WORLD SUSTAINABLE BUILDING 2014
BARCELONA CONFERENCE

Sustainable Building: RESULTS
Are we moving as quickly as we should?
It's up to us!

CONFERENCE PROCEEDINGS
VOLUME 3

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The Conference was organised by GBCe (Green Building Council España), co-promoted by iiSBE, UNEP-SBCI, CIB and FIDIC, and counted on the participation of World GBC*.

This volume gathers papers presented in the oral sessions from the Conference area "Creating New Resources", presented at World SB14 Barcelona on the afternoon of day 2 of the Conference. All the papers in this volume were double blind peer reviewed by the Scientific Committee of World SB14 Barcelona.

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***iiSBE:** International Initiative for a Sustainable Built Enviroment
UNEP-SBCI: United Nations Environment Programme - Sustainable Buildings and Climate Initiative
CIB: Conseil International de Batîment
FIDIC: International Federation of Consulting Engineers
World GBC: World Green Building Council

INDEX

DAY 2 - AFTERNOON

ANNEX

PEER REVIEWED SESSIONS - “TRANSFORMING REALITY”

Session 75
Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (I)

Session 93
Are current building regulations adequately advancing sustainable buildings? If not, what is missing, and how should they be changed? (II)

ISBN: 978-84-697-1815-5

Session 85:

Which are the key elements to follow-up environmental targets at an urban scale?

Chairperson:

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Directora de proyectos de Gea21

ISBN: 978-84-697-1815-5

Impact Assessment and Life Cycle improving energy efficiency in urban areas

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Abstract: *With increasing importance in urban sustainability, the improvement of the environmental performance of urban areas requires mathematical models able to integrate the different aspects of each system that constitute them from a life cycle perspective. A simplified method that uses the life cycle assessment (LCA) methodology is proposed in this paper in order to analyse the impact assessment improving energy efficiency in urban areas, including the main alternatives for water and waste water treatment, electricity/fuel supply including heating and cooling equipment of buildings, public lighting, the citizens' mobility, the architectural design of buildings, green areas and the waste management techniques. The aim is to compare the environmental performance of selected solutions considering its production, use, maintenance and end-of-life stages. Thus, the proposed methodology allows assessing the sustainability level of different types of urban areas considering their life cycle, and establishing scientific criteria for the design and planning of eco-cities.*

Keywords: Urban areas, life cycle assessment, eco-efficiency, energy savings

Introduction

Urban areas have become one of the most intensive sectors in the use of energy and raw materials. According Eurostat, in 2011, approximately 41% of the population of the EU27 lived in urban areas. Urban areas are characterized by the demand of the necessary infrastructure for urban mobility (streets and roads), water supply, sewerage, waste management, electricity, gas, etc., involving a considerable land occupation. The United Nations Environment Programme (UNEP) identifies five key infrastructure areas for achieving resource efficient urban areas: (i) building energy efficiency, (ii) waste management, (iii) sustainable urban transport, (iv) water/wastewater, and (v) urban ecosystem management; also remarks the importance of an integrated analysis between sectors within the assessment of their environmental implications [1]. These infrastructure areas are related to the durability of their buildings, which also requires prior land development, e.g. at an urban level, the generation of Municipal Solid Waste (MSW) and construction and demolition waste (CDW) is mostly related to the life-cycle of buildings. In this sense, the improvement of the environmental performance of urban areas requires mathematical models able to integrate the different aspects of each system from a life cycle point of view. Thus, the Life Cycle Assessment (LCA) methodology provides better decision support when optimising environmentally favourable design solutions that consider the impacts caused during the entire lifetime of buildings [2], urban water systems [3], urban waste water systems [4], district energy systems [5], urban energy lifecycle [6], lighting technologies [7], earthwork activities [8], waste management systems [9], urban mobility [10], green areas [11] and urban areas [12].

Some methodologies and tools exist for assessing different aspects of the environmental impact of urban areas. On the one hand, a greenhouse gas (GHG) accounting protocol has been developed recently; this is the PAS 2070:2013 – Specification for the assessment of GHG emissions of a city by direct plus supply chain, and consumption-based approaches [13]. PAS 2070 specifies requirements for the assessment of GHG emissions of a city or an urban area following two methodologies: direct plus supply chain (DPSC) methodology and consumption-based (CB) methodology. It includes 6 different GHG emission sources categories: (i) stationary – fuel combustion in buildings and facilities and or energy generation, (ii) mobile – fuel combustion for transport, (iii) industrial processes and product use (IPPU), (iv) Agriculture, forestry and other land uses (AFOLU), (v) waste and wastewater treatment and (vi) goods and services – water provision, food and drink and construction materials. On the other hand, Neighbourhood Evaluation for Sustainable Territories (NEST) is a supporting tool which allows a quantitative estimation of urban projects environmental impacts, since the sketch stage of the project. It relies on the LCA methodology to assess the environmental impacts of the neighbourhood under study. The system considered in the NEST tool is the whole neighbourhood (in terms of geographical scale). Within the tool, the system is defined by the following characteristics: the implantation site (location), the number, size and types of buildings, public spaces, green spaces, roads and parking [14].

Since NEST tool only considers some aspects or key infrastructure areas for achieving resource efficient urban areas and in some of them only considers the materials and energy flows regardless their lifecycle, there is a need to a wider application of the LCA methodology for the assessment of the environmental implications of urban areas ensuring an effectively improvement of their life cycle energy efficiency and also bringing this methodology closer to a broad public not necessarily familiar or specialist in LCA. In this sense, on the framework of UrBiLCA project, a simplified method that uses the LCA methodology is proposed in this paper in order to analyse the impact assessment improving energy efficiency in urban areas, including the main alternatives for (i) water and waste water treatment, (ii) electricity/fuel supply and generation, including heating and cooling equipment of buildings, (iii) public lighting, (iv) the citizens' mobility, (v) the architectural design of buildings, (vi) green areas and (vii) MSW and CDW management.

The UrBiLCA project

The "UrbiLCA project –Assessing the life cycle impact and improving energy efficiency in urban areas", co-financed by the European Regional Development Fund (ERDF) – SUDOE Interreg IV B, started in January 2013 and will run until December 2014. It aims to promote energy savings, efficient use of raw materials and the reduction of the environmental impacts of the management of urban areas during its construction, operation and maintenance, and end-of-life, as well as promoting the use of LCA as evaluation technique during the design and planning of new urban areas and the rehabilitation or retrofitting of existing ones. From the scientific point of view, one of the main project milestones is the development of mathematical models of processes and associated infrastructure to the life cycle of urban areas, including the main alternatives for the provision of water, electricity and fuels, user´s mobility, the architectural design of buildings and equipment, and the collection and treatment of MSW and CDW.

The UrbiLCA project is the capitalization of the products and results of the EnerBuiLCA project "Life Cycle Assessment for Energy Efficiency in Buildings”[1] which is part of the Interreg IV - B SUDOE Programme. In the course of the EnerBuiLCA project, which concluded in December of 2012, it has developed a database of environmental impacts of construction products from the SUDOE region, a LCA tool in buildings, as well as an on-line thematic platform of LCA. As regards of the development of the LCA tool, it has identified the necessity to expand its spatial scale by extending the system boundaries of the buildings to urban areas.

Methodology

The LCA methodology is used to evaluate the environmental impacts of each of the stages under consideration. This provides a structured analysis of inputs and outputs at each stage of the life cycle of products and services [15]. ISO 14040:2006 [16] prescribes the clear definition of the goal and scope of all LCA studies including the system boundary, the functional unit and the inventory analysis by means of data collection within the system boundary. The assessment process is divided into four basic steps: (1) defining the goal and scope of the analysis; (2) inventory analysis; (3) impact assessment; and (4) interpretation. Assessment is performed on the entire life cycle of the process or activity, including the extraction and processing of raw materials, manufacturing, transportation, distribution, use, recycling, reuse, and final disposal.

Goal and scope definition. The main objective is to compare the environmental performance of selected systems in urban areas considering its production, construction, use and end-of-life stages. The functional unit is the unit of reference for all the inputs and outputs of the system to be obtained from Inventory Analysis [17]. When applying LCA at urban level, defining a functional unit is a complex task as urban areas includes several systems and infrastructures. It is even more complex to define a generic functional unit. In this sense, the following functional units have been defined in the methodology:

- Buildings: the building itself is selected as functional unit, considering its life span. In order to simplify the characterization of buildings in an urban area, it will be selected a set of representative buildings based on the EnerBuiLCA tool.

[1] EnerBuiLCA Project. funded through the Interreg IV B programme, started in March 2011 and will run until December 2012: (/www.enerbuilca-sudoe.eu/)

- Water and wastewater: distribution and treatment of water to supply 1 m^3 of water to the inhabitants of the urban area. In case of the rainwater a 1 m^3 of rainwater managed is considered.
- Street lighting installations: provision of lighting and distribution of electricity to supply 1lumen.hour/m^2 of an urban area.
- Generation of district heating, cooling and distribution system: supply the user of an urban area of 1 MJ (or kWh) of energy for heating or cooling
- Earthworks and earthmoving: transport of 1 ton of ground
- MSW and CDW management: 1 ton of MSW and CDW collected and treated
- Urban mobility: 1 passenger * km
- Green areas: 1 m^2 of green areas

The LCA of these different systems is based on the weighted aggregation of the respective LCAs of their various components and subcomponents.

Target areas and quality data.

In order to validate the method proposed, 6 case studies in different regions of Spain, France and Portugal are used:

- Case study 1 - Ecocity Valdespartera – Localisation: Zaragoza (Spain).
- Case study 2 - Txomin Enea - Localisation: Donostia/San Sebastián (Spain).
- Case study 3 - Eco-quartier du Maharin - Localisation: Anglet (France).
- Case study 4 - Eco-hameau - Localisation: Andernos-Les-Bains (France).
- Case study 5- Parque das Nações - Localisation: Lisbon (Portugal).
- Case study 6- Alto dos Moinhos - Localisation: Lisbon (Portugal).

System description and boundaries of the system

Based on the life cycle stages of a building presented on CEN/TC 350 standard, EN 15643-2 [18], the systems and stages considered in the proposed simplified methodology are presented below:

ISBN: 978-84-697-1815-5

I. Product Stage

The list of urban modules to be evaluated in the UrbiLCA project, 8 in total, and the list of systems and infrastructure associated with each module are presented as follows:

Buildings

a) Processes associated to the supply of raw materials
b) Transport up to the factory gate
c) Manufacturing processes for the construction products, including the processing of any waste arising from these processes.

Waste treatment infrastructure

a) MSW
    i. Collection and transport systems
        - Conventional systems for collection and transportation of MSW
        - Pneumatic systems for collection and transportation of MSW
b) CDW
    i. Collection and transport systems
        - Conventional systems for collection and transportation of CDW

Water cycle infrastructures

a) water consumed and treated
    i. Supply
        - Distribution systems in the urban area:
          Pipes (cement / casting / PVC / polyethylene / ceramic / steel) and Pumps
    ii. Sanitation
        - Sewage collection systems
          Pipes (cement / PVC)
        - Pre-treatment in-situ and treatment of grouped domestic sewage
        - Rainwater collection systems
        - Greywater recycling systems
b) Rainwater collected and treated
    i. Pipes
    ii. Storage structure and rainwater drainage (excluding driveway)
    iii. Drainage
    iv. Infiltration wells
    v. Retention basins
    vi. Retention basins / infiltration areas
    vii. Phytodepuration systems

Roads and infrastructure for urban mobility

a) Vials and surface parking areas (m^2)
b) Cycle routes

ISBN: 978-84-697-1815-5

Installations for air conditioning and district electrical / thermal energy production

a) Electric power
   i. Generation Systems - within urban area limits. At the building level they are included in EnerBuiLCA tool.
   ii. Photovoltaic systems
   iii. Micro - turbines
   iv. Trigeneration
b) Thermal energy
   i. Heating and cooling district systems
      - Geothermal heat pumps
      - Chiller : centralized ventilation systems and air conditioning
      - Boilers (single or double function)
      - Electric thermal storage
      - Solar thermal collectors
      - Trigeneration
   ii. Heat and cold distribution systems
      - Gas pipes
      - Storage tanks
      - Heating and cooling networks

Urban street lighting systems

a) Lamps
   i. Fluorescent
   ii. High intensity discharge (mercury vapour, high-pressure sodium vapour, metal halide)
   iii. LEDs
   iv. Magnetic induction
b) Luminaires (vials, residential, ornamental)
   i. Luminaire structure
c) Holding devices
   i. Column
   ii. Crosier

Green areas

a) Lawn
b) Green roof /wall
c) Trees in mineral area

For each urban module, the environmental impacts of the production of the elements that form the infrastructure are considered. Those elements are included within the perimeter of the urban area (e.g. pipes, containers, lighting). In this sense, a database associated with the environmental impact information (primary energy consumption and CO_2 equivalent emissions), lifetime and mass for each system listed above is used. This aggregate data represents all infrastructure elements that constitute the whole system. Finally, the module

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on earthworks is not included in this stage since it is not associated to an infrastructure. At this stage, only the impacts of the production of the infrastructure are included in the scope of the urban area.

II. Construction process stage

The construction process stage for buildings is already considered in the building module of the EnerBuiLCA tool. For the rest of modules, the environmental impacts of the construction phase are neglected except for those associated with the consumption of fuel and electricity for heavy machinery used in earthworks and earthmoving during the construction process of all modules considered.

III. Use stage

In the use phase of the urban area, the environmental impacts related to the following aspects are included:

- The MSW management, considering the amount of MSW generated in the urban area. Also, it will include a treatment and disposal scenario for each region studied.
- The distribution and treatment of drinking water and the collection and treatment of rainwater.
- The use of vehicles.
- The distribution of electricity in the urban area and the generation and distribution of heat and cold.
- The benefits of the atmospheric CO_2 fixation in the green areas.

The impacts related to maintenance of infrastructure are not included in the use phase. In contrast, the environmental impacts of substitution infrastructure´s elements of the modules considered (except for earthworks) are included, also considering their life span.

For the operational energy consumption, the fuel and electricity consumption will be considered taking into account the following aspects:

- MSW transport and treatment
- Water pumping and distribution
- Energy consumption for urban mobility
- Electric and thermal energy distribution
- Street lighting
- Machinery used for site preparation and earthworks and green areas

The operational energy consumption for heating, cooling and domestic hot water in the building is already considered in the building module of the EnerBuiLCA tool. Finally, the use of operational water includes the water consumption associated with the treatment of waste, distribution losses of water and the process of generation of thermal energy and the maintenance of green areas expressed in litres per year.

ISBN: 978-84-697-1815-5

IV. End-of-life stage

The environmental impacts of transport will be included at the end-of-life stage including the treatment of CDW in all modules. As a general rule, the amount of input raw materials in the production phase will be considered as the amount of CDW. Additionally, the impacts of processing and treatment of CDW is specified to each region of SUDOE.

Life Cycle Impact Assessment

The environmental impacts will be determined from a midpoint-level approach. Taking into account the phases of the impact assessment (classification, characterisation, normalisation, and weighting) at the midpoint level, the potential environmental impact of the Life Cycle Inventory (LCI) are those presented in the IPCC 2007 GWP 100a V1.02 impact assessment method [19], which summarises the GHG emissions in terms of CO_2 equivalent emissions. Additionally, the Cumulative Energy Demand (CED) method V1.08 will be used to calculate the total embodied primary energy of the systems studied measured as MJ-equivalents [20].

The UrBiLCA tool

An user friendly tool for the quantitative assessment of direct and indirect energy related impacts of urban areas in Spain, the South of France and Portugal (SUDOE area) is on developing based on the proposed simplified method in this paper. The scope of the EnerBuiLCA tool is extended to include the end-of-life of the buildings and infrastructures related to systems considered. Thus, the processes of deconstruction, demolition, waste collection and their subsequent transport and treatment, are included in the tool. In this sense, the tool will allow the development of the appropriate strategies for reducing energy related impacts throughout the urban area´s life cycle, from materials production, building and infrastructure construction, use and maintenance to building refurbishment and end-of-life. The technical specifications of the tool are the same as those presented in the EnerBuiLCA tool for buildings. It will measure the primary energy consumption and the associated CO_2 equivalent emissions to the life cycle of an urban area. To evaluate urban areas it will be included the new specifications listed below:

1. Expanding the EnerBuiLCA data base with impact information of the systems and production processes of the infrastructure elements specified in the system description.

2. The inclusion of water consumption as new impact category in the use phase of the building and urban area.

3. The creation of a calculation module for comparing reference scenarios at building and urban area level.

Expected results and conclusions

The results will allow assessing the sustainability level of different types of urban areas considering all the stages of their life cycle, and establishing scientific criteria for the design and planning of eco-cities, promoting integration and use of Best Available Techniques (BAT) in several processes and urban infrastructures. Besides, information and new scientific

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knowledge will be obtained in order to make recommendations for policy makers related to the reduction of environmental impact in urban areas and to improve the present national legislative framework or to suggest new legislative requirements. The project will provide a software tool for incorporating environmental information and the application of the LCA methodology in the design, construction and/or rehabilitation of urban areas. Finally, the results may be used by real estate companies and the inhabitants themselves when evaluating their purchase-sale or rent, as well as by public authorities in defining sustainability policies for municipalities.

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