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To evaluate the sustainability of urban planning projects through an LCA approach: example of application of the NEST tool and requirements for its use in the context of Ecuador and Latin America

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Abstract

Urban planners are facing a growing demand for high performance projects in terms of control and reduction of environmental impacts. However, the complex and multi-dimensional concept of sustainable urban development often loses its core substance when confronted to practice realities of urban projects because of a lack of adapted decision support tools. The question arises as to how the effective consideration of the environment and the limitation of the project impacts can be taken into account as soon as the early design stages? As an answer to this question, we developed NEST (Neighborhood Evaluation for Sustainable Territories), a life cycle assessment (LCA) tool for the built environment at the neighborhood scale. LCA has been increasingly used to assess the environmental impacts of construction products and buildings during the last 25 years. And today, a new trend stems in the application of LCA to larger systems such as urban islets or neighborhoods. NEST addresses early design stages, and uses 3D models of neighborhood projects to quantitatively assess a set of environmental impacts. In this paper we propose a presentation of the tool, and an application through the case study of a new development project for a peri-urban area. Moreover we analyze the opportunity and the requirements for the adaptation of the tool, initially developed in Europe, under the context of Latin America, whether it is for the availability of data and for the coherence with specific challenges and political objectives in the area of South America.

1 Introduction

More than fifty percent of the world population (2011) lives in urban areas [1] and the built environment, referring to the building and transportation sectors, is a major hotspot of resource use and environmental impacts. For instance it accounts for 62% of global final energy consumption (2009) [2] and 55% of greenhouse gas emissions (2004) [3]. In industrialized countries, buildings are responsible for 42% final energy consumption, 35% greenhouse gas emissions and more than 50% of all extracted materials [4].

In this general context, urban planners are facing a clear demand for projects of higher environmental performance from both public and private sectors. This environmental performance and associated environmental impacts are related to numerous interconnected issues such as: resources consumption, waste production, water consumption, greenhouse gases emissions, biodiversity protection, air quality, etc. The neighborhood scale appears to be relevant to address most of these issues [5]. It is a typical operational scale for urban development projects and integrates key levers for urban eco-design. Indeed, this focus on the neighborhood scale is driven by the need to address district scale levers to design buildings and neighborhoods of higher environmental performance and to address key issues such as bioclimatic design, shared equipment (e.g. district heating), urban density or mobility issues. For instance, decisions made at the settlement level (orientation, compactness, urban density) largely affect heating / cooling loads, a major contributor to the energy balance of an urban area. [6] states that it seems more likely that the environmental and energy concerns that nowadays focus mainly on buildings will soon be transferred to neighborhood planning.

As an answer to this growing interest for sustainability investigation and planning at the neighborhood scale, we developed NEST (Neighborhood Evaluation for Sustainable Territories): a tool based on life cycle assessment (LCA) for quantitative assessment of environmental impacts of urban project.

NEST has been designed taking into account the operational practice of urban design and to be used from the sketch stage of a project. Based on the 3D model of a development project, NEST assesses a set of indicators reflecting major environmental issues in sustainable urban design. NEST calculates LCA indicators as well as more classical urban sustainability indicators in order to provide a broad and quantitative assessment of the environmental performance of neighborhood projects. All indicators are expressed per user to facilitate comparison of alternative scenarios (a neighborhood user is either an inhabitant or a non-resident worker).

NEST has already been applied on several urban planning operations in France and has proven its ability to enhance the design process by allowing a continuous analysis of the project environmental performance with a life cycle perspective [7]. In the context of Latin America the use of NEST may also be of great interest, however its application faces two major difficulties:

- Data integrated in the tools are originated from Europe and specific key data has to be adapted. This is a technical issue but it is complicated by the lack of LCA data for South America.
- Regional issues and challenges for cities are different from Europe and these different stakes need to be integrated in the approach if indicators can be produced to evaluate them

2 NEST tool

NEST was developed within Nobatek and the GRECAU laboratory (ENSAPBx) through a PhD thesis [8] focused on environmental assessment of eco-neighborhoods. NEST is a PlugIn for Trimble SketchUp, which is the most used 3D modeler among city planners and architects. NEST analysis is performed directly on the 3D master plan of the neighborhood and performs the assessment of a set of indicators that was developed associating a scientific approach as well as operational urban planning objectives. The list of indicators has been thought to be broad enough to address key issues of sustainable urban planning and enable a comprehensive assessment of the project, but still limited to be kept operational. NEST assesses both environmental indicators and socio-economic indicators:

- Environmental indicators deal with energy, CO2, biodiversity loss, waste, air quality and water
- Socio-economic indicators address user's satisfaction and project investment costs

In terms of methodology, NEST is an LCA tool for the built environment at the neighborhood scale. The neighborhood is considered as a system responsible for environmental impacts associated with its location, construction and operation. This system is analyzed as an aggregation of components and the LCA at the neighborhood scale is an aggregation of the respective LCAs of its various components and subcomponents. This aggregation takes into account the particular lifetimes of the different neighborhood components, with replacement rates for roads and for some building parts (analysis duration in NEST is 50 years, lifetime of buildings is 50 years and lifetime of infrastructures is 30 years). In terms of system boundaries, three major components of the neighborhood are taken into account; (i) the buildings, (ii) the open spaces (roads, parking, green spaces, etc.), and the daily mobility of neighborhood users (inhabitants and non-resident workers). As for life cycle steps, the analysis is performed over the entire lifecycle of the neighborhood with the exception of demolition/deconstruction phase which is neglected. The little significance of deconstruction works in terms of life cycle energy consumption is reported by Ramesh et al. [9]. In a life cycle energy assessment performed on a multifamily residential building, the authors found that demolition works account for only 0.1% of life cycle energy. Thus NEST accounts for (i) the production phase of construction materials for buildings and open spaces (from the extraction of raw materials to construction works), (ii) the maintenance of both buildings and open spaces, (iii) the operation of buildings (heating, domestic hot water production, ventilation, lighting and specific electricity) and open spaces (public lighting), (iv) the end of life of buildings and open spaces materials, and (v) operational requirements of the daily mobility. NEST LCA indicators are those indicators related to the energy, CO2 and biodiversity:

- Primary energy consumption indicator (in MJpe/year/user) is based on CML 2002 method [10]. It accounts for primary energy use for production of construction materials, for construction works, for building and open spaces operation, for end of life of construction materials, and for daily mobility.
- Climate change indicator (kgeqCO2/year/user) is based on IPCC 2007 gwp 100a method [3]. It accounts for GHG emissions associated to production of construction materials, construction works, building and open spaces operation, end of life of construction materials, and daily mobility.
- Biodiversity Loss indicator (PDF/year/user) is a score of potential biodiversity loss related to both land conversion and land use. It is based on the land use indicator of the Eco-Indicator 99 method [11]. The PDF (Potentially Disappeared Fraction) is the rate of species loss in a particular area of land during a particular time due to

unfavorable conditions, such as land conversion, land occupation, toxicity, increase in average global temperature, or eutrophication.

At the master planning stage of a neighborhood project, the buildings have not yet been designed. Nevertheless buildings' data are needed in order to perform the analysis (building materials and building energy consumptions).

As for building materials, the embodied energy and associated greenhouse gases emissions are estimated based on a meta-analysis of detailed life-cycle assessment. Rather than performing a process-based LCA, NEST relies on a database of former analysis that estimates embodied energy of different building types (in terms of energy per floor space). This analysis assumes an average rate of embodied energy per square foot, by building type and associated constructive systems. Energy use in buildings is assessed from target energy performances associated with French standards, and according to location, altitude and type of building.

Other environmental indicators are:

- Air quality indicator (m^3 of polluted air/year/user) is based on the "air pollution" indicator of French NF P01 010 standard [12]. It accounts for emission of polluted air from transportation and heating systems.
- Waste indicator (t/year/user) deals with waste flows from neighborhood construction and operation stages.
- Water consumption indicator (m^3/year/user) assesses water consumption for construction works, during buildings operation and for maintenance of public spaces. Another water-related indicator assesses storm water infiltration on the neighborhood.

The social indicator gives a score of user's satisfaction based on the aggregation of five sub-indicators that are scored on a four-point scale. These sub-indicators are square meters of housing, green spaces and parking lots per user, as well as the quality of the transportation offer and the accessibility to everyday services. The scoring scales are based on Nobatek's experience on urban development projects as well as technical literature. The economic indicator gives an insight on construction costs (buildings, public spaces, streets, etc.) and operation costs (lighting of public spaces, water for maintenance, waste management, energy and water consumption in buildings).

3 Case study

NEST was experimented in several urban projects in France, allowing for its validation regarding its ability to start and feed the discussions on sustainability between project stakeholders (urban planner, developer, mayor, technicians, etc.). For instance, it enables a quick and broad comparison of scenarios for urban planners to improve their proposal. This type of analysis has been conducted together with a design team on a new development project for a peri-urban area located in the southern France area "Pyrénées Atlantiques". The aim of the study was to investigate to which extent environmental impacts of an environmental-friendly scenario (sc.0) differ from those of a business as usual scenario (sc.1) (Fig. 1).

Figure 1: (left) scenario 0, (right) scenario 1

The project aims at creating a new neighborhood (1.73 ha) close to the center of a small community located 10 km away from the main agglomeration. The population carrying capacity of the site was set to 350 users; this information is critical for the impacts calculation and emphasizes the importance of density in an urban project. There is also a target of functional mixity with a majority of housing but also some offices, shops and a school.

Two scenarios were established with the design team: one with a stronger investment on sustainability and higher density (sc.0) and another more representative of “business as usual” planning approaches in this area (sc.1) with more individual houses. Both scenarios respond to the same initial program (regarding equipment, parks, roads, parking and housing) but in different ways, leading to different impacts, quality of life, usage and technical answers.

Sc.0 is more interesting from an environmental point of view. The master plan is based on integrated urban gardens, pedestrian areas, smaller roads for cars, fewer parking spaces per dwelling, vegetated parks, deeper functional mixity (more offices and shops). All buildings are energy efficient (45 $kWh/m^2/year$), most of them include solar energy production (PV and thermal). Regarding soil sealing and storm water management, there are large areas of green spaces and green roofs. All buildings have dedicated spaces for waste “at source recycling”, local bicycles shelters, and are equipped with water consumption reduction systems. Grey water reuse is considered in some buildings. Sc.0 has a capacity of 386 users (75% inhabitants and 25% non-resident workers).

Sc.1 has a lower density with more individual houses. There are more mineralized surfaces and more parking lots per user. Buildings energy performance is lower (corresponding to the French RT2012 standard criteria). There is no renewable energy production and no green roofs. Sc.1 has a lower capacity of 291 users (67% inhabitants and 33% non-resident workers).

Both scenarios have the same population distribution that is representative of a long term trend in the area of the project with 45% active people, 25% children and students and 30% retired people.

Due to the fact that the nearest town is located 10 km away and that public transportation services are insufficient, both mobility scenarios are largely based on individual vehicles. However, sc.0 gives more importance to cycling and walking with dedicated facilities. Mobility scenarios are specified for different types of users; at the level of the whole community of users, scenarios are detailed below (Table 1).

Scenario	Car	Bus	Cycling	Walking
0	71%	5%	6%	19%
1	79%	5%	2%	14%

Table 1: mobility scenarios

Both projects were modeled in NEST, which means 3D modeling (Fig. 1) and input of scenario characteristics, in order to evaluate their impacts. Main results for each indicator are presented in the following section.

4 Results

4.1 Primary energy consumption (Fig. 2)

The total level of primary energy consumption of sc.1 (33 000 MJpe/year/user) is 36% higher than for sc.0 (24 300 MJpe/year/user). In sc.0 buildings operation, building materials and individual transportation respectively account for, 37%, 26% and 33% of primary energy consumption. Even if buildings operation remains the main contributor, the strategy towards density, high performance buildings and renewable energy production leads to 85% less impact (9 100 MJpe/year/user) than sc.1 (16 900 MJpe/year/user). It is also interesting to note the really high contribution of individual transportation due to the fact that the project is located 10 km away from the main employment and services area. We also observe the impact of a neighborhood facilitating walking and cycling with 10% less impact from individual transportation in sc.0.

Scenario 0 - Primary Energy / year / user (MJ)		
Category	Primary Energy	%
Building Materials	6 302	26%
Building Operation	9 064	37%
Infrastructure Materials	553	2%
Individual transport	8 092	33%
Collective Transport	282	1%
TOTAL	**24 293**	100%

Scenario 1 - Primary Energy / year / user (MJ)		
Category	Primary Energy	%
Building Materials	6 068	18%
Building Operation	16 921	51%
Infrastructure Materials	863	3%
Individual transport	8 891	27%
Collective Transport	282	1%
TOTAL	**33 025**	100%

Figure 2: (left) primary energy consumption (sc.0); (right) primary energy consumption (sc. 1)

4.2. Climate change (Fig. 3)

With 1430 kgeqCO2/year/user, sc.1 shows a 31% increase compared to sc.0. For both scenarios, individual transport is the most impacting contributor to this indicator with around 43% of the emissions in sc.0 and 36% of emissions in sc.1. This point is well representative of the importance of transport on the environmental performance of a project. If the site is in a rural or peri-urban area, the impact of transport might counterbalance the sustainability efforts realized at the scale of buildings, roads and other project elements. In sc.0, due to highly energy efficient buildings, the second contributor is building materials (30%) whereas in sc.1 it is buildings operation (34%). This distribution and difference between energy and Climate Change indicators is mainly explained by the 10 km distance between the site and the main economic area, and by the fact that electricity use is a low generator of CO2 in France (for energy consumption in buildings).

Scenario 0 - CO2 / year / user (KgEq)		
Category	Primary Energy	%
Building Materials	327	30%
Building Operation	221	20%
Infrastructure Materials	55	5%
Individual transport	470	43%
Collective Transport	17	2%
TOTAL	1 090	100%

Scenario 1 - CO2 / year / user (KgEq)		
Category	Primary Energy	%
Building Materials	317	22%
Building Operation	491	34%
Infrastructure Materials	86	6%
Individual transport	517	36%
Collective Transport	17	1%
TOTAL	1 428	100%

Figure 3: (left) climate change indicator (sc.0); (right) climate change indicator (sc. 1)

4.3. Other indicators

In order to assess the impact of land conversion on biodiversity, the initial land occupation is characterized as follow: 50% artificial, 30% agricultural, 10% urban and 10% vacant green land. The score of biodiversity loss related to land use is 33% higher for sc.1 (88 PDF/y/user vs. 67 PDF/y/user for sc.0) because of higher areas of mineralized public spaces and less areas of gardens. For both scenarios, the score of biodiversity loss related to land conversion is negative (-6 PDF/year/user for sc.0, -9 PDF/year/user for sc.1) which means that through land conversion, the development brings biodiversity potential.

Both scenarios have a similar total waste production of about 4.5 t/year/user (87% comes from construction works). In sc.0 all buildings have a dedicated area for recycling and organic waste composters. Furthermore a specific “low waste agreement” for construction works is mandatory for all buildings to be contracted. These measures lead to 42% less non sortable waste for sc.0 than for sc.1.

Air pollution is essentially tied to individual transport (about 95% for both scenarios).

In sc.0 strategies like water saving systems or recovery and treatment of drinking water and rainwater, leads to a quite low level of drinking water consumption (35 m3/y/user) and a significant use of non-potable water (34% of total water consumption). Sc.1. is less engaged in terms of limitation of water consumption with 87 m3/y/user of drinking water only. Regarding storm water management, there is still more to do to manage rain water infiltration through the choice of pavement materials (65% runoff for sc.0 and 73% runoff in sc.1).

Both scenarios show good results in terms of m² of housing and green spaces per user. Sc.1 is better in terms of parking availability but sc.0 is better in terms of transportation offer (with dedicated facilities for cycling and walking). In terms of accessibility to services both scenarios are similarly handicapped by the distance to the agglomeration and the fact that all services cannot be secured within the neighborhood.

5 Discussion

Our analysis allowed visualizing two alternatives based on two different urban principles and demonstrated the interest of such quantitative assessment. Sustainability is a complex matter for urban planning and quantitative assessment of environmental impacts in line with urban planning practice makes it more tangible and realistic to address.

In comparison with sc.1, the neighborhood user (inhabitant or non-resident worker) in sc.0 is clearly less energy consumer (-36%), emits less greenhouse gases (-31%), generates less non sortable waste (-42%), and consumes less drinking water (-65%). It is also important to note that the neighborhood includes more comfortable buildings and hosts more people; 24% more users and 32% more inhabitants than in sc.1 (the “baseline scenario”). Furthermore in sc.1, the low density model impeded reaching the 350 users target and the number of users is 291 only.

Cost analysis is also a critical part of the assessment and may generate contrast with the environmental assessment. For now, NEST only accounts for an estimate of construction costs and some operation costs and requires further research to shift to an overall view of the project lifecycle economics.

At a more general level, this case study highlighted the relevance of an evaluation process for the early stage of urban project design. The tool enables the quantification of a number of environmental impacts indicators, some of which are LCA indicators. This quantification relies on a simplified LCA methodology (i.e. meta-analysis of LCAs of neighborhood components) which is appropriate for early stage assessment in a project. Indeed this methodology is aligned with the data availability at the master planning stage of an urban development project.

NEST analysis revealed comparable contributions of building materials, building operation and transportation to both life cycle primary energy consumption and life cycle greenhouse gases emissions. These individual contributions in both scenarios and for both indicators range from 20% to 50%. The compared analysis of the two scenarios permitted to highlight major differences between scenarios such as the fact that in the sustainable scenario the predominance of the operation phase is lessened, or the fact that the buildings embodied energy in the sustainable scenario is higher than in the business as usual scenario.

NEST tool allows for a new approach of knowledge-based design for urban planning. This evaluation proved to be really complementary to the planner’s design skills and was a powerful mean to emphasize the dialogue about sustainability and particularly environmental performance between the design team, engineers and the local city.

6 Requirements for an application to Ecuador and Latin America

The use of NEST in a new regional environment means that some adaptation has to be realized to consider two important issues:

- LCA data is geographically specific; it means for example that data corresponding to a production in France will not be pertinent for an analysis realized in another country because processes are different. This is the case for example of the energy production processes. Other data are on the contrary not strongly dependent of the region; this is the case for example of global products and processes like the use of cars.
- Indicators have to correspond to both global and local environmental stakes, and need to reflect also local societal challenges that may differ from one world region to another. For example urban security and poverty mitigation are key stakes in Latin America whereas they are not priority considerations in urban projects in France.

6.1 Background data adaptation

Key data has to be reconsidered in order to insure a proper assessment. This is especially the case for energy data that is very sensitive to national energy production infrastructures and that is integrated in many other data sets. This modification will impact directly on the energy (considering energy efficiency of the energy production system) and greenhouse gas emissions indicators. Data about energy consumption and production is not available for specific countries like Ecuador but it is on a regional Latin American scale. This data can be used as a first estimation. However, considering the specificity of a country like Ecuador that develop a particularly high capacity of hydroelectricity production, it will be much more pertinent for a proper analysis of urban projects to develop a specific data set corresponding to

the energy mix of each country. Such development is possible as the background data is available and pertinent at global scale in this case.
Another key data to be adapted is the set corresponding to building construction. In this case NEST calculation is based on a database developed by Nobatek from a statistical approach of numerous LCA of buildings realized in France. This data has to be replaced either by a generic data about building construction available at global scale within the Eco Invent database, or, better, by a specific data to be created through the realization of LCA of representative buildings in Ecuador. This last option is possible as the core data for this exercise (traditional building materials and processes) are available either for Latin America or at global scale.
The other indicators are much less sensitive to geography and could be applied directly.

6.2 Local indicators corresponding to local challenges

Beyond the urban planning theories and sustainability principles that founded the initial choice and development of indicators [8], the adaptation of NEST to Latin America implies to consider local perspective in terms of challenges and threats for the cities in this area. A first approach of this indicators' construction work is based on the following multi scale societal and political inputs:

- Global scale: the UNO adopted in 2016 a set of world objectives, called sustainable development goals for 2030 [13], that are considered as prime importance in Latin America. Goal number 11 is dedicated to cities, looking for "making cities inclusive, safe, resilient and sustainable". It includes the following considerations
    - access to housing, services and transport
    - participatory, integrated and sustainable human settlement planning
    - heritage protection
    - protection from disasters
    - impact of cities (i.e. air quality and waste management)
    - access to green and public spaces
    - links between urban, peri-urban and rural areas
    - integrated policies towards inclusion, resource efficiency, mitigation and adaptation to climate change, and resilience to disasters
    - building sustainable and resilient buildings utilizing local materials
- Latin America scale: a private initiative from the company Siemens with a great number of large Latin American cities [14] has lead in 2010 to the definition of an index for green cities in Latin America. It takes into account the following issues:
    - Energy and CO2 emissions
    - Buildings and land use
    - Transport efficiency
    - Waste
    - Water
    - Sanitation
    - Air quality
    - Sustainability governance
- Country scale, the example of Ecuador: the Ecuadorian government settled through its "Plan nacional del buen vivir" [15] for the period 2013-2017 a large set of objectives, stakes and policy orientations. For the sustainability in cities, it includes:
    - Access to a safe and inclusive habitat (3.8 and 3.9); it integrates with more details:
        - Heritage conservation and refurbishment
        - Participatory process for decision making in urban planning

    - Urban model integrating sustainability and quality of life
    - Housing for people suffering handicap
    - Safe and sure housing
    - Use of natural resources for construction and alternative energy production
    - Housing quality
    - Housing deterioration prevention
  - Access to water and sanitation services (3.10)
  - Meeting and public spaces (5)
    - Spaces for physical activity promoting health
    - Public spaces free of pollution
    - Priority to walking and cycling in urban planning
    - Support to urban regeneration
  - Deficiency and renewable energy (7.7)
  - Mitigation and adaptation to climate change (7.10)
- City scale, the example of Quito: the Quito metropolitan district defined in 2014 a set of indicators [16] to follow the efficiency of its policy in terms of sustainable city. These indicators include the following considerations for the urban environment:
    - Energy and CO2
    - Land use
    - Transport
    - Waste management
    - Water
    - Sanitation
    - Air quality
    - Urban agriculture
    - Ecological footprint

From this global analysis we see logically that several issues cannot be integrated in the evaluation provided by an LCA approach as it is not directly correlated to the neighborhood project scenario (which is what is evaluated by NEST) but to the process of urban planning: for example governance participatory issues. Beyond these process aspects, we can detect several potential improvements in the NEST indicator set that could help the tool to be more pertinent within the context of Latin America and more especially Ecuador. For example the promotion of alternative transport like walking and bicycling is considered as a mean (for air quality improvement, energy consumption reduction and CO2 emissions reduction) and not as an objective itself, like it could be for public space occupation quality or for health reasons. Another example is urban agriculture that is considered in the land use calculation but not as an objective itself, it could be easily integrated.

A large improvement potential and adaptation need is in the social aspect, with issues correlated to accessibility and inclusion. Such issues correlated to social science would require integrating works from social LCA approach, which is an interesting perspective for future developments. Lastly, resilience, risk management and safety are today not directly considered in LCA tools and here also the social LCA science may be a new field of sourcing for solutions for NEST to integrate such issues in its evaluation.

7 Conclusion

NEST development was based on two observations: (i) urban planners lack resources to take into account the environmental impacts of their projects early enough and, (ii) urban sustainability cannot be addressed through a monocriteria optimization approach (e.g.

building energy efficiency) and requires a multicriteria approach enabled by a quantitative-based decision support tool.

The scientific and practical interest of such life cycle assessment is twofold. On the one hand it enables the comparison of a neighborhood's main contributors to life cycle environmental impacts. On the other hand, and through scenario comparison, it enables to put in perspective the relative effects of some environmentally friendly design choices compared with the overall impacts in a specific impact category.

NEST current version has already been used on several projects and has proven its effectiveness. However, to help urban planners make the best compromises between various sustainability dimensions, some new developments are in progress. Among others we are working on taking into account urban microclimate (solar radiation, natural light, wind, etc.) as design inputs.

Another development approach is, as discussed in this document, the adaptation of NEST to other geographical areas. First work has been realized to adapt it to other European countries; it is now proposed to develop NEST applicability to the case of Latin America and more especially Ecuador. The assessment presented in this document is a first step to define a new set of indicators that could be compatible with NEST approach (quantitative analysis and short panel of indicators for an efficient communication) and integrator of the most recent environmental and societal stakes in Latin America.

References

[1] United Nations Department of Economic and Social Affairs, *“Population, Development and the Environment 2013,”* 2013. ISBN: 9789211515091.

[2] IEA, *World Energy Outlook 2011*. IEA Publications, 9 rue de la Fédération, 75739 Paris Cedex 15, 2011

[3] B. Metz, O. Davidson, P. Bosch, R. Dave, and L. Meyer, *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press, 2007. ISBN: 978-0-521-88011-4.

[4] European Commission, *“Roadmap to a Ressource Efficient Europe,”* Brussels, 2011.

[5] C. Charlot-Valdieu and P. Outrequin, *Concevoir et évaluer un projet d’éco-quartier: avec le référentiel INDI.*, Editions du Moniteur, Paris, 2012. ISBN: 2-281-19499-X.

[6] J. Oliver-Solà, A. Josa, A. P. Arena, X. Gabarrell, and J. Rieradevall, *“The GWP-Chart: An environmental tool for guiding urban planning processes. Application to concrete sidewalks,”* Cities, vol. 28, no. 3, pp. 245–250, Jun. 2011

[7] M. Lotteau, G. Yepez, N. Salmon 2015, “*Environmental assessment of sustainable neighborhood projects through NEST, a decision support tool for early stage urban planning”* Procedia Engineering, Volume 115, Pages 69-76, 2015,

[8] G. Yepez-salmon, *“Construction d’un outil d'évaluation environnementale des écoquartiers : vers une méthode systémique de mise en œuvre de la ville durable,”* Université Bordeaux 1, 2011.

[9] T. Ramesh, R. Prakash, and K. K. Shukla, *“Life Cycle Energy Analysis of a Multifamily Residential House: A Case Study in Indian Context,”* Open J. Energy Effic., vol. 2, no. March, pp. 34–41, 2013

[10] J. B. Guinée, M. Gorrée, R. Heijungs, G. Huppes, R. Kleijn, A. de Koning, L. van Oers, A. W. Sleeswijk, S. Suh, H. A. U. de Hae, H. de Bruijn, R. van Duin, and M. A. J. Huijbregts, *Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards.* Dordrecht: Kluwer Academic Publishers, 2002.

[11] M. Goedkoop and R. Spriensma, *"The Eco-indicator99: a damage oriented method for life cycle impact assessment: methodology report,"* Amersfoort, 2000. ISBN: 9072130774.

[12] AFNOR, Norme NF P01-010, *Qualité environnementale des produits de construction,* AFNOR Editions. La Plaine Saint-Denis, 2004.

[13]United Nations sustainable development goals, www.un.org/sustainabledevelopment

[14] Economist intelligence unit, Siemens, "Indice de ciudades verdes de America Latina", 2010

[15] Secretaria Nacional de Planificación y Desarrollo del Ecuador, "*Plan nacional del buen vivir 2013-2017"*, 2014

[16] Distrito Metropolitano de Quito, J.C. Baca, D. Enriquez, N. Narvaez, D. Salvador, *"Indicadores de ciudad sostenible"*, 2014