful life. By comparing these data, designers can theoretically identify aspects of a device that cause environmental damages. LCA is believed to be particularly useful for comparing devices that perform the same function but have different initial and operating costs to select the one that maximizes net savings.

The development of the Eco-indicator 99 methodology started with the design of the weighting procedure [46]. This study used Eco-Indicator 99 and the Eco invent Version 7 database to perform the LCA on variables that mainly affected the admissible solar windows heat gain on the south walls of buildings [47].

However, we did not analyze relative solar heat gain, which involves variables that are relatively complex, such as the measured amount of heat transmitted through the glass under standardized conditions accounting for interior humidity and the direct and diffuse solar radiations [46].

III. RESULTS

Comparing the recorded temperatures to the historical temperatures (Table 1 above) indicates a 4° C increase in the low temperatures, suggesting evidence of climate change. The LCA evaluated energy performance during the buildings' operational phase with allowable solar heat gain per functional unit at the same time during the hottest days of that same month. Using Ecuadorean Construction Standards, we analyzed the design variables used for the buildings [55].

The permissible indoor heat gains due to thermal load (during the hot season) were considered constant for both case studies. The incoming heat caused by sunlight on the windows increased the ambient temperatures, which was undesirable in the hot areas because the indoor temperatures increased to the point of discomfort. Other building characteristics, such as structural components, which mainly were bricks and reinforced concrete, were not analyzed because of the high consumption of natural resources and energy and, further, their influences were inconvenient for visualizing the data of the variables under observation.

The comparison of the end environmental impacts in both case studies found high levels of fossil fuel energy consumption for air conditioning and its contribution to the adverse environmental impacts of climate change.

Table 2 compares the two cases. The differences between them were that the area of aluminum profile fixed glass three-mm thick windows was much smaller for Case 2, and, although the concrete block wall areas were similar, there was a one-m wide projecting eave (Case 2).

The environmental benefits included less solar heat in the interiors of the air-conditioned rooms, which thereby lowered the air conditioning and electricity consumption requirements during the life of the buildings. It was found that smaller windows on the south walls and those that were protected with one-m wide eaves annually used 50% less electricity for air conditioning, which is considered a significant energy saving.

In general, windows should have glass areas equal to or less than 25% of the total wall area for air-conditioned buildings designed to protect the interiors from direct solar radiation, and, when selecting materials and components, to account for the amount of energy used during the buildings' life cycles. The results found that, in most categories, the biggest influence related to electricity because of the extended period of use and the aggressiveness of the generation processes.

The objective of the simulation was to ascertain the amount of electricity consumed by air conditioning. Two models were created in which the selected variables were combined. Both case studies of the rooms of the buildings were conducted during the operational stage, which is the most significant energy use period. The LCA's functional unit was one m² of south-facing wall with an estimated area of 42 m².

The correct design of windows in buildings, with comfortable indoor environments at the same time zeroing energy demand for heating, ventilation, and air-conditioning. The environmental impacts, energy consumption, and potential for contributing to global warming due to inefficient building designs in the within case studies were much higher than for other building designs, particularly for buildings with windows directly aligned with exposure to the maximum possible solar radiation.

The data revealed a correlation between the design of the window area with aluminum profiles and the fixed transparent four-mm thick glass covering one-half of the walls without solar protection eaves on the windows during the period of maximum sun exposure between noon and 3:00 PM (Case 1). In Case 2, significantly less fossil fuel energy consumption by air conditioning was observed because of its different window design with one-m wide eaves for solar protection on the southern windows (Figure 1).

IV. FIGURES AND TABLES

Table.1: Temperatures (Celsius) in Esmeraldas Ecuador compared to historical averages

	Temperature	Timeframe
	Case study 1	Case study2
Actual	24°/10°	24°/14°
Historical	20°/8°	20°/8°

Table 2. Comparison of the results of the LCA.

Variables	Case 1	Case 2
Orientation	South	South
Area	18 m ²	10 m ²
Width eaves	0.30 m	0.90 m
Concrete area	42 m ²	40 m ²
Solar heat	0.25	0.38

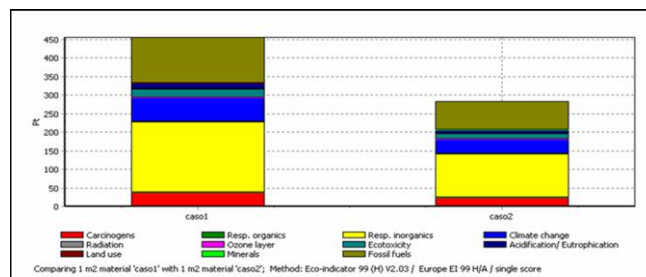


Fig.1: Comparison of environmental impacts of selected buildings.

V. CONCLUSION

This analysis concludes that the most important characteristics in the design are the size of the windows and the external protections of solar energy (awnings). The results obtained contribute to the study of buildings in hot coastal areas that require air conditioning, which could be reduced if bioclimatic designs were used on exterior walls that are more exposed to solar radiation, which have an adverse internal heat gain. Unprotected buildings on the beaches can reduce their energy consumption in air conditioning.

The research hypotheses were verified with the results of the analysis that determined that more solar energy was filtered inside the buildings and more electricity was used for air conditioning through larger windows.

The method for modeling the bioclimatic conditions that air-conditioned buildings' exterior designs should meet and revealed the strong influence of certain designs on the amount of energy consumed during the operational stage of air-conditioned buildings and the usefulness of employing LCA during the design phase

Buildings tend to consume large amounts of natural resources and generate environmental pollutants. Energy consumption is a major cause of these impacts, which aggravate the effects of climate change in coastal cities with dry hot climates, such as Esmeraldas, Ecuador. Building designers need updated tools to help them address energy management and sustainability criteria in their air-conditioned building designs and the results of this study contribute to their ability to develop designs and regulations for buildings in equatorial coastal cities that will minimize the negative impacts of energy consumption on the environment.

REFERENCES

- [1] Galindo L., Samaniego J, Alatorre J., Ferrer J. (2014). Procesos de adaptación al cambio climático, Análisis de América Latina. CEPAL, 5-7.

- https://www.cepal.org/sites/default/files/events/files/2._adaptacion_imgalindo.pdf
- [2] Economic Commission for Latin American and the Caribbean (2018). Economics of climate change in Latin America and the Caribbean. A graphic view. United Nations, Santiago S.18-00475.
https://repositorio.cepal.org/bitstream/handle/11362/43889/1/S1800475_en.pdf
- [3] International Panel on Climate Change, Climate Change (2007). The physical science basis: Working group I contribution to the fourth assessment report of the IPCC, Cambridge University Press, New York.
<https://www.ipcc.ch/report/ar4/wg1/>
- [4] N. Stern (2007). The Economics of Climate Change: The Stern Review, Cambridge University Press, New York.
http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete
- [5] L. Andersen, D. Verner (2010). Simulating the effects of climate change on poverty and inequality, in: D. Verner (Ed.), Reducing Poverty, Protecting Livelihoods, and Building Assets in a Changing Climate: Social Implications of Climate Change in Latin America and the Caribbean, World Bank Publications, Washington.
<https://elibrary.worldbank.org/doi/pdf/10.1596/978-0-8213-8238-7>
- [6] World Resources Institute, (2019) Climate Analysis Indicators Tool (CAIT), 2019. <https://www.wri.org/our-work/project/cait-climate-data-explorer>
- [7] Ministerio de Medio Ambiente del Ecuador (2011). Segunda Comunicación Nacional sobre Cambio Climático, U, N. Quito.
- [8] A. Abdel, (2010). Aboulgheit, Assessing housing interior sustainability in a new Egyptian city. The Procedia – Soc. Behav. Sci. 564–577.
- [9] G. Assefa, M. Glaumann, T. Malmqvist, O. Eriksson, (2010). Quality versus impact: comparing the environmental efficiency of building properties using the Eco Effect tool. Build Environ 45 1095–1103.
- [10] L. De Garrido (2015). Proceso de diseño bioclimático. Control ambiental arquitectónico.
<http://luisdegarrido.com/publications/designmethodology-luis-de-garrido/>
- [11] F. Celis, (2000). Arquitectura bioclimática, conceptos básicos y panorama actual. Ciudades para un futuro más sostenible. <http://habitat.aq.upm.es/boletin/n14/afcel.html>
- [12] W.W. Nazaroff, (2013). Exploring the consequences of climate change for indoor air quality. Environ. Res. Lett., 8 p. 015022.
- [13] Institute of Medicine (IOM) (2011). Climate Change, the Indoor Environment, and Health. The National Academies Press, Washington, DC
- [14] J.D. Spengler (2012), Climate change, indoor environments, and health. Indoor Air, 22 pp. 89-95
- [15] W.J. Fisk, (2015). Review of some effects of climate change on indoor environmental quality and health and associated no-regrets mitigation measures. Build. Environ., 86 pp. 70-80. <https://doi.org/10.1016/j.buildenv.2014.12.024>
- [16] X. Zhang, L. Shen, Y. Wu, (2011). Green strategy for gaining competitive advantage in housing development: a China study. J Clean Prod. 2 157–167.
- [17] US Environmental Protection Agency, (2016). EPA Definition of Green Building.
<https://archive.epa.gov/greenbuilding/web/html/about.html>
- [18] Building Research Establishment, (2016). Environmental Assessment Methodology (BREEAM).
<http://www.breeam.com>
- [19] LEED (2016). Leadership in Energy and Environmental Design. <http://www.usgbc.org/leed>
- [20] W. Wei, O. Ramalho, C. Mandin. Indoor air quality requirements in green building certifications. Build. Environ., 92 (2015), pp. 10-19.
<https://doi.org/10.1016/j.buildenv.2015.03.035>
- [21] A. Steinemann, P. Wargocki, B. Rismanchi (2017). Ten questions concerning green buildings and indoor air quality. Building and Environment, 112, 351-358.
<https://doi.org/10.1016/j.buildenv.2016.11.010>
- [22] B. Blocken, J. Carmeliet (2004). Pedestrian Wind Environment around Buildings: Literature Review and Practical Examples. Thermal Envelope and Building Science, 28, 2, 107-159-
- [23]. K. Mehaoued, B. Lartigue (2019). Influence of a reflective glass façade on surrounding microclimate and building cooling load: Case of an office building in Algiers. Sustainable Cities and Society, 46, 101443.
<https://doi.org/10.1016/j.scs.2019.101443>
- [24]. S. i, S. Yang, J Hun, S. Chang, S. Kim (2019). Climatic cycling assessment of red clay/perlite and vermiculite composite PCM for improving thermal inertia in buildings. Building and Environment, 167, 106464.
<https://doi.org/10.1016/j.buildenv.2019.106464>
- [25]. B. Li, P. Wild, A. Rowe (2019). Free cooling potential of air economizer in residential houses in Canada. Building and Environment, 167, 106460.
<https://doi.org/10.1016/j.buildenv.2019.106460>
- [26]. United Nations Environment Programme (2018) Global Status Report. United Nations Environment Programme and Global Alliance for Buildings and Construction.
- [27]. ANSI/ASHRAE (2016). Standard 62.1-2016 Ventilation for Acceptable Indoor Air Quality, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.
- [28]. ANSI/ASHRAE (2017). Standard 55 - Thermal Environmental Conditions for Human Occupancy, 2017, Refrigerating and Air-Conditioning Engineers, Atlanta
- [29]. R. Chan, X. Li, B. Singer, T. Pistochini, D. erson, S. Outcalt, A. Sanguinetti, M. Modera (2019)- Ventilation rates in California classrooms: Why many recent HVAC retrofits are not delivering sufficient ventilation. Building and Environment, 167, 106426.
<https://doi.org/10.1016/j.buildenv.2019.106426>
- [30]. G. Cao, H. Awbi, R. Yao, Y. Fan, K. Sirén, R. Kosonen, J. Zhang, (2014). A review of the performance of different ventilation and airflow distribution systems in buildings.

- Build. Environ., 73 pp. 171-186 .
<https://doi.org/10.1016/j.buildenv.2013.12.009>
- [31]. A.Melikov, (2016), Advanced air distribution: improving health and comfort while reducing energy use. *Indoor Air*, 26 pp. 112-124. <https://doi.org/10.1111/ina.12206>
- [32]. L. Perez, J. Ortiz, C. Pout. (2008), A review on buildings energy consumption information
Energy Build, 40, pp. 394-398.
<https://doi.org/10.1016/j.enbuild.2007.03.007>
- [33]. S. Aghniaey, T. Lawrence (2018). The impact of increased cooling setpoint temperature during demand response events on occupant thermal comfort in commercial buildings: A review. *Energy and Buildings*, 173, <https://doi.org/10.1016/j.enbuild.2018.04.068>
- [34]. Miño et al., (2014). Implementation of simple GIS methodology and bioclimatic strategies to improve the quality of social housing in the Andean region of Ecuador. Paper Conference: World Sustainable Building. Barcelona, Volumen: 3
- [35]. S. Ron (2016). Amphibia Web Ecuador. Versión 2016.0. Museo de Zoología, Pontificia Universidad Católica del Ecuador. <http://zoologia.puce.edu.ec/Vertebrados/anfibios>
- [36]. A. Alvear, J. Hernán, E. Tapia, G. Ordoñez, (2016). Declaraciones consensuadas del Seminario-Taller: “Arquitectura Sostenible” Un enfoque sobre estrategias de diseño bioclimático: Caso Ecuador. *Estoa*. Universidad De Cuenca 5 133-149. <https://publicaciones.ucuenca.edu.ec/ojs/index.php/estoa/article/view/1032>
- [37]. Pohl J., Suski P., Haucke F., Piontek F.M., Jäger M. (2019). Beyond Production, the Relevance of User Decision and Behavior in LCA. In: Teuteberg F., Hempel M., Schebek L. (eds) *Progress in Life Cycle Assessment 2018. Sustainable Production, Life Cycle Engineering and Management*. Springer, Cham
- [38]. Polizzi di Sorrentino E, Woelbert E, Sala S (2016) Consumers and their behavior: state of the art in behavioral science supporting use phase modeling in LCA and ecodesign. *The International Journal of Life Cycle Assessment* 21:237-291. <https://doi.org/10.1007/s11367-015-1016-2>
- [38]. V. Campos, M. Socorro, N. Espinosa, A. Urbina (2019). Life Cycle Analysis with Multi-Criteria Decision Making: A review of approaches for the sustainability evaluation of renewable energy technologies. *Renewable and Sustainable Energy Reviews*. 104, 343-366. <https://doi.org/10.1016/j.rser.2019.01.031>
- [40]. Pigné, Y., Gutiérrez, T.N., Gibon, T. et al. (2019). A tool to operationalize dynamic LCA, including time differentiation on the complete background database. *Int J Life Cycle Assess*. <https://doi.org/10.1007/s11367-019-01696-6>
- [41]. Lois J. Hurst, Tadhg S. O'Donovan (2019). A review of the limitations of life cycle energy analysis for the design of fabric first low-energy domestic retrofits. *Energy and Buildings*, 203, 109447. <https://doi.org/10.1016/j.enbuild.2019.109447>
- [42]. Ming Hu (2017). Balance between energy conservation and environmental impact: Life-cycle energy analysis and life-cycle environmental impact analysis. *Energy and Buildings*. 140, 131-139. <https://doi.org/10.1016/j.enbuild.2017.01.076>
- [43]. X. Oregi, P. Hernandez, R. Hernandez (2017). Analysis of life-cycle boundaries for environmental and economic assessment of building energy refurbishment projects. *Energy and Buildings*, 136, 12-25. <https://doi.org/10.1016/j.enbuild.2016.11.057>
- [44]. C. Draper, S. Reichle, R. Koster, (2018). Assessment of MERRA-2 land surface energy flux estimates. *J Climate (MERRA-2 Special Collection)* 31 671-691. <https://doi.org/10.1175/JCLI-D-17-0121.1>
- [45]. National Aeronautic and Space Agency (2019). Goddard Earth Sciences Data and Information Services Center (GES DISC), 2019. <https://earthdata.nasa.gov/eosdis/daacs/gesdisc>
- [46]. PRÉ, (2019). SimaPro Database Manual Methods Library. <https://simapro.com/wp-content/uploads/2019/02/DatabaseManualMethods.pdf>
- [47]. Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Doka, G.; Dones, R.; Hirschler, R.; Hellweg, S.; Humbert, S.; Margni, M.; Nemecek, T.; Spielmann, M. (2007). Implementation of Life Cycle Impact Assessment Methods: Data v2.0.ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland. [48] Instituto Nacional de Estadísticas del Ecuador (2020). VII Censo de Población y Vivienda del Ecuador. <https://www.ecuadorencifras.gob.ec/base-de-datos-censo-de-poblacion-y-vivienda/>
- [49]. Prefectura de Esmeraldas, (2020). Plan Operativo Anual 2020. Esmeraldas. <http://prefecturadeesmeraldas.gob.ec/wp-content/uploads/2020/05/POA-2020-Editado-1.pdf>
- [50]. Maunier, Daniel P. (1970). Historia de la Trata de Negros. México. A.L.D.
- [51]. Mauler, Lawrence E. (1972). Genética de las Poblaciones y Evolución. México. Centro Regional de Ayuda Técnica.
- [52]. Markert, Clement L, (1973). Genética del Desarrollo. México. Edit. A.L.D.
- [53]. Moncada, José. (1976). Ecuador. Pasado y Presente. Quito. Edit. Universitaria.
- [54]. Weather Spark (2019). El clima promedio en Esmeraldas Ecuador. <https://es.weatherspark.com/y/18290/Clima-promedio-en-Esmeraldas-Ecuador-durante-todo-el-a%C3%B1o>
- [55]. Norma Ecuatoriana de la Construcción, (2014). Vidrios, Código NEC-HS-VIDRIO, Ministerio de Desarrollo Urbano y Vivienda (MIDUVI), Ecuador. http://www.normacontruccion.ec/capitulos_nec_2015/NE_C_HS_VIDRIO.pdf