Sustainable Building Design Lab Potential Research Topics

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1. Climate change and future occupant thermal comfort: implications for occupant health, welfare, building performance, environment and economic consequences

Citizens of Liege, including seniors and children, are predominantly kept in confined living spaces during summer heatwaves. By modeling the relationship between humans, building, and the ventilation system, the indoor thermal climate, air quality, and airborne emissions will be simulated. For a reference (1985-2010) and the future dataset (2036-2065), the occupants' system's vulnerability will be assessed. For various adaptation strategies, including shading, active cooling, dehumidification, night cooling, their economic and social effects will be evaluated to increase the resilience of dwellings in Belgium.

2. Characterization of a Belgian Representative Residential Housing Model

This study aims to characterize representative building energy data sets and benchmark models for the Belgian residential sector. This study will report the results of a recent field survey for residential apartment buildings in Belgium. Two building characterizations will be created, reflecting the average energy consumption characteristics of heating residential apartments in Brussels, Liege, and Antwerp.
This study will establish two detailed models describing the energy use profiles for heating, lighting, domestic hot water, and appliances in respect to buildings layout and construction. The aim is to evaluate future nearly zero-energy target's energy efficiency. The collected surveyed data will be used as input for two building characterizations using descriptive statistical methods. The characterization will be verified against the national characteristic found in the literature. This intern will present details of the building models, including the energy use patterns and profiles created for this study.

3. Life cycle analysis of a circular building in Belgium (Only Interns - confidential)

Circular building design is a concept that is gaining significant interest from architects, building engineers, and their clients but is still rarely adopted in practice. The choice of constructive and structural systems, such as columns, beams, and slabs, is crucial to upgrade the reuse cycles in the future. Camp C is a circular construction project located in Westerlo, Belgium. The project is designed to be disassembled every 5 years and re-constructed, covering 20 years as the first circular building in Belgium. A life cycle analysis will take place using One Click LCA software for different building construction. Parametric analysis will take place for different construction systems scenarios involving a steel structure and a timber structure. Life Cycle Assessment and comparisons of the various construction systems are made based on ISO 14040, 14044, and CEN/TC 350 standards, focusing on carbon neutrality.

4. Overview and future challenges of nearly Zero Energy Buildings (nZEB) design in Eastern Europe

In times of great transition of the European construction sector to energy-efficient and nearly zero energy buildings (nZEB), a market observation containing qualitative and quantitative indications should fill out some of the current gaps concerning the EU 2020 carbon targets. Next to the economic challenges, there are equally important factors that hinder renovating the existing residential building stock and adding newly constructed high-performance buildings. Under these circumstances, this paper summarises the findings of a cross-comparative study of the societal and technical barriers of nZEB implementation in 11 Eastern European countries. The study analyses the present situation and provides an overview of prospects for nZEB in Eastern Europe. The result presents an overview of challenges and provides recommendations based on available empirical evidence to lower those barriers in the European construction sector. The paper finds that most Eastern European countries are poorly prepared for nZEB implementation and especially to the challenge/opportunity of retrofitting existing buildings. Creating a common approach to develop nZEB targets, concepts further, and definitions in synergy with the climatic, societal, and technical state of progress in Eastern Europe is essential. The paper provides recommendations for shifting the identified gaps into opportunities for future climate-adaptive high-performance buildings.

5. Life cycle environmental and cost analysis of vacuum glass facades

The study aims to build an environmental and economic analysis on the viability of vacuum glass facades. According to the literature review, the use of vacuum glass technologies is novel, and almost no study

investigated its environmental impact compared to insulated glass units. That could lead to a better understanding of their impact on the buildings, leading to better choices during the design process. The case study is a low energy consumption office modeled on One Click LCA based on the LCI database. The study is mainly looking at the environmental impact and life cycle cost of vacuum glass systems. The economic analysis should be linked with the technical analysis. The life cycle cost of the vacuum glass is based on the net present value. It is calculating the operation cost and maintenance cost while is taking into account the discounted factor. The method analysis the difference of investment to make based on their influence on energy consumption.

6. Object recognition for building archetypes characterization in Belgium

This research aims to study deep transfer learning to overcome object recognition challenges encountered in the field of digital building characterization. The research will investigate various uses of neural network architectures and different combination schemes with random forests for feature selection and train them through several experiments. The experiments on 300 houses datasets will train the object recognition algorithm to identify the best performance accord strategies. The work will involve fine-tuning, and using specific architectural features will be part of the approach to increase the accuracy of object recognition.

7. A cost-optimal analysis for nearly zero-energy building solutions in line with the EPBD-recast 2020 for Belgium

Finding cost-optimal solutions towards nearly-zero-energy buildings (nZEBs) following the European energy performance of buildings directive (EPBD-recast 2020) is challenging. It requires exploring many possible combinations of energy-saving measures (ESMs) and energy-supply systems, including renewable energy sources (RESs), under a comparative framework methodology. The current study introduces an efficient, transparent, and time-saving simulation-based optimization method for such explorations. The method is applied to find the cost-optimal and nZEB energy performance levels for a study case of a single-family house in Belgium. Different options of building-envelope parameters, heat-recovery units, and heating/cooling systems, as well as various sizes of thermal and photovoltaic solar systems, are explored as design options via three-stage optimization. The resulted economic and environmental trade-offs show that primary energy consumption is cost-optimal energy performance level.

8. Decision Support Tool for Economic and payback calculations of Zero Energy Buildings

This research aims to develop a decision support tool (excel) to help architects estimate zero energy buildings' cost. The main cost of building materials and construction in the decision analysis of buildings will be categorized. This tool is essential for architects and future researchers to estimate the cost of sustainable and efficient construction. The tool has to be simple to use, enabling users to enjoy and make the right choice of performance and development of their future construction. The student should develop an excel tool and test it at the end of his/her thesis.

9. What is the optimal material configuration for a Zero Energy Retrofit Buildings?

Life cycle assessment (LCA) of conventional and bio-based materials. **Only between September and December with prof. Angelique Leonard, a student, must follow an LCA course at Liege University.**

10. How can thermographic images improve the renovation policy and strategy for Liege

The importance and benefits of using thermographic images are gradually starting to generate an interest in Belgium. This research will explore the use of aerial thermographic images in the renovation policy-making context and, more precisely, its use to improve the renovation implementation and increase its rate in Liege's city. A decision matrix will be developed to identify the most useful data types for renovation. The main result will focus on action plans and renovation strategies to cope with the information asymmetry issue. The past and current roof renovation subsidy policy of Liege will be investigated as a concrete application to illustrate how aerial thermographic images can enhance the effectiveness of a renovation strategy. The results will focus on roof renovation solutions and design packages by directly identifying poorly insulated houses. The research will seek to evaluate aerial thermographic images' benefits to accelerate the renovation rate, increase the annual energy savings, and consequently reduce the pollutants emissions.

11. Development of Design Criteria and Strategies to avoid overheating in NZEBs

The importance of designing domestic buildings to perform well in winter and summer in terms of energy efficiency and comfort is recognized as key to good design. In summer, well-insulated buildings are at risk of overheating if not effectively shaded and ventilated. This risk is likely to increase with the effects of climate change – posing potentially serious health risks to residents. By modeling different Passivhaus standard buildings over a range of future climate scenarios, insights can be found into which measures to control overheating may be necessary. These recommendations apply equally to 'standard' buildings, particularly as building regulations tighten. The key is to apply building simulation models (DesignBuilder) appropriate to each specific situation. Finally, the risk of overheating will be identified, and appropriate design strategies is suggested (Energy Conversion and Management + Solar Energy)

12. Development of comparison tool of adaptive thermal comfort standards

Using Excel or Matlab equations, boundaries and limits of different comfort models' applicability will be embedded in a new tool. The tool allows comparing and visualizing the indoor temperature indoor measures. A case study will be used to validate the tool.
(Thermal comfort standards, measured internal temperatures and thermal resilience to climate change of free-running buildings: A case study of hospital wards)

13. Control Strategies for Adaptive Facades

This research aims to assess different control strategies for adjusting three facades technologies with a simplified building simulation model of an office. The assessed control strategies should test the different overall energy demands and take the interior temperature into account. The control strategies should respect the thermal comfort based on a Predicted Mean Vote (PMV) index to achieve low energy demand, presuming that a deviation from the highest comfort level is acceptable. With the ESBO tool's help developed by the European Solar Shading Organisation, the researcher will explore different shading control strategies and test them for a shoebox office unit. The studied control strategies should be compared for all climate conditions to achieve the highest energy reductions. The researcher should investigate the potential of a control strategy that can universally be applied. This study in line with the development of ISO 52022-5. For similar studies check: Ritter, V., Matschi, C., & Schwarz, D. (2015). Assessment of five control strategies of an adjustable glazing at three different climate zones. *Journal of Facade Design and Engineering*, *3*(2), 129-141.

14. Technical and economic analysis of the viability of advanced shading technologies

The study aims to build a technical and economic analysis on the viability of advanced shading technologies. According to the literature review, none of the technical and economic analyses studied advanced technologies in Belgium. That could lead to a better understanding of their impact on the buildings, leading to better choices during the design process. The case study is a low energy consumption house modeled on DesignBuilder based on EnergyPlus. In particular, the study is looking at the energy consumption and the house's discomfort hours when advanced shading systems are used. The economic analysis should be linked with the technical analysis. The life cycle cost of the shading devices is based on the net present value. It is calculating the operation cost and maintenance cost while is taking into account the discounted factor. The method analysis the difference of investment to make based on their influence on energy consumption.

15. Technical and economic analysis of the viability of electrochromic glass technologies

The study aims to build a technical and economic analysis on the viability of electrochromic glass technologies. According to the literature review, none of the technical and economic analyses studied advanced technologies in Belgium. That could lead to a better understanding of their impact on the buildings, leading to better choices during the design process. The case study is a low energy consumption office modeled on DesignBuilder based on EnergyPlus. In particular, the study looks at the energy consumption and the discomfort hours of the house when electrochromic glass systems are used. The economic analysis should be linked with the technical analysis. The life cycle cost of the shading devices is based on the net present value. It is calculating the operation cost and maintenance cost while is taking into account the discounted factor. The method analysis the difference of investment to make based on their influence on energy consumption.

16. Influence of Solar Shading Usage Factor in the EPBD calculation on cooling load

The Belgian EPBD (PEB) is used to calculate the monthly solar gains for openings. The equation considers the opening's surface area, monthly average radiation, and the solar factor or solar heat gain coefficient based on NBN EN 410. This later forms an excellent reason for uncertainty because it assumes a hypothetical value for solar shading usage for opening and closing (*facteur d'utilisation*). Therefore, this study will aim to review the literature and observe several residential buildings to identify how people interact with external solar protection devices and the patterns of their use. The researcher will seek to find an accurate value for solar shading usage and assess their impact on cooling load and thermal comfort based on a building simulation model. DesignBuilder and ESBO tool, which the European Solar Shading Organisation develops, will be used for estimating the influence of changing this factor.

17. Developing bioclimatic design guidelines for energy-neutral residential buildings design in a Indian Ocean

The Indian Ocean Commission is looking to develop a design guide for nearly zero-energy dwellings in Comoros, Madagascar, Mauritius, Reunion, and Seychelles. Employing passive design of main building elements, materials, and techniques significantly impacts buildings' energy efficiency. Accordingly, the researcher will conduct an iterative sequence of validated parametric simulations to investigate the effect of employing different design principles on energy consumption and carbon emissions of residential buildings in the five islands. The investigated design principles will be chosen according to the literature. The results should indicate optimum solution and design recommendations. The study recommendation should support design decisions and can be integrated into regional building code.

18. Resilient cooling of buildings: A framework for assessment criteria

With climate change, extreme events are going to increase in intensity and frequency. Overheating caused by heatwaves or power outages is a disruption, which will have a bigger impact on buildings. To mitigate the overheating effects, the use of air conditioning is popularized in buildings. However, it is not a sustainable solution. That is the reason why the term resilient cooling was introduced. Resilient cooling denotes low energy and low carbon cooling solutions that strengthen individuals and our community's ability to withstand and prevent thermal and other impacts of changes in global and local climates. Our objective is to identify criteria, which can determine if building cooling is resilient. Based on the literature review and focus group discussions, a framework for resilient cooling criteria is proposed.
We study four main criteria: vulnerability, resistance, robustness, and recovery.

19. Green Liege

This research will aim to figure out the locations of 60,000 trees in Liege. With the help of Google Tree Canopy Lab and based on collected aerial imagery from Google Maps and Google Earth, the student will estimate Liege's tree coverage. The information gathered on tree cover will be fed to an interactive map with additional data, including population density, heat risk, land use, and neighborhood boundaries. Putting together all the information, the thesis will indicate which areas are more vulnerable to high temperatures to locate the tree green infrastructure.