



# Book of Abstracts

**4th Doctoral Seminar on Sustainability  
Research in the Built Environment**

*26th & 27th April 2017*

Organizaed by ULg, UHasselt, KU Leuven & VUB

**KU LEUVEN**

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**VUB**

Organized by



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Edited by: Prof. Shady Attia, Prof. Gregory Mahy, Prof. Jacques Teller (Liège University)

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# Brief Introduction

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The DS<sup>2</sup>BE is a joint initiative of research groups working on sustainability issues at eight Belgian universities: ULB, VUB, KU Leuven, UCL, ULg, UHasselt, UAntwerpen and UGent. It started in 2014 with three noon sessions at ULB and in 2015 it was extended to a two-day seminar at ULB and in 2016 it was held in Leuven.

Conceived as a platform for PhD researchers whose work engages the built environment at different scales in the framework of sustainability, these seminars provide an excellent opportunity for the doctoral students of the partner institutions to present their ongoing research. They will get feedback from a broad panel of sustainability experts, including invited specialists and peers, for furthering their research.

The DS<sup>2</sup>BE 2017 is a two-day event, organized by Liège University (ULg), Hasselt University (UH), KU Leuven (KUL) and Vrije Universiteit Brussel (VUB). The seminar takes place at the ULg on Wednesday the 26th and Thursday the 27th of April 2017.

More information on the program and activities at the seminar can be found at the seminar webpage: <http://www.ds2be2017.ulg.ac.be/index.html>

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## **REINTEREST Renewable Energy and Cleantech-Based Multifunctional & INTElligent Envelope Retrofitting Systems' Toolbox**

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Buildings account for 40% of the European Union's total energy consumption and for 36% of EU CO<sub>2</sub> emissions, representing Europe's largest source of GHG emissions. For this reason, the reduction of energy consumption and the increase of the use of energy from renewable sources in the building sector are two measures that play a vital role in reducing the energy dependence and greenhouse gas emissions in the European Union. Therefore, increasing buildings' energy performance is a key to secure the transition to a low-carbon economy and to achieve the EU Climate & Energy objectives. REINTEREST project represents a toolbox for Intelligent Renewal (sensors, monitoring and control) and Multifunctional (PV, electrical storage, thermal capture and storage, insulation and ventilation) of the Building Envelope, based on Renewable Energies and Clean Technologies. It aims to design multi-functional products (materials and/or constructive systems) for existing residential buildings in order to optimize the use of buildings envelopes, by employing renewable energy sources, reducing heating, cooling and lighting. In addition, it aims to optimize building performance by employing energy modeling programs, optimize system control strategies by using occupancy sensors and other air quality alarms and Monitor project performance through a policy of commissioning and metering. This project is divided into 8 work packages, each work package will cover a specific area of the project and it will provide outputs for another work package, receive inputs from another work package, or both. These work packages will cover the definition of building specifications and requirements, the architecture, the energy and the energy efficiency of the building, the home automation and monitoring, the energy integrations and economic feasibility. At the end of the project, a demonstration, a tool validation and a dissemination and valorization will be carried out. The designing of these multifunctional products will be used for a larger energy savings with attractive returns through integrative design, right-timing and bundled energy efficiency measures.

Funding: Project funded by the Public Service of Wallonia – Department of Energy and Sustainable Buildings.

## **A Methodology to Determine Urban Densification Potential Through Roof Stacking**

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Population movements towards major cities in Europe are growing exponentially. By 2020, it is expected that 80% of Europe's population will live in cities, which creates the need to develop more compact districts and suburbs by increasing their density. This research aims to establish a methodology that aids decision making on urban densification through roof stacking. The methodology adopts a systematic approach on three consecutive levels; urban, engineering, and social. A multiple criteria are identified that maps roof stacking potential in terms of location and number of added floors. Brussels Capital Region is chosen as a case study to experiment the workflow using ArchGIS software and to validate the developed approach creating a map on the city scale. The results show the potential to accommodate more than the expected population increase by the year 2040 in Brussels through roof stacking only. Yet, further applications on different cities around Europe would help valorising the applied methodology and to open further opportunities to develop an automated tool that estimates those potentials on wider scope.

## **A Dynamic Way of Living Throughout the Seasons, as an Alternative Design Approach for Current Energy-Efficient Housing Concepts: A Conceptual Framework**

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In the past, energy efficiency has been the main focus of sustainable housing in Flanders. The applied object-centred design approach, where the resident is seen as a static actor, is mostly directed at optimization of the building envelop to lower the energy consumption. However, current energy-efficient housing concepts induce new problems: higher material consumption and investments costs. Moreover, the lack of user interaction and inefficient occupant behaviour generate an increase in energy demand when the building is in use. Therefore, the research explores an alternative solution by means of a user-centred design approach to promote efficient use of the indoor environment where the resident is seen as a dynamic actor. The aim is to create an overview of current design challenges and propose new design criteria by means of a conceptual framework. Through a literature study, the research explores: the complex user interaction between dynamic resident, static building and seasonal changes; lack of user interaction in relation to occupant behaviour and comfort studies; definition and objective of user-centred design methodology. The resulting conceptual framework presents that implementation of active systems and high quantities of insulation can lead to a static, controlling and constant built environment. Secondly, the framework aims for providing varying climatic conditions, an adaptable and flexible built environment and guidance of the resident by stimulating an intuitive, easy-to-use living environment. Therefore, a user-centred design approach, is suggested which aims for more effective user interaction and efficient occupant behaviour in the living environment. The dynamic way of living throughout the seasons takes into account the varying comfort needs and diversified spatial preferences of a dynamic resident. The framework was implemented as design input in the conceptual phase of an educational pilot-study and serves as an incentive for the further development of an alternative dwelling concept for energy-efficient housing concepts.

## **Design and Properties of Self-Compacting Concrete Based on Recycled Fine Particles**

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During the last few years, the construction sector has greatly evolved and the reuse of construction and demolition wastes (C&D&W) became a very important purpose for protecting environment and saving natural aggregates. Recycled materials (C&D&W) are not enough used in the construction sector because fine particles able to induce water caption and freezing. These fine particles are composed of adherent hardened cement paste and aggregates: the main goal of this research is to use them in the design of new concrete, such as self-compacting concrete (SCC), which is a concrete able to consolidate under its own weight. The design of SCC let us to use huge quantity of fine particles in order to assure a good workability. A specific physical, chemical and mineralogical characterization of these fine particles is planned in order to understand the behaviour of this type of material; rheological and mechanical properties will be afterwards determined and durability evaluation will allow verifying long term behaviour. This research is a part of the INTERREG VALDEM project.

## Gypsum Residues in Recycled Materials

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Globally, half a ton of construction and demolition wastes (C&DW) are generated per person per year. This waste could be reused into the manufacture of new concrete, but most countries do not yet implement a real circular economy. Fine particles present in this waste are often contaminated with substances harmful for the durability of concrete, which is why their incorporation is generally avoided. One of these harmful substances are gypsum residues, who may complicate and accelerate sulfate attack. Sulfate attack, and the related Delayed Ettringite Formation (DEF), is a deteriorating process that causes the expansive formation of sulfate containing minerals like ettringite. The high volume of these minerals will cause an expansive stress within the concrete, with degradation and cracking as a result.

In this project, the amount of sulfates present in recycled waste from different sources will be analyzed, and we research how much residual gypsum contamination from demolition waste is acceptable for designing new concretes. After the experimental part, the gypsum contamination will be quantitatively related to the volumetric deformation of building materials. Providing a better understanding of the effects of sulfate attack in the context of demolition waste will promote the use of these recycled materials in the building sector.

## From Sociobiology to Urban Metabolism: Landscape Design, Ecology and Engineering in Belgium (1900-2016)

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Today, landscape design plays an increasingly important role in ecological development and infrastructure planning, leading to a disciplinary realignment between landscape designers and ecologists. Current research and design proposals in Belgium tie in with international trends in design, based on a balance between ‘the urban’ and ‘the natural’ and the potential of landscape design to act as an integrative instrument for several disciplines and experts. However, these concepts are not new. This research mobilizes a historical understanding of the role of landscape design in relation to a complex field of knowledge production, policy making and planning and shifting conceptions of city and nature in Belgium since the early 20th century. It adds academic and historical profundity to current design discourse and contributes to recent developments in urban history. The research consists of two case studies that allow the exploration of shifting alliances between designers, scientists and policy makers in Belgium between 1900 and today, with Brussels as geographical focus: (1) Biologist Jean Massart and landscape designer Louis Van der Swaelmen, who developed an ‘ethologic’ view on landscape design and a ‘sociobiologist’ theory on urban planning; (2) Biologist Paul Duvigneaud and the Brussels Agglomeration, developing the scientific field of urban ecology and bringing it into practice in designs for the Brussels Region. These case studies are subject to a network, discourse and a design analysis, with the following questions in mind: Which discourses on the urban and the natural were developed? How were terms and concepts used and how did their meaning evolve? How did the examined alliances affect the design and vice versa? The research offers new perspectives on ongoing academic discussions, in both urban history and urban design. Also, it approaches ecology and engineering from a landscape design perspective, and it introduces ideological, sociocultural and aesthetical perspectives in a hitherto technical discussion.

## Comparison of Small Building-Mounted Wind Turbines and Photovoltaic Panels

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Sustainable energy systems require space. In cities, rooftops are one of the last remaining bit of free space. Moreover, rooftops have a good exposition to wind and sun, which makes them suitable for sustainable energy production. In the last decades, photovoltaic panels (PV) have shown to be a good solution for rooftop energy production. Also, the market of small wind turbines (SWT) is growing and dedicated legal frameworks are being developed. This new trend opens up new perspectives for rooftop retrofitting. As a preliminary study, we assessed the annual energy production (AEP) and the levelised cost of energy (LCOE) of PV panels and SWT on a flat and rectangular rooftop in Brussels. This poster reports the comparison of AEP and LCOE for both energy systems on an increasing rooftop surface. Two efficient wind turbines, one of 3 kW and one of 10 kW, have been considered.

We observed that depending on the available roof surface and the average wind speed, the two wind turbines sometimes have a better AEP than the PV panels. The LCOE results have more contrast. The 3 kW wind turbine is always more expensive than the PV panels. Conversely, with a wind speed above 5 m/s, the 10 kW wind turbine shows a cheaper energy price than the PV panels. To conclude, we have seen that small-building mounted wind turbines can sometimes be a more profitable solution than PV panels. Hence, PV panels should not always take priority over SBMWT when one considers to produce renewable energy on a rooftop. Nevertheless, we believe that the combination of both energy systems may lead to even better result. Our future work will first assess the sensitivity of the mathematical model. Then we will investigate the potential for combination with a closer look at the economic parameters.

## Sustainability Assessment of Advanced Window Systems

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Facades are a crucial interface between the external conditions and the required conditions inside a building. Using glazing in the building envelope provides daylight, views and ventilation and windows can hence contribute significantly to indoor environmental quality. Even though windows have many advantages the energy exchange through them has an important impact on energy consumption in buildings. Windows performance has been improved over the years by using double and triple glazing, low-e coatings and filling the spacing with gases such as argon and krypton. More recently, novel technologies have emerged that promise to further improve windows performance; smart windows, electrochromic filters, PV glazing, advance coatings etc. In order to avoid high energy loads, selecting the appropriate size, proportion, shape, location and type of window along with the orientation and shading is a fundamental part of early design stage decisions, and are difficult to change later on. The challenge is to provide a balance between energy efficiency, occupant comfort and saving resources. This can be achieved by obtaining an integrated performance analysis where the link between various window design parameters and their combined effect on energy consumption, daylighting, comfort, environmental impact and cost are considered. The goal is to create a set of guidelines, an improved design method and a framework to assist architects in the early design stage; recommending optimal window system design and suggesting architectural design scenarios for improving the overall performance focusing on places where occupants spend substantial time inside e.g. patient rooms, elderly housing. A screening study was performed with a sample patient room to understand the impact of window systems on energy efficiency, daylighting and environmental impact and to identify key factors for further research, this poster summarises parts of the results regarding this phase of the research.

## Evaluating the Role of Historic Urban Landscapes in Urban Regeneration Projects - An Integrated Approach Based on the Use of Social Media Data.

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Research and urban planning practices have been concerned about environmental transformations generated by rapid urbanization and the need to develop strategies capable of achieving urban sustainability in existing and future human settlements. As cities undergo changes in their different subsystems, cultural heritage is recognized as a brace to the environmental, economic, and social pillars, and as an enabler for sustainable development that adapts and evolves through time with the changes occurring in the city, and at the same time maintains its identity, integrity, and continuity. In 2011, UNESCO stressed on the role of cultural heritage conservation for achieving sustainable urban regeneration and recommended the application of the Historic Urban Landscape (HUL) approach. The HUL is a landscape value-based approach that addresses the city as a 'living heritage', as a historic layering of different tangible and intangible attributes and values, and calls for integrating conservation practices within the broader context of urban management and development. Our research aims to highlight the value of cultural heritage in achieving a balance between conservation and development concerns in urban regeneration projects. It addresses the challenges of developing a value-oriented and pluralistic definition of heritage. In this context, it proposes the use of social media to complement traditional survey methods, to include more users in the process, and to provide an inclusive interpretation of different cultural values associated with the tangible assets of the city. This presentation elucidates the outcome of the review of the literature that covers the genesis of the HUL approach to cultural heritage conservation and the essence of the HUL approach. The attempt is to connect the ontology of HUL with the epistemology of urban and landscape studies to highlight the contribution of the latter to the documentation and conservation of historic urban landscapes. The outcome showed that the integration of different concepts and analytical methods developed in urban and landscape studies complement each other to provide an interpretation of the urban cultural landscape that is cognitive and semiotic at the same time. This interpretation helps connecting the interface between physical and perceived landscapes, between tangible and intangible attributes and values, exposing the different driving forces contributing in developing the structure and the character of a place, and landscape preferences. Moreover, this review highlighted the concepts and themes embedded in the notion of urban landscape. The interpretation of the outcome led to the development of the conceptual framework for addressing the HUL.

## Methodological Framework for Assessing State Effectiveness in Collaborative Planning

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Collaboration between different urban actors including in spatial planning facilitates mobilization of resources and ownership. It enables, among other things, integration of policy decisions and coordination of action. It becomes even more critical in developing countries where resource limitation is debilitating. Unfortunately, such collaboration is not always forthcoming or is limited at best where it is needed the most. The rhetoric in collaborative planning forwards normative prescriptions based on ideal situations that may not be present under all contextual settings. It does not provide clear insight into what may inhibit collaborative action. Nor does it offer instruments for how to measure the degree of collaboration of a planning exercise or its implementation.

The research aims to contribute to the discussion on collaborative planning by presenting a methodological framework for assessing a collaborative exercise. It adapts a different analytical perspective that focuses on the effectiveness of the state within the framework of formulating and implementing public spatial policies in collaboration with others. The article has three parts-Introduction positions collaborative planning within 'the communicative turn'; highlights some of its normative prescriptions and why it is not always possible to achieve everywhere. Planning being a public domain, the state is the most important institution with great power of influence and thus, its effectiveness facilitates or hinders collaborative action. The second part discusses the constructs under State Effectiveness. The final part presents the Methodological Framework for assessing the effectiveness of the state in collaborative planning.

## Optimization of Hygrothermal Properties of Earthen Bricks Walls of Housing in Burkina Faso

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Burkina Faso is a landlocked West African country with limited natural resources. It has a sudano-sahelian climate. The country's mean precipitation is relatively low with an annual average of 748 millimeters. The average temperature ranges between 28°C and 42°C. Urban zone in Burkina Faso is characterized by two contrasting architectural structures. The first ones are formed by constructions made mainly with earth in informal settlements. They are precarious and spontaneous houses. The second ones are formed by "modern" houses. The dynamic of construction in urban pole show that modern dwelling which have walls made of cement block, roofing in metal sheet, windows in glass is constantly increase [1]. Materials and architecture used for construction of these modern houses in Burkina Faso are not adapted for sudano-sahelian climate and create discomfort [2]. Nevertheless, earthen materials such as compressed earth blocks (CEBs) or clay bricks can improve the comfort in housing due to their high thermal inertia and capacity to regulate the moisture [2]. Earthen walls are porous media which are the simultaneous actions of heat, air and moisture transfer (HAMT). Using HAMT model we reduce the radiant temperature of earthen wall and the operative temperature. This is possible by modifying the basic hygrothermal parameters of the CEBs at the manufacturing stage. A sensitivity analysis of these parameters is carried out in order to determine the most important ones. The goal is to reduce discomfort throughout the year in sudano-sahelina climate and specifically in Burkina Faso based on the adaptive comfort model. Analytical comfort based on the PMV / PPD calculation will be used to compare the architectural solutions between them. In order to reduce the spread of housing in the capital, this study makes the numerical simulation on two types of dwellings: a single storey house and a two storey house.

## The Energy of Spatiality

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Is it possible in our Belgian climate to realize highly energy efficient low-tech buildings with a natural ventilation strategy without heat recovery and heating system, similar to the prototype building be2226 build in Lustenau Austria in 2013 by the architects Baumschlager Eberle? The hypothesis of the present research is "yes". But what are the principles and parameters we need to deal with to conceive this type of buildings and are the common simulation tools appropriate for it?

To find this out, the applicate methodology begins with the understanding of what had been done precisely in the be2226 concept. Go further with the validation of an appropriate dynamic parametric algorithm based simulation tool. Simulation program which runs on two simulated, build and monitored office buildings what allows the calibration of it by the concordance of the results between simulation and monitoring. Once validated the two models runs with investigation on different strategies and parameters. The goal is to find out, for example, if the spatiality with the increase in ceiling height is for real one of the most important conception keys of this type of building? And if this is the case with kind of spatiality allows us to eliminate classic building services? The expected results concern the influence of the paradigm of spatiality on a low-tech energy concept with a high user comfort and reduced global building costs.

## The Spatially Structuring Potential of Energy Infrastructure in the Flemish Nebular City

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The Flemish energy system is embedded in a condition of dispersed urbanization, that is increasingly considered to be fundamentally unsustainable. The emerging energy transition is an opportunity to rethink the spatial structure of this nebular city. This research explores the relation between the spatial logics of new energy systems and their impact on territorial structures, urban morphologies and public spaces. It builds upon the body of knowledge about the structuring role of networks in the development of the dispersed Flemish territory, ties in with the recent interest of design disciplines in ‘urban metabolism’ and ‘designing with flows’, and engages with local energy and transition practices often developed without spatial designers’ involvement. The research starts from the hypothesis that new energy systems have a (re)structuring capacity that can be used as a lever to retrofit the nebular city. It explores this potential by developing a typology of energy projects, combining theoretical models for energy-conscious urban design with an exploration of ongoing energy practices in Flanders. This strategic classification, allows to understand the spatial questions encountered in a diverse range of local projects and shows the limits of the existing dispersed urbanisation pattern and fragmented ownership structure. Second, a number of spatial practices is identified across different categories, that approach energy projects on a ‘collective’ level and create impact beyond the individual plot. These offer starting points for more in-depth case-studies using research-by- design to develop integrated approaches for spatial energy projects.

## Performance Assessment of Residential Buildings in Humid Climate in Algeria, using Life Cycle Analysis Method

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Actually, Algeria faces a challenge to control energy. Moreover, national energy consumption has progressed, especially in the residential sector which represents 34.2% of final energy use. Energy efficiency is an appropriate response to this problem; the evidence is that residential buildings present a real threat to the environment through their high energy consumption. It becomes imperative that the design of housing projects in the future be oriented towards new strategies mainly aimed to reducing the impact on the environment and improving energy efficiency, the development and implementation of sustainability strategies and energy efficiency aspects in residential buildings, especially in humid climate, that are necessary in order to control energy consumption in the residential sector. The main objective of this study is to explore the different methods of energy performance evaluation in residential buildings and their impact on reducing energy consumption in humid climate and to develop a research framework based on Life cycle analysis in terms of reduction of environmental impact and improving energy efficiency within residential building in humid climate in Algeria.

## The Importance of Comfort Indicators in Home Renovations

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Literature, governmental and policy goals reveal a need to merge the, until now separately considered, concepts of Universal Design (UD) and Energy Efficiency (EE) in home renovations. Using the concept of Comfort as a framework that unifies UD and EE a list of 21 comfort indicators was developed based on literature research and a set of 3 qualitative studies. The indicators were developed to describe comfort at home from the perspective of residents so that they may be used by the residents to better understand their renovation needs, to communicate those needs with professionals, and so that policy can be better targeted accordingly. This poster discusses a survey with 145 homeowners to check whether these comfort indicators were indeed important from a homeowner's perspective when building or renovating their home. Of particular interest was how important the indicators are relative to each other; and if there are any inter-relations between them. The investigation included the important triggers and goals of renovation, their relations to each other and to socio-economic data. Among other things the results show that the list of comfort indicators used can be considered reasonably concise and complete. The indicators fall into 3 groups in order of importance with EE associated indicators located somewhere in the middle pack. This order remains similar regardless of whether the respondents' plan to build a new home, renovate, or have no concrete plans yet. An increase in comfort and an increase of the energy efficiency of the home are the most common triggers and goals for renovations. There is little change between the reasons why people started to think of a renovation (triggers) and the final goals of the renovations. The involvement of an architect seems to have no effect on this. The deeper understanding of comfort indicators, as a link between EE and UD, and their importance for homeowners supports our efforts to develop a user-focused synergetic merger of UD and EE in practice and research. The indicators can be used to build communication or assessment tools that bridge the gap between homeowners and professionals of all types involved in home renovations.

## Borderline Ecologies: Landscape between zoning and networks in Flanders and Brussels (1970-today)

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In recent years, advances in environmental sciences, namely the understanding of ecosystems as complex and dynamic networks, have trickled into the theory and discourse of urban planning and landscape design. Nonetheless, these advances have remained mostly theoretical, and have rarely been grounded in empiric case study research showing the full complexity of applying a network rationale to contemporary planning systems, which are predominantly based on land-use zoning principles. Moreover, this spatial zoning is paired with disciplinary and administrative zoning: in Flanders as well as in the Brussels Capital Region, nature policy (based on the network rationale) on the one hand, and (heritage) landscape policy and urban planning (based on zoning principles), are treated within distinct departments, each with its own agendas, tools, experts, practices and responsibilities. This PhD research will mobilize 3 ecological projects in Belgium as testbeds for alternative solutions to two contemporary rifts: Between theory and practice, and between planning/design and environmental science expertise. By exploring multiple permutations of zoning/network juxtapositions, thus tackling the problem from multiple angles within a common geographical frame, this research will attempt to find innovative general strategies which allow the mediation of competing spatial claims, thus contributing to international theory and practice in which these two core rifts are in need of urgent deliberation. Existing theoretical frameworks in the field of landscape ecology, political ecology and urban planning/landscape design will be combined and revised in the light of three case studies in the Brussels Capital Region, representative for the balancing act of ecology at the borderline between (1) zoning and networking, (2) expertise and disciplines, and (3) administrative and political bodies. Throughout the PhD, these case studies will unravel juxtapositions of networks/zoning together with different complexities of social, political, administrative and cultural contexts within a common geographical frame. Network and discourse analyses, based on interviews and archival research, will be complemented with a spatial/design analysis and critical cartography, functioning as a mapping instrument that spatializes, renders explicit and confronts spatial, non-spatial, historical and current-day data obtained during the case-study analysis.

## Methodology for the Design & Development of a Sustainable House Concept for Quetta, Pakistan

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Quetta, the capital of Balochistan province, Pakistan, is facing problems due to increasing population and shortage of energy and water. The aim of this PhD is to develop a methodology for the design of sustainable houses in Quetta, taking into account the best possible solutions for the energy and water shortage and maximizing the use of local materials. In the first phase of the PhD, an inventory of the existing housing stock is made. Due to the unsatisfactory law and order situation, a safety questionnaire was distributed online to identify the safe areas for the housing survey. The areas identified as safe were complemented with areas in which university students and staff, who helped with the housing stock survey, live, to get more representative data. Then 215 houses were surveyed in 32 residential areas of Quetta by filling in the questionnaire, taking pictures and drawing sketches. In the survey, demographic information, data on the energy consumption and systems, construction types and material use is gathered. Three common structural systems are identified, i.e. R.C.C frame, brick masonry and sundried bricks. For each structural system, the main materials for the construction and finishing of walls, roof and floor are inventoried. The most common housing type is R.C.C frame structure for all income groups, with a plot size depending on household size and income. In phase-II, this type of houses will be further analyzed in detail for their energy performance, environmental impact, construction patterns, water and energy consumption and the household characteristics. In phase-III, a sustainable house concept has to be developed taking into account all the information collected in phase-I & II. It will be further validated by simulations of energy, comfort and water performance and discussion with experts and future occupants.

## Development of A Methodology for Architects for the Assessment and Integration of Sustainable Material Use from the Early Design Phase On

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The focus of sustainability in building design is shifting from energy performance towards the more global environmental impact assessment (EIA), to which building materials contribute a significant share. As architects are key actors in design, they are most likely the ones to perform an EIA in the future. However, their knowledge on and familiarity with EIA is found to be quite limited. Therefore, there is a need for design support for architects on environmental impact assessment of building design and materials choices. Environmental feedback should be provided from the early design stage on, as changes can still easily be implemented at this stage. Therefore, this PhD research focusses on the architect-friendliness of environmental impact assessment tools. The final goal is to obtain an architect-friendly methodology for a tool for the assessment and integration of sustainable material use in building design, usable from the early design phase on. In the first phase of the research, the knowledge and practice of Flemish architects was studied and insights in usability and user-friendliness from the viewpoint of the architect were developed. In the second research phase, these insights are used to develop a methodology for an EIA tool, which allows early design environmental impact assessment and provides design-supportive environmental feedback on design and material choices. In the final phase, this methodology will be tested and fine-tuned to really fit the Flemish architects' needs.

## City Environmental Footprint

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To date, more than one person out of two is living in urban areas and projections say that two thirds of human beings will live in cities by 2050. The subsequent resource and energy demands are great, as well as the related environmental impacts. The density of people, energy and economic activities pose big challenges, but also opportunities for cities to be a driver for change, if properly addressed. Current methodologies available to measure environmental performances are however not completely appropriate for these purposes. The goal of this research is to identify a new systemic and systematic approach (City Environmental Footprint, City EF) to assess the environmental impacts of cities, taking into account the heterogeneity of the urban space and avoiding the risk of burdens shifting. The City EF shall be able to identify major hotspots and subsequent sources of impacts, as well as priorities of measures for the reductions of such impact. The development of the proposal started from an extensive analysis of the most important and innovative researches on the topic and from the study of methodologies currently available to identify negative and positive key features for application at the urban level. The methodologies considered are: UM, Input-Output Analysis, Carbon and Water Footprint, LCA. The City EF proposed comprises five main steps, iterative and customizable according to the needs and the specific reality of the urban context considered. The qualitative approach aims at providing an overview of the dynamics inherent to the city, while the quantitative approach is mainly LCA based and includes specific refinements for application to the urban context (functions of the system and functional unit, system boundaries, allocation procedures). The proposal is still under development and is focusing primarily on the identification of urban categories and priority entities, and specific impact assessment procedures.

## Effect of the Nature of Clay and Substitution Materials on the Physico-Mechanical Properties of Compressed Earth Blocks (CEBs)

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Most African cities like Ouagadougou, the capital city of Burkina Faso (BF), records critical demand for affordable sustainable housings. Earth, being indigenous, naturally available with low energy input and able to create more jobs, is regarded an alternative building material (ABM) to cater for this need. Historically, Burkinabe have been living in earthen houses “Banco” given the harsh weather conditions and higher cost of “imported” building materials. Nevertheless, skepticism still arises about long term performance of these “local” materials. While the mechanical strength and toughness of natural fibers reinforced CEBs stabilized with cement are well understood; their hydrothermal and durability properties and onsite performance are still not fully investigated. This study questions whether clay materials from BF can be stabilized/ filled or reinforced with agro/industrial by-products to yield into CEBs with required performances. These CEBs should be able to perform well in both dry and wet conditions and keep that performance after extended time of exposure to mechanical and environmental constraints. The main aim is to add value to local clay and by-products materials and achieve CEBs able to carry a two storey building, i.e having at least 4 MPa of dry compressive strength. Firstly, different clay deposits available in the vicinity of Ouagadougou and by-products (hydrated lime, pozzolan, and fibers) for stabilization are characterized. The study of their interactions is then carried out on chemical, physical and mechanical basis. Owing to their characteristics, the potential materials are used to fabricate stabilized CEBs. The resulting CEBs are tested for improved physico-mechanical, microstructural and hydrothermal properties. Additionally, their performance in wall construction is investigated. The stabilization effect is evaluated on the basis of pozzolanic activity and fiber reinforcement. The durability study of CEBs vis-a- vis water, drying-wetting, fracture, erosion, etc. is carried out in the Sahelian context.

## Thermal Comfort in Tropical and Humide Climate: Coastal Strip of Benin

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The thermal comfort in buildings is often defined using the theory of heat exchange between the human body and its environment. Using measurements made at the University of ABOMEY CALAVI in Benin, the Predicted Mean Vote (PMV) model developed by FANGER has been used to characterize the thermal comfort in Benin's tropical humid climate (coastal strip). A discrepancy has been found between the actual mean and the predicted thermal sensation. This paper proposes an adaptation of this PMV-PPD model to the climatic conditions and to those who live in this region. This error seems to be related to the thermo-physiological shades, especially to the black skin ethnic shades. Therefore, Beninese people may be less sensitive to high temperature than relative humidity and would accept more easily high temperatures than low temperatures. Using the systemic approach, we have shown the complementarity between the rational analytical FANGER's method and the adaptive one. This confirms the hypothesis that FANGER's method would be sufficient to describe thermal comfort in indoor air-conditioned environments, only if the discrepancy has been corrected. The adaptive GRIFFITH'S models with coefficients 0.33; 0.4; 0.5; 0.6 and 5 and that of HUMPHREYS have been tested in this region. The most suitable is the GRIFFITH'S coefficient 5 model. The acceptable comfort range by 90% is between 27.47°C and 30°C and the ideal adaptive comfort temperature would be 28.74°C. However, the 0.5 value as expectancy factor does not seem to be applicable in this region. A comfort zone included in one defined by GIVONI for hot and humid climates have been located in the psychometric chart and meets the usual observations in that region.

## Airpath50 – Characterization of infiltration and exfiltration at building component scale (air paths) based on in-situ testing and numerical models

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A few years ago, worldwide political leaders recognized the need to set ambitious challenges in energy consumption. Among other performances, airtightness is probably the most underestimated. Indeed, air infiltration can be responsible for up to 30% of the heating demand in winter and is poorly mastered by designers and contractors. Furthermore, it impacts insulation thermal performances, hygrothermal performances, occupant comfort, ventilation system efficiency and acoustic insulation. Unfortunately, at a time when all building actors should get involved in the challenge to reduce energy consumption, contractors cannot rely on effective tools to help them meet requirements specifications. This project aims to develop a tool to give contractors information about the impact, the time and the complexity of different corrective measures taken during building construction. In this project, the researcher creates a catalogue based on in-situ testing (blowerdoor test) and numerical modeling (Computational Fluid Dynamics). For example, the contractor could predict the improvement in if he adjusts the bottom joint of the front door. He can also decide if he has to undertake other retrofit measures.

In this project the researcher has to tackle three important issues. First, uncertainties on blowerdoor measurements are important and have to be assessed to make results reliable. Ways to reduce measurement uncertainties must be developed in this work. Second, nowadays the CFD is not used in the description of single building components regarding air infiltration. Nothing has been done yet, and the researcher has to take the first steps in this field. Last important point is the classification and understanding of different air leakage paths. Indeed, air infiltration phenomenon at component scale is poorly developed by researchers and equally mastered by designers and contractors.

## **Towards Climate Resilient Building: Strategies to Design Future-Proofed Medium-Sized Offices in Flanders**

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Climate change is a fact and today the question is rather how strong the effect of this phenomenon will be. Adaptation to climate change is therefore a major challenge as well as building robustness considering the current climate uncertainties. This research aims to define strategies to design climate resilient medium-sized office buildings in urban areas in Flanders. The impact of the expected future climate in Flanders on buildings will be investigated in terms of indoor thermal comfort, and heating and cooling demand. Recently developed climate scenarios for Flanders are used for the analysis. Strategies for an improved comfort and reduced energy demand will be searched for in order to avoid excessive costs and environmental impact over the building's life cycle. In addition, this research aims to investigate and improving the resilience of the building even when changing the function, to residential, over time. Moreover, the effect of a changing surrounding on the climate resilience of the building will be explored in order to guarantee a robust building design. In a final, rather explorative step, there will be investigated how a climate resilient building can also contribute to climate change mitigation. The research will translate the strategies used to build climate resilient into opportunities for the building sector (innovation in technology, innovation in building design, adaptability of construction parts, ...) and likely for software developers. Recommendations for policy makers will be formulated regarding building regulations from a climate resilient point of view.

## **Typologies of Institutionalised Co-production of Water and Sanitation Services in the Urban South**

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This contribution enters the debate on sustainable urban service provision in the Global South as part of a research project on institutionalized co-production of water and sanitation services (WSS). The spread of these new forms of service provision and related territorial and socio-economic implications is suitable for being investigated under a double fold perspective, combining public management considerations with environmental and spatial ones. A comparative analysis will be performed by analysing a number of selected case studies in 5 cities (Hanoi, Mumbai, Addis Ababa, Kinshasa and Cochabamba), with the aim to cover a wide range of typologies of WSS co-production. Cases will be analysed in the following dimensions:

- i) The actors, with the purpose to define how and at which stage of the water cycle institutional actors and communities are involved in the service provision and whether co-production is stimulated by top-down policies or bottom-up initiatives.
- ii) The flows, through a mapping of WSS networks and clusters and the multiple technical solutions that communities and single households adopt to access water and sanitation in order to establish their impact on the environment and the water resources.
- iii) The areas, by highlighting the link between water infrastructures and urban forms. The purpose is to formulate hypothesis on the urban and environmental dynamics that may facilitate or prevent co-production activities, to identify the areas where they take place and assess their impact on the spatial dimension.

Goal of the comparative research is to assess the impact of those practices on communities, settlements and the environment in order to establish whether they are sustainable in terms of life cycle costing, socio-spatial equity, environmental and urban quality.

## Interviews on Residential Building Deep Renovation

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Belgium should increase the deep renovation rate of existing residential building stock at least to 3% a year to achieve the EU objectives of decreasing by 80% the Green House Gas Emissions before 2050. Since the first thermal legislations (between 1985 and 2000, depending on the Region), efficiency and comfort of newly built houses have met higher standards. But the renovation rate of residential buildings remained stable in the last 20 years. Only 25000 renovation permits are issued each year, in which a small amount of them are highly energy efficient. Literature review has showed that drivers and barriers of deep renovation are many and varied, sometimes contradictory and often underestimated. Conducted interviews with experts who study different facet of renovation present some others viewpoints on this subject. According to their own specific experience, each interviewee thinks differently on possible solutions. The poster set out the interview analysis. Some points are very close to the literature review, such as the environmental and economic issues of the residential renovation, while other results are solely extracted based on the interviews' results.

Amongst others, the necessity to maintain and improve the existing building stock to new standards takes an important place. The regulation appears to be a good driver as much as a barrier, depending on the local legislations and buildings context particularly in Belgium where the diversity of the building stock is very important. Public policies seem to be the first tools to unlock the renovation rate even if the development of new financial model and the information of stakeholders are also highlighted. This analysis increases the comprehension of the renovation topic on a new level, including some adjacent ideas that lead to better understanding of the existing barriers and possible strategies to overtake them, so that to involve everyone in the renovation strategy definition to promote the most efficient one.

## Evaluating the Hospital Building Sustainability: Applying a Screening LCA and LCC to the New General Hospital in Mechelen

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The past decade has been marked by an increased interest in the way hospital buildings are designed and operated. With the urge to decrease the negative impacts of the building stock around the world, healthcare facilities are equally called upon to respond to this matter. In order to tackle the hospital building sustainability, a quantitative approach, using the life cycle thinking perspective, seems to be an appropriate method for analysing the environmental impacts of these buildings. However, due to the complexity and various medical preconditions a hospital needs to fulfil, no such method that would facilitate its sustainability assessment has yet been proposed. An attempt has been made to gain better insight into the environmental impacts of the hospital buildings in Flanders. For this purpose, a screening Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) study has been carried out on the new general hospital Sint-Maarten in Mechelen. The aim is to pinpoint the major obstacles for such a quantitative analysis as well as to identify the hotspots from both an environmental and economic point of view. Furthermore, the results will serve as one of the important inputs in laying the cornerstones for the development of the quantitative sustainability assessment method for hospital buildings in Flanders.

## Information Framing of the Flemish Energy Performance Certificate: a Proposal for Experimental Studies

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The energy performance certificate (EPC) is an information provision tool that enables prospective buyers and renters to compare dwellings in terms of energy performance. Besides, the EPC encourages the uptake of the recommended energy efficient renovation measures. Therefore, in order to be effective, dwellers have to be able to understand and interpret correctly the two key elements of the certificate: the energy performance indicator and the recommendations. Previous research regarding the EPC scheme assumed that dwellers are able to process the technical information of the certificate in a rational way, whereas literature review on experiments regarding information framings in energy related contexts shows that consumers interpret in a heuristic way the information regarding energy consumption and energy efficiency of appliances and vehicles. Our research hypothesis is that the framing of the information plays an important role for the efficiency of the EPC, alongside calculation method and quality assurance.

The present paper presents proposals for experimental studies that verify the following clues from our previous qualitative analysis. Firstly, it will be investigated whether the energy indicator of the Flemish EPC reflects properly the energy performance of a dwelling in comparison with the rest of the building stock. Findings from a focus group with experts suggest a possible over-optimism in assessing the energy performance of one's dwelling. Secondly, our experiments aim to verify whether dwellers process the information in a rational way or if they are influenced by biases. The comparative analysis of nine European EPCs have revealed a wide range of possible ways of framing the information of the energy indicator and the recommendations. Many include nudges such as anchoring, social norm, salience and discounting the future. No information framing is neutral and the information on the EPC can be subject to heuristic interpretation even if nudging is not the purpose.

## Spatializing the Economic Roles and Prospect of Small towns in Ethiopia: The Case of Amdework

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Urbanization in Ethiopia reached only 19 percent in 2014. Although the urbanization base is very low the annual growth rate observed during these years is high because it grew by 4.8 percent, 3.8 percent and 4 percent between the years 1984 and 1994, between 1994 and 2007 and between 2007 and 2012, respectively, which is higher than the national population growth rate. There are myriads of challenges urban centers face in Ethiopia. Literatures identified six key challenges in Ethiopian urban centers. These are lack of infrastructure and services, shortage of housing, environment related problems, poor urban-rural linkage, poor urban-urban linkage and lack of good governance. Hence, it would be of great importance to identify those factors that influence the development of these small towns, and reverse the inverse relationship between level of poverty and the size of towns. Many scholars have singled out different factors that have hindered the development of small towns in different corners of the world.

This study will, therefore, try to identify those factors that affect the development of small towns in the Ethiopian context. To achieve this, the study will intensively investigate both internal and external factors identified in the previous part on the selected case town, Amdework. To achieve this goal, the research will be divided into three work packages. The first work package is dedicated to identifying "Role of a Small Town in the Regional Urban System" to see if there are external opportunities in the regional urban system that can be harnessed to develop a small town. The second work package will be to investigate internal opportunities in small businesses typical to small towns. This is important because the growth of small towns, as hypothesized in the research, partly lies in the small businesses that reside in them. And lastly, the research will also investigate if there are further internal opportunities by studying bottom up initiatives that would help the economies of these small towns to be more circular and more sustainable.

## Regulation Regimes for the Development of Hybrid Places Regarding Urban Sprawl and Fragmentation: a Cross European Comparative Analysis

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Today's working life, in particular the development of mobile work and new working spaces, and the emerging social realities, influences housing quality and its evolution. It is hereby considered that work and living activities will increasingly tend to develop in shared spaces in the years to come, especially for activities related to the service sector, either continuously or throughout the life cycle of the building. This has brought to a redefinition of the traditional division between office and residential spaces, which has been addressed either through the notion of "hybrid" or "third places" in the literature. This research will thus focus on hybrid places, i.e. a combination of professional and living activities within the same building, considering both new constructions and reconversions/adaptations of present office and residential building units, either through formal or informal procedures.

This project assumes that such a development may contribute to increased social fragmentation, due to the exclusion of precarious households from central locations, and to fuelling urban sprawl, through further relaxation of home-to-work travel demands. Then the objectives are (i) to map the current development of hybrid places in metropolitan areas, (ii) to mitigate the induced risks, by offering an adequate regulation regime for the production of hybrid places, and (iii) to consider the specific potential of hybrid places in social housing. A comparative research will be carried out in three European cities: Brussels, Amsterdam and Stockholm. This will consist of analysing the local market dynamics, mapping the role of public and private stakeholders in office and residential development, both front-line people and policy-makers, and exploiting the existing incentives and governance tools devoted to the production and enhancement of hybrid places. Finally the results will be applied to a sample area of Brussels to set up practical regulation facilities.

## Spatial Use Patterns in Flemish Dwellings: Analysis and Impact on Energy Consumption

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In Belgium, dwellings are relatively large in comparison to other countries and research shows that the effective occupancy rate of living spaces is quite low. However, the effective space use might have a crucial impact on the actual energy consumption, since currently, rooms are often fully acclimatized, while only a part of them is used effectively. The hypothesis of this research is that the energy efficiency of dwellings could be increased if the design of the house as well as the systems for heating, ventilation and lightning, are better adapted to the actual use patterns within the dwelling. Occupant behavioural patterns describe the effective use of a dwelling in relation to the indoor climate and the energy consumption. The occupant behavioural patterns consist of spatial use patterns and actions, each having a specific impact on indoor climate and energy consumption:

- The Spatial use patterns can be subdivided in occupancy patterns, circulation patterns and activity patterns.
- The Actions describe the interactions of the occupant with the building and with the systems.

This research focuses mainly on the analysis of circulation patterns of occupants throughout a dwelling, since this is an under-examined part of occupant behaviour in dwellings. It is expected that insights into circulation patterns can be used to provide local and personal comfort for the occupants and as input for the design of dwellings, which can result in more energy or space efficient dwellings. This research consists of three main parts. Firstly, a methodology to monitor circulation patterns inside buildings will be developed. Secondly, knowledge on and insights into the occupant behavioural patterns in Flemish dwellings and other buildings will be developed from case studies. Thirdly, these patterns will be implemented into applications and techniques to increase the energy and space efficiency.

## Development of a BIM Method to Assess the Lifelong Impacts of Transformable Design

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Circular material management is a key aspect towards a sustainable built environment. Transformable Design contributes to the reduction of excessive waste generated by maintenance and demolition, through the reuse of building components and materials. Nevertheless, current building practices will only shift towards Transformable Design provided expected (mid or long term) environmental benefits and financial viability. Therefore, there is a need for a usable assessment tool considering the lifelong impacts of Transformable Design. As preliminary research, a user requirements analysis, conducted through interviews and surveys among several construction actors, will define which data visualization means are relevant for the tool's users. Then the research will elaborate a method to assess the capacity of building to be adapted (instead of demolished) to transformation and refurbishment scenarios. Therefore, on one hand, we will select and arrange parameters in order to model the service life of a building. Service life scenarios will define transformation and refurbishment needs according to the specific building's context, type and use. On another hand, we will integrate in the assessment the previously established Transformable Design criteria. Because these criteria mainly rely on qualitative aspects (e.g. accessibility, simplicity, functional dependency), their integration into a numerical assessment method will require the input of surveyed stakeholders' experience and the use of sensitivity analyses. In order to guaranty the objectivity of the overall method and its compatibility with the design process, the method will be implemented in a Building Information Modelling (BIM) tool, through the use of Autodesk Revit and Dynamo. Finally this tool will be tested on different case studies. Architects will test the user-friendliness and the relevance of the feedback provided. Experts in Transformable Design and Material Flow Analysis will confirm the results' accuracy. Using this tool, designers will be then able to compare different service life models and design scenarios to make better-informed decisions.

## Environmental life cycle optimization of prefabricated timber frame systems for rooftop extensions

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As urban sprawl is becoming an issue of increasing concern, Flanders is facing some key challenges in the near future. Firstly, the density measured within the built-up fraction is too low despite a high Flemish population density. Secondly, additional housing is currently required due to the growing Flemish population and decreasing household size. Densification of the built-up fraction by means of compact building design offers a solution to address these current housing needs and to avoid further fragmentation of remaining valuable open space. The emphasis in this PhD research is on designing and evaluating prefabricated timber frame systems for rooftop extensions on existing residential buildings. A previous research step identified the timber and timber-based parts in a timber frame wall applied in rooftop extensions as hotspots. The results furthermore indicated the wood treatment as an important environmental aspect. Therefore, this paper focuses on environmental impact calculations of treated and untreated timber frame. Different treatment methods for wood are described. An environmental impact assessment of the most common wood preservative in Belgium is made and compared with the generic datasets in the MMG database (based on generic datasets from Ecoinvent). The calculations are made by the use of three versions of the Ecoinvent database (version 3.1, 3.2 and 3.3) in order to reveal the importance of the choice of database on the assessment results.

## Public Space Qualities in the Ethiopian Context: The Case of Addis-Abeba

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Public spaces are considered the platforms for most human beings' day-to-day activities. They are able to deliver a range of benefits across economic, social and environmental spheres enhancing the urban life. This important role they play has both a global similarity and local individuality making each of these spaces unique places. This article, therefore, looks at public spaces in Addis Ababa to identify qualities that are attached to these spaces in an effort to find out what is a "working public space" in the Ethiopian context. This is achieved by looking at the global level and understanding the qualities Public spaces have through the concept of sense of place; Activity, Image, Form and Management. This is, then, reviewed at a local level in order to assemble a framework and do case study analysis to understand the context. In the case studies selection, an acupuncture approach using the principle of hierarchy of space was adopted where four use & scale dependant levels were recognized. This was due to the extensive size of what public spaces is in the city. Accordingly, The study identified four cases namely: Meskel Square, Sholla Market, Lideta Church and Beherawi Area in the capital city Addis Ababa. The study concluded that Necessary activities like education & work are as important as Optional activities such as seating, playgrounds & sporting activities for the success of a place. Also, third spaces like Cafe's and internet cafe's are an important integral part of the public spaces. In addition, the management aspect including the up keep quality of a place is highly affected by ownership where corporate ownership is welcomed and works effectively.

## Socio-Anthropological Study of the Conditions of Population and Diffusion of Constructions in CEBs in Burkina Faso. Field Studies in Ouagadougou

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The housings in Burkina Faso, a landlocked country having limited natural resources and experiencing harsh weather conditions, are mostly built in local materials. Indeed, about 69.4% of the houses have their walls in raw earth as opposed to the remaining 13.8% .In fact, the very high cost of building materials (cement, steel, metal sheet, aggregates), whose domestic market is dominated by a few large importers, challenges the vast majority of the population. The "local" contrary to the "imported" has a negative image in Burkina Faso. This results into middle-class houses being currently constructed in concrete blocks which is contradicting on the aesthetic and thermal points of view. The cornerstone of this doctoral thesis is based on a socio-anthropological approach theorized by Jean Pierre-Olivier de Sardan ;1995. To sum up, this research seeks, through empirical work, to understand the mechanisms and the representations that revolve around the arena of construction with CEB in the city of Ouagadougou.

Doctoral Seminar on Sustainability Research in the Built Environment

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