Sustainable Building Design Lab Potential Research Topics

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1. Climate change and future occupant thermal comfort in 3°C warmer Belgium: implications for occupant health, welfare, building performance, environment, and economic consequences

According to the Intergovernmental Panel on Climate Change (IPCC), the global mean temperature is expected to increase from 1.4————————————C to 5.8°C by 2100. The implications will be particularly significant in urban areas as indoor and outdoor comfort levels will be disrupted, leading to significant health impacts. One of the expected impacts is indoor overheating, as it has been identified as one of the major causes of thermal discomfort and is directly linked to the potential increase in mortality levels in the future. This thesis focuses on the potential implications of increased overheating hours on human health in an old low-income residential neighborhood. We study the effect of three main factors: population coping capacity, building thermal performance, and human physiological response to heat exposure. This is achieved by examining an old low-income neighborhood in Liege, Belgium during summer, whose residents have limited cooling systems access. The study's findings can be considered a starting point to examine the relationship between exposure duration, indoor air temperature range, and potential health risks for vulnerable urban communities with limited access to cooling mechanisms such as AC units.

Available Dataset: Low ★★
Relevant Standard(s): TBD
Partnerships: Occupant Project Consortium and IEA Annex 80 on Resilient Cooling
Methodology: Building Energy Modeling and Literature Review
Relevant Studies:

- Bayomi, N., Elkholy, M., Rakha, T., & Fernandez, J. E. (2021). Passive survivability under extreme heat events: The case of AlDarb Al Ahmar, Cairo. Science and Technology for the Built Environment, 27(8), 1144-1163.

What are you going to learn from this project: future climate change scenarios modeling, thermal comfort evaluation, modeling building stock on a national scale.

2. Passive survivability under extreme heat events: the case of Liege, Belgium

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.

Available Dataset: Low ★★
Relevant Standard(s): TBD
Partnerships: Occupant Project Consortium
Methodology: Building Energy Modeling and Observationa (Surveys)
Relevant Studies:

-Zhongming, Z., Linong, L., Wangqiang, Z. and Wei, L., 2021. The risks to Australia of a 3° C warmer world.
-Santamouris, M., & Kolokotsa, D. (2015). On the impact of urban overheating and extreme climatic conditions on housing, energy, comfort and environmental quality of vulnerable population in Europe. Energy and Buildings, 98, 125-133.

What are you going to learn from this project: future climate change scenarios modeling, thermal comfort evaluation, modeling building stock on a neighbordood scale, surveys making and community interaction.

3. Sensitivity analysis of different future climate change and urban heat island effect scenarios on the effectiveness of ventilative cooling in Liege's dwellings

The International Panel for Climate Change (IPCC) estimates extreme and frequent climate scenarios and heat waves by 2050. Ventilative cooling is a key passive design technology to improve thermal comfort and limit additional electricity use and associated GHG emissions for space cooling. However, in the urban dense city center of Liege and under the heat island effect there are doubts that ventilative cooling can become an effective adaptation measure. Using building performance modeling the simulation of overheating risk in typical buildings in Liege will be modeled including different types of ventilative cooling and control strategies based on three different future climate change scenarios. The existing building stock

will be modeled on DesignBuilder based on EnergyPlus. Three ventilative cooling scenarios with different assumptions on ventilation rates and uptake will be projected. Several indicators will be used to assess the environmental and economic impact including the CAPEX for avoided AC units and OPEX for energy and maintenance savings.

Available Dataset: Low ★★
Relevant Standard(s): EN16798
Partnerships: Occupant Project Consortium
Methodology: Building Energy Modeling
Relevant Studies:
-https://www.zdf.de/dokumentation/planet-e/planet-e-hitzefalle-stadt---wenn-es-tropisch-wird-100.html
What are you going to learn from this project: building performance modeling, thermal comfort, ventilative cooling technologies and control strategies, future climate change scenario modeling

4. Towards heat waves and heat domes plan for Liege: Protecting the health and reducing harm from hot tropical weather

The Heat Weather Plan for Liege is a framework intended to protect the population from harm to health from hot weather. It aims to prevent the major avoidable effects on health during periods of heat weather in Liege by alerting people to the negative health effects of hot weather and enabling them to prepare and respond appropriately. It recommends a series of steps to reduce the risks to health from hot weather for example: on the city level, air-conditioned refuge centers, and the urban level, conditioned streets with mist sprinklers, shading devices, and water fountains. The study will involve contacting local authorities, social care, and other public agencies including professionals working with people at risk and individuals, local communities, and voluntary groups.

Available Dataset: Low ★★
Relevant Standard(s):
Partnerships: Occupant Project Consortium
Methodology: Qualitative
Relevant Studies:
-Österreicher, D., & Sattler, S. (2018). Maintaining Comfortable Summertime Indoor Temperatures by Means of Passive Design Measures to Mitigate the Urban Heat Island Effect—A Sensitivity Analysis for Residential Buildings in the City of Vienna. Urban Science, 2(3), 66.
What are you going to learn from this project: heat waves, indoor and outdoor thermal comfort, cooling shelters, urban passive cooling, strategic planning

5. Sleep: Sweltering bedrooms are a blind spot in climate action

Belgium is getting hotter very quickly, but we still know little about the climate in our homes. This summer, you will visit the warmest rooms in Belgium for a study into heat stress. Based on future climate change scenarios calculated by the Climate Unit at ULiege a hot scenario assumes extreme global warming and a high humidity rate by 2050. We are also dealing with more and more heatwaves. The number of 'tropical' days, when the temperature rises above 30 degrees during the night, will at least double by 2050, but in the unfavorable case, it could even be five times higher than it is now. People in multi-unit residential buildings or apartments are particularly bothered by the heat because they are, trapped between their neighbors and heat urban environment. In the event of a new heatwave, you will measure how hot it can get in and around houses in Liege. What are the differences per neighborhood, street, and house, and which groups have the least survival abilities? We also look for the consequences of this heat on your health and we find out how well Liege Province's municipalities and housing associations are prepared for the future. Welcome to.

Available Dataset: Medium ★★
Relevant Standard(s): EN16798
Partnerships: Occupant Project Consortium
Methodology: Mixed: Observational and qualitative
Relevant Studies:
- https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/snikhete-slaapkamers-zijn-blinde-vlek-in-klimaataanpak.html
What are you going to learn from this project: fieldwork and field measurements, survey, statistical analysis of comfort data, engaging with citizens, and understanding how people behave during heat waves.

6. Influence of the urban environment on the effectiveness of ventilative cooling in residential buildings

The effectiveness of ventilative cooling including natural night ventilation in the Belgian urban environment depends on local climate characteristics, but also solar shading and wind shielding effects of the surrounding buildings. However, the impact of the latter factors on the effectiveness of ventilative cooling is

often overestimated by building designers. In this thesis, the cooling effect of night ventilation for a representative residential building placed in the center of urban areas of increased density is analyzed for three Belgian locations. The energy demand of the unventilated building is first assessed, also considering the effect of environmental albedo and a simplified Urban Heat Island scenario. Then, night ventilation rates and energy savings for the ventilated building are calculated to estimate the variation of the cooling effect of night ventilation. Results show a strong reduction of the energy savings in high-density urban areas and point out that a detailed description of the surroundings is crucial to assess the suitability of passive cooling solutions.

Available Dataset: High ★★★★
Relevant Standard(s): EN16798
Partnerships: MK Engineering
Methodology: Building Energy Modeling
Relevant Studies:

-Ramponi, R., Gaetani, I., & Angelotti, A. (2014). Influence of the urban environment on the effectiveness of natural night-ventilation of an office building. Energy and Buildings, 78, 25-34.

What are you going to learn from this project: building modeling, climatic analysis, future climate change scenarios modeling, thermal comfort evaluation.

7. The introduction of new occupancy profiles and building characteristics for the elderly in residential buildings in Belgium

Many occupancy models have been utilized to predict occupancy profiles of individual dwellings as part of the larger residential building stock. However, none of the existing models consider senior occupancy profiles to generate high-temporal resolution heating load profiles. The current paper uses surveys data to develop a high-temporal resolution residential building occupancy model. The key feature of the proposed model, implemented using EnergyPlus/DesignBuilder, is the ability to generate stochastic occupancy time-series data for national population subgroups characterized by senior occupancy profiles.

Available Dataset: Medium ★★★
Relevant Standard(s): ISO 18523-2
Methodology: Mixed approach: Qualitative, Observational and Modeling
Relevant Studies:

-Santin, O.G., Itard, L. and Visscher, H., 2009. The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. *Energy and Buildings*, *41*(11), pp.1223-1232.
-Buttitta, G., & Finn, D. P. (2020). A high-temporal resolution residential building occupancy model to generate high-temporal resolution heating load profiles of occupancy-integrated archetypes. *Energy and Buildings*, *206*, 109577.
-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. *Energy and Buildings*, *244*, 111052.

What are you going to learn from this project: understand and learn about the influence of occupancy in buildings, learn about elderly lifestyle, represent occupants in an energy-building model.

8. Clothing behavior and their metabolic rates and their relation to comfort and residential energy use

The study discusses the way occupants clothe themselves when they are at home and how this behavior can influence thermal comfort and residential energy use. The study is based on answers gathered from a logbook survey and an online questionnaire. The clothing behavior and metabolic rates are statistically analyzed and it is determined which of the five main variables have a significant impact on the clothing behavior. In the first part, the terms occupant behavior and clothing behavior are defined. The influence of five important variables on occupants' clothing behavior are researched; indoor temperature, outdoor temperature, weather history memory, gender, and age. Finally, the relation between clothing behavior, thermal comfort, and energy use in a building is described.

Available Dataset: Low ★★
Relevant Standard(s): ISO 18523-2:2018
Methodology: Mixed approach: Qualitative,Observational and Modeling
Relevant Studies:

- De Ceuste, 2019, Clothing behaviour and its relation to comfort and residential energy use, UGhent.
-Attia, S. (2020). Spatial and behavioral thermal adaptation in net zero energy buildings: an exploratory investigation. Sustainability, 12(19), 7961.
-Buttitta, G., & Finn, D. P. (2020). A high-temporal resolution residential building occupancy model to generate high-temporal resolution heating load profiles of occupancy-integrated archetypes. Energy and Buildings, 206, 109577.

What are you going to learn from this project: understand and learn about the influence of occupancy in buildings, learn about Belgian residents' lifestyles, represent occupants in an energy-building model

9. On the impact of residential housing renovation with a focus on high-performance windows (confidential with AGC glass)

This research presents the results of energy and environmental assessment of a set of envelope retrofit actions implemented to residential buildings in Belgium. Outcomes arise from a life cycle approach focused on the following issues: (i) construction and insulation materials and components used during retrofits; (ii) windows technologies involving double and triple glazing and vacuum glass windows; (iii) impacts related to the building envelope, for the different elements and the whole building. The results are presented according to the data format of the Environmental Product Declarations. Synthetic indices, as energy and Global Warming Potential, payback times, and energy return ratio, are defined to better describe the energy and environmental performances of the actions. The project highlights the impact of the implementation of envelope retrofit actions.

Available Dataset: Low ★★
Relevant Standard(s): TBD
Partnerships: AGC Glass
Methodology: Building Energy Modeling and Literature Review
Relevant Studies:

-Ardente, F., Beccali, M., Cellura, M. and Mistretta, M., 2011. Energy and environmental benefits in public buildings as a result of retrofit actions. Renewable and Sustainable Energy Reviews, 15(1), pp.460-470.
-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.

What are you going to learn from this project: future climate change scenarios modeling, thermal comfort evaluation, modeling building stock on a national scale

10. Developing a building energy model for a nearly zero-energy senior house in Kain, Belgium

This study aims to develop a building simulation model for a nearly zero-energy senior house (multi-unit residential building) located in Kain. The model creation will involve data collection based on post-occupancy measurements and field survey campaigns. The study will report the energy characteristics and occupancy profiles of the building. An analysis of energy consumption (electricity and natural gas) and a walkthrough survey will be conducted. The benchmark model's validity will be further checked against public statistics and verified through model calibration and monthly energy bill comparison. The findings on indoor environmental quality, energy needs, and intensity are useful to estimate the energy gap and real comfort for similar archetypes in Western European countries. The project will take place in collaboration with the MK Engineering firm.

Available Dataset: Medium ★★★
Relevant Standard(s): TBD
Partnerships: MK Engineering
Methodology: Building Energy Modeling
Relevant Studies:

-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.

What are you going to learn from this project: drone flying, photogrammetry based modeling, building performance modeling, senior houses, nearly zero energy buildings, monitoring of thermal comfort, performing energy audits.

11. Developing a building energy model for a nearly zero-energy semi-detached home

This study aims to develop a building simulation model for a nearly zero-energy semi-detached home located in Belgium. The model creation will involve data collection based on post-occupancy measurements and field survey campaigns. The study will report the energy characteristics and occupancy profiles of the building. An analysis of energy consumption (electricity and natural gas) and a walkthrough survey will be conducted. The benchmark model's validity will be further checked against public statistics and verified through model calibration and monthly energy bill comparison. The findings on indoor environmental quality, energy needs, and intensity are useful to estimate the energy gap and real comfort for similar archetypes in Western European countries.

Available Dataset: Full ★★★★★
Relevant Standard(s): TBD
Methodology: Building Energy Modeling
Relevant Studies:

-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.
-Attia, S., Canonge, T., Popineau, M. and Cuchet, M., 2022. Developing a benchmark model for renovated, nearly zero-energy, terraced dwellings. Applied Energy, 306, p.118128.

What are you going to learn from this project: photogrammetry based modeling, building performance modeling, nearly zero energy buildings, monitoring of thermal comfort, performing energy audits.

12. Developing a building energy model for a zero energy senior house (full electric) in the Netherlands

This study aims to develop a building simulation model for a nearly zero-energy senior home (row house) located in Gisseburg, the Netherlands. The model creation will involve data collection based on post-occupancy measurements and field survey campaigns. The study will report the energy characteristics and occupancy profiles of the building. An analysis of energy consumption (electricity) and a walkthrough survey will be conducted. The benchmark model's validity will be further checked against public statistics and verified through model calibration and monthly energy bill comparison. The findings on indoor environmental quality, energy needs, and intensity are useful to estimate the energy gap and real comfort for building with heat pumps and PV panels.

Available Dataset: Full ★★★★★
Relevant Standard(s): TBD
Methodology: Building Energy Modeling
Relevant Studies:

-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.
-Attia, S., Canonge, T., Popineau, M. and Cuchet, M., 2022. Developing a benchmark model for renovated, nearly zero-energy, terraced dwellings. Applied Energy, 306, p.118128.

What are you going to learn from this project: photogrammetry based modeling,building performance modeling, senior houses, nearly zero energy buildings, monitoring of thermal comfort, heat pumps, and PV performance modeling and monitoring, performing energy audits.

13. Developing a building energy model for 1960s multi-unit residential buildings

This study aims to develop a building simulation model for a nearly zero-energy senior home (row house) located in Gisseburg, the Netherlands. The model creation will involve data collection based on post-occupancy measurements and field survey campaigns. The study will report the energy characteristics and occupancy profiles of the building. An analysis of energy consumption (electricity) and a walkthrough survey will be conducted. The benchmark model's validity will be further checked against public statistics and verified through model calibration and monthly energy bill comparison. The findings on indoor environmental quality, energy needs, and intensity are useful to estimate the energy gap and real comfort for building with heat pumps and PV panels.

Available Dataset: High ★★★★
Relevant Standard(s): TBD
Partnerships: MeterBuy
Methodology: Building Energy Modeling
Relevant Studies:

-Touchie, M. F., & Pressnail, K. D. (2014). Using suite energy-use and interior condition data to improve energy modeling of a 1960s MURB. Energy and buildings, 80, 184-194.
-Rasooli, A., & Itard, L. (2020). Automated in-situ determination of buildings' global thermo-physical characteristics and air change rates through inverse modelling of smart meter and air temperature data. Energy and Buildings, 229, 110484.

What are you going to learn from this project: building performance modeling, monitoring of thermal comfort, performing energy audits.

14. Building inspection procedures using drones for energy performance cetrtification (with BBRI)

Drones with remote sensing or thermal imaging gear present an opportunity for analysis and inspection of existing building stocks, where architects, engineers, building energy auditors as well as owners can document building performance, visualise heat transfer using infrared (IR) imaging, and create digital models using 3D photogrammetry. None destructive testing can measure thermal properites of an envelope, detect moisture, invisible physical defects, and can be carried on a drone. Used in inspecting the envelope drone assistested characterisation techqniues drive down labor and repair costs, are safer, and faster that tradional methods. The existing Walloon energy audits establish best practices for conducting and reporting energy and creating energy performance certification for existing buildings. This master thesis is aimed to develop a framework on ULiege campus site to showcase: (i) pre-flight inspection procedure parameters and methodologies; (ii) during-flight visually identified areas of thermal anomalies using a drone equipped with IR cameras; and (iii) 3D model creation and printing: modelling developed through data gathered using drone.

Available Dataset: High ★★★★
Relevant Standard(s): ISO 9869
Partnerships: BBRI (CSTC)
Methodology: Mixed approach: qualitative and energy modeling

Relevant Studies:

-Rasooli, A., & Itard, L. (2020). Automated in-situ determination of buildings' global thermo-physical characteristics and air change rates through inverse modelling of smart meter and air temperature data. Energy and Buildings, 229, 110484.
-El Masri, Y., & Rakha, T. (2020). A scoping review of non-destructive testing (NDT) techniques in building performance diagnostic inspections. Construction and Building Materials, 265, 120542.

What are you going to learn from this project: 3D printing, drone flying, photogrammetry based modeling, thermal imaging, envelope performance characterisation (modelling and monitoring).

15. 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.

16. 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 are suggested (Energy Conversion and Management + Solar Energy)

17. 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)

18. Evaluation of adaptive facades: The case study of the Solar Leaf an algae bio-reactive facade in Hamburg

Adaptive facades include new envelope technologies that can help neutralize building energy use or improve the indoor environment dynamically and interactively. In this context, this study presents a case study of an adaptive algae bio-reactive facade and an evaluation of its performance and occupant behavior. Documentation of the case study describing the post-construction occupant comfort and façade operation will be prepared. This study's audience comprises mainly architects, and building facade engineers together with facility managers who are concerned with the process of design, construction, and operation of adaptive solar active facades.

Available Dataset: Full ★★★★
Relevant Standard(s): TBD
Partnerships: Jan Wurm,Arup
Methodology: Qualitative methods
Relevant Studies:

- Attia, S., 2018. Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE. QScience Connect, 2017(2, Special Issue on Shaping Qatar's Sustainable Built Environment-Part I), p.6.
-Wurm, J. and Pauli, M., 2016. SolarLeaf: The world's first bioreactive façade. Arq: Architectural Research Quarterly, 20(1), pp.73-79.

What are you going to learn from this project: advanced façade engineering, solar active envelope, heat production and algae industry, building physics.

19. Evaluation of adaptive facades: The case study of ING head office retrofitted facade with air-purifying technologies in Brussels

Adaptive facades include new envelope technologies that can help neutralize building energy use or improve the indoor environment dynamically and interactively. In this context, this paper presents a case study of an adaptive façade with an integrated mechanical ventilation system and an evaluation of its energy and indoor environment's performance. Documentation of the case study describing the comfort and façade operation will be prepared. This study's audience comprises mainly architects, and building facade engineers together with facility managers who are concerned with the process of design, construction, and operation of adaptive solar active facades.

Available Dataset: Low ★
Relevant Standard(s): TBD
Partnerships: Brink Climate Systems France
Methodology: Building Energy Modeling
Relevant Studies:

- Attia, S., 2018. Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE. QScience Connect, 2017(2, Special Issue on Shaping Qatar's Sustainable Built Environment-Part I), p.6.
-Wurm, J. and Pauli, M., 2016. SolarLeaf: The world's first bioreactive façade. Arq: Architectural Research Quarterly, 20(1), pp.73-79.

What are you going to learn from this project: advanced façade engineering, ventilative active envelope, indoor air quality, building physics.

20. Life cycle environmental and cost analysis of electrochromic glass facades (confidential with AGC Glass)

The study aims to build an environmental and economic analysis on the viability of electrochromic facades. According to the literature review, the use of electrochromic 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 electrochromic glass systems. The economic analysis should be linked with the technical analysis. The life cycle cost of the electrochromic 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.

Available Dataset: Medium★★★
Relevant Standard(s): CEN TC350, ISO 14040, and ISO 14044
Partnerships: AGC Glass
Methodology: LCA Modeling, Costing, Building Energy Modeling
Relevant Studies:

- Attia, S., 2018. Evaluation of adaptive facades: The case study of Al Bahr Towers in the UAE. QScience Connect, 2017(2, Special Issue on Shaping Qatar's Sustainable Built Environment-Part I), p.6.
-Wurm, J. and Pauli, M., 2016. SolarLeaf: The world's first bioreactive façade. Arq: Architectural Research Quarterly, 20(1), pp.73-79.

What are you going to learn from this project: advanced façade engineering, solar active envelope, electrochromic glass, materials environmental impact, life cycle analysis, building performance modeling, building physics.

21. Modeling the influence of the adaptive façade of Baumschlager Eberle (BE) 2226 building on thermal comfort

This study aims to develop a building simulation model for a BE 2226 in Austria. The model creation will involve data collection based on post-occupancy measurements and field survey campaigns. The study will report the influence of the adaptive façade control strategy on thermal comfort and the overall energy performance.

Available Dataset: Medium ★★★
Relevant Standard(s): TBD
Partnerships: Lars Junghans and University of Michigan
Methodology: Building Energy Modeling
Relevant Studies:

-Hueber, E., Eberle, D., & Aicher, F. (2016). be 2226-Die Temperatur der Architektur: Portrait eines energieautonomen Hauses. Basel: Birkhäuser,[2016].

What are you going to learn from this project: building performance modeling, thermal comfort, solar shading, natural ventilation, windows opening, passive design, low-tech buildings design, and operation.

22. The potential of dynamic solar shading to avoid cooling demand and overheating in European households

The International Energy Agency (IEA) estimates air conditioners (AC) in Europe to soar from 115 million units in 2020 to 275 million units in 2050. Higher Greenhouse Gas (GHG) emissions from AC increase the risk to miss the climate neutrality by 2050 target. Dynamic solar shading devices on windows are a key technology to limit additional electricity use and associated GHG emissions for space cooling. Using building performance simulation the simulation of overheating risk in typical buildings will be modeled including different types of shading and control strategies based on three different future climate change scenarios. The existing building stock will be modeled on DesignBuilder based on EnergyPlus. Three shading scenarios with different assumptions on shading uptake will be projected. Several indicators will be used to assess the environmental and economic impact including the CAPEX for avoided AC units and OPEX for energy and maintenance savings.

Available Dataset: High ★★★★
Relevant Standard(s): EN16798
Partnerships: Ramin Rahif, IEA Annex 80
Methodology: Building Energy Modeling
Relevant Studies:

- Hutchins, (2015) High performance dynamic shading solutions for energy efficiency and comfort in buildings, European Solar Shading Organisation
- ESSO (2021) Solar shading – Synergising mitigation of GHG emissions and adaptation to climate change, The potential to disrupt rising cooling demand and overheating in European buildings, Guidehouse, Berlin, Germany

What are you going to learn from this project: building performance modeling, thermal comfort, solar shading technologies and control strategies, future climate change scenario modeling

23. Improving shading design quality in high-performance buildings: Lessons learned

Delivering excellent shading design solutions in high-performance buildings is a winning strategy for comfort and energy efficiency. Shading solutions sustain climate change and users' comfort and are essential for an energy-neutral building. Yet many building firms are struggling to integrate shading solutions, wasting money on ill-conceived facades and undermining occupant discomfort during the operation stage of a buildings' life. Are there guidelines to help architects and building designers chart a design-improvement strategy for their buildings? We think so. In this thesis lessons from an extensive review of recently built high performance, buildings are presented—lessons that we believe apply across the architecture, engineering and construction industry and are essential to the design improvement and integration of shading solutions in new buildings.

Available Dataset: Medium ★★★
Relevant Standard(s):
Partnerships: MK Engineering
Methodology: Interview and case studies analysis
Relevant Studies:

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What are you going to learn from this project: shading design, solar protection, high-performance buildings design, passive design, low-tech buildings design, and operation.

24. 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.

25. 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.

26. 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.

27. *Les Colibris* Citizen science project

Weather and climate are of great importance to assess thermal comfort and air quality in Liege. More powerful supercomputers make it possible to make increasingly accurate weather forecasts, and local weather measurements are becoming increasingly important for this. In this unique citizen science project, Liege schools students, researchers, and local partners will monitor the weather in Liege neighborhoods using weather stations. There is currently no data on the urban climate of Liege. Reliable weather observations are usually limited to weather stations in very open and rural environments. ***Les Colibris*** project aims to change this and to deliver a measurement network in very diverse environments (rural, city centers, industrial sites, forests,...) around Liege. Researchers can't organize this themselves on such a scale. That is why the project calls on schools to place weather stations in the most diverse environments. The students of the participating schools will search for locations, build weather stations and analyze the measurements. For the measurements, an accurate weather station will be compiled by the master student or intern at SBD Lab. The meteorological sensors (Davis Vantage Pro 2) are high-quality and measure temperature, relative humidity, wind, and precipitation. The latest Internet of Things (IoT) technology is used for communication. The power is supplied by a solar panel with a battery system and is calculated in such a way that the weather station can continue for about 1 month on a full battery. An Arduino-type microcontroller will be used and designed to control the measuring station. The weather station will be developed in such a way that the school students can build and place it themselves.

Available Dataset: Medium ★★
Relevant Standard(s): The project will involve asking for funding from ARES development durable under the Wallonia Brussels Federation for 5000 to 10000 euros.
Partnerships: Liege University Green Office and ISSeP
Methodology: Qualitative and observational
Relevant Studies:
-https://vlinder.ugent.be/
-https://www.ares-ac.be/fr/developpement-durable/793-appel-a-projets-2021-4e-edition-de-l-appel-a-projets-de-developpement-durable-ouvert-aux-etablissements-d-enseignement-superieur-de-la-federation-wallonie-bruxelles-2
What are you going to learn from this project: weather stations assembly, Arduino control, strategic fieldwork and field measurements, statistical analysis of weather data, mobilizing citizens, fundraising, and proposal writing.

28. LCA-based environmental assessment of the use and maintenance of heating and ventilation systems in Belgian dwellings

This paper describes how life cycle assessment (LCA) methodology can be applied to quantitatively assess the environmental performance of the use and maintenance of heating and ventilation systems. The studied climate systems include individual noncondensing boilers and condensing boilers and hot tap water. The study is a follow-up of an existing study that characterized the energy performance of a typical single-family household archetype.

Available Dataset: Low ★★
Relevant Standard(s): CEN TC350, ISO 14040, and ISO 14044
Partnerships: Prof Andre Stephan, UCLouvain
Methodology: LCA Modeling
Relevant Studies:

-Blom, I., Itard, L. and Meijer, A., 2010. LCA-based environmental assessment of the use and maintenance of heating and ventilation systems in Dutch dwellings. Building and Environment, 45(11), pp.2362-2372.
-Attia, S., Mustafa, A., Giry, N., Popineau, M., Cuchet, M., & Gulirmak, N. (2021). Developing two benchmark models for post-world war II residential buildings. Energy and Buildings, 244, 111052.

What are you going to learn from this project: carbon footprinting, building performance modeling, materials environmental impact, life cycle analysis.

29. Life cycle analysis of a circular building in Westerlo, 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. The 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.

Available Dataset: Full ★★★★★
Relevant Standard(s): CEN TC350, ISO 14040, and ISO 14044
Partnerships: Benees Architecten
Methodology: LCA Modeling and Literature Review
Relevant Studies:

-Al-Obaidy, M., Santos, M.C., Baskar, M. and Attia, S., 2021. Assessment of the circularity and carbon neutrality of an office building: The case of 'Centrum in Westerlo, Belgium. Crossing Boundaries.

What are you going to learn from this project: circularity of buildings, carbon footprinting, building performance modeling, materials environmental impact, life cycle analysis, advanced building sustainability evaluation.

30. Life cycle analysis of a circular building in Liege, Belgium, Connect Immo (confidential with Helium3)

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. Connect Immo is a circular construction project located in Liege province, Belgium. The project is designed to be a renovated and the first circular building in Wallonia, Belgium. The philosophy of this project lies in the application of the principle of the three Rs: Reuse - Reduce – Recycle. A life cycle analysis will take place using One Click LCA software for different building construction. The parametric analysis will take place for different construction systems scenarios involving ecological materials 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.

Available Dataset: Medium ★★★
Relevant Standard(s): TOTEM**,** CEN TC350, ISO 14040, and ISO 14044
Partnerships: Helium3
Methodology: LCA Modeling and Literature Review
Relevant Studies:

- Al-Obaidy, M., Santos, M.C., Baskar, M. and Attia, S., 2021. Assessment of the circularity and carbon neutrality of an office building: The case of 't Centrum in Westerlo, Belgium. Crossing Boundaries.

What are you going to learn from this project: circularity of buildings, carbon footprinting, building performance modeling, materials environmental impact, life cycle analysis, advanced building sustainability evaluation.

31. Comparative life cycle analysis of Baumschlager Eberle (BE) 2226 building for a timber construction scenario versus a heavy mass concrete construction scenario

This study aims to perform an LCA for two scenarios of BE 2226 in Austria. The first model represents the original building in heavy mass and the second model is for a fictitious timber construction scenario. The study will involve the use of the TOTEM method. The study will report the influence of material choice on thermal comfort with a focus on thermal mass/inertia, carbon emissions, and the whole low-tech approach of the BE 2226.

Available Dataset: Low ★★
Relevant Standard(s): TOTEM**,** CEN TC350, ISO 14040, and ISO 14044
Partnerships: Lars Junghans and University of Michigan

Methodology: LCA Modeling and Literature Review
Relevant Studies:
-Hueber, E., Eberle, D., & Aicher, F. (2016). be 2226-Die Temperatur der Architektur: Portrait eines energieautonomen Hauses. Basel: Birkhäuser,[2016].
What are you going to learn from this project: carbon footprinting, building performance modeling, materials environmental impact, life cycle analysis, thermal mass.

32. Developing a management plan to integrate ISO 14001 and carbon footprinting as design criteria to be applied on a project from BESIX (collaboration with BESIX)

As a leading construction company, BESIX is looking to integrate embodied carbon and environmental management as a key performance indicator in its design practice to improve on its value engineering on material level. This study will develop a framework to inform the design decision-making for future building and infrastructure projects. The study will involve formulating a protocol and steps to take into account and quantifying the impact of embodied carbon during design, sizing, material choice, and supplier's requirements.

Available Dataset: Medium ★★★
Relevant Standard(s): TOTEM**,** CEN TC350, ISO 14040, and ISO 14044
Partnerships: BESIX
Methodology: LCA Modeling and Literature Review
Relevant Studies:
-Hueber, E., Eberle, D., & Aicher, F. (2016). be 2226-Die Temperatur der Architektur: Portrait eines energieautonomen Hauses. Basel: Birkhäuser,[2016].
What are you going to learn from this project: carbon footprinting, materials environmental impact, life cycle analysis, environmental business administration

33. Developing bioclimatic design guidelines for energy-neutral residential buildings design in the Indian Ocean (collaboration with Reunion Uni., France)

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 the optimum solution and design recommendations. The study recommendation should support design decisions and can be integrated into the regional building code.

Available Dataset: Low ★
Relevant Standard(s): TBD
Partnerships: Reunion University, Prof. Francois Garde
Methodology: Building Energy Modeling
Relevant Studies:
- Khambadkone, N.K. and Jain, R., 2017. A bioclimatic analysis tool for investigation of the potential of passive cooling and heating strategies in a composite Indian climate. Building and Environment, 123, pp.469-493.
- Attia, S., Lacombe, T., Rakotondramiarana, H.T., Garde, F. and Roshan, G., 2019. Analysis tool for bioclimatic design strategies in hot humid climates. Sustainable cities and society, 45, pp.8-24.
What are you going to learn from this project: building performance modeling, energy efficiency in tropical climates

34. CFD simulation of cross-ventilation in buildings using windcatchers: a case study of an education building in Cairo, Egypt (only for interns: mechanical engineering*/thermicien*)

Cross-ventilation using wind-catchers is very complex as it is influenced by a wide range of interrelated factors including aerodynamic characteristics of the windcatcher, approach-flow conditions, and building geometry. This paper presents a detailed evaluation of the impact of the inlet openings and shafts sizing on the ventilation performance of a multi-story educational building with windcatchers. The evaluation is based on three ventilation performance indicators: (i) induced airflow rate, (ii) age of air, and (iii) air change efficiency. High-resolution coupled 3D steady DesignBuilder and OpenFoam CFD simulations of cross-ventilation are performed for different sizes and types of outlet openings. The CFD simulations are validated based on wind-tunnel measurements.

Available Dataset: Medium ★★
Relevant Standard(s): TBD
Methodology: CFD Modeling and Literature Review
Relevant Studies:
-Montazeri, H. and Montazeri, F., 2018. CFD simulation of cross-ventilation in buildings using rooftop wind-catchers: Impact of outlet openings. Renewable Energy, 118, pp.502-520.

What are you going to learn from this project: building performance modeling, CFD modeling, thermal comfort, aerodynamics in buildings.

35. Comparision of the hygrothermal performance of a solid wall versus a living wall

The study investigated the hygrothermal performance of two wall systems with a closed-cell structure and a diffusion-open and capillary active walls systems. The focus will be on the conditions in two masonry/insulated walls complying with Walloon building regulations, and the performance of the two systems will be compared for a diffusion-open insulation system and one diffusion-tight insulation system.

Available Dataset: Medium★★★
Relevant Standard(s): ISO 9869
Partnerships: Darmstadt University, Walloon bio-based materials manufacturer
Methodology: hygrothermal modeling using Delphi and EnegryPlus
Relevant Studies:

- Jensen, N. F., Bjarløv, S. P., Rode, C., Andersen, B., & Møller, E. B. (2021). Hygrothermal performance of six insulation systems for internal retrofitting solid masonry walls. Journal of Building Physics, 1744259120988745.

What are you going to learn from this project: building performance modeling, learn about conventional and bio-based building envelope composition, envelope design, envelope renovation, local bio-based materials manufacturers.

36. Thermophysical characteristics of biobased building materials for envelope wall constructions

An experimental study will be carried out to determine the properties of local and biobased materials used as construction materials. Wall compositions including cement stabilized compressed bricks will be tested. The thermal properties of lateritic soil-based materials will be determined. The objectives of the work reported in this paper are to determine the effect of the addition of biobased materials on thermal properties. The thermal conductivity and density are measured. The moisture content of these materials and their influence on thermal performance are monitored. Thus a study of the influence of the water content on the thermal conductivity k and the thermal diffusivity α is presented. The thermal diffusivity curve presents a maximum for values of water content. The experimental results will focus on coupling the hygrothermal performance and the strength of samples studied.

Available Dataset: Low ★★
Relevant Standard(s): ISO 9869
Partnerships: Prof. Luc Courard
Methodology: Experimental research and hygrothermal modeling
Relevant Studies:

- Meukam, P., Jannot, Y., Noumowe, A., & Kofane, T. C. (2004). Thermo physical characteristics of economical building materials. Construction and Building Materials, 18(6), 437-443.

What are you going to learn from this project: occupant behavior, building energy modeling

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

Life cycle assessment (LCA) of conventional and bio-based building materials.

Available Dataset: Medium ★★★
Partnerships: Walloon bio-based materials manufacturer
Relevant Standard(s): TOTEM**,** CEN TC350, ISO 14040, and ISO 14044
Methodology: LCA Modeling and Literature Review
Relevant Studies:

-Ben-Alon, L., Loftness, V., Harries, K. A., & Hameen, E. C. (2021). Life cycle assessment (LCA) of natural vs conventional building assemblies. Renewable and Sustainable Energy Reviews, 144, 110951.

38. Sustainability Strategy for a carbon-neutral and circular ULiege Campus

Liege University is working to make the campus more sustainable. However, there is a need for an ambitious strategy of a CO_2 neutral and circular campus in 2030. As the ARI (*administration de resource immobilier*) and other stakeholders continue to develop the campus, your focus will be set on limiting environmental impact. The strategy should be focused on reducing the use of energy and materials (reduce) and by generating as much energy as possible from renewable sources (produce). We reuse materials and products wherever possible (reuse). New materials and products are produced as sustainably as possible. Making the campus more sustainable contributes to a liveable and healthy learning and working environment.

Available Dataset: Low ★

Relevant Standard(s): TBD
Partnerships: Green Office of Liege University
Methodology: Qualitative: Interviews, scenarios building, and modeling: building energy modeling, carbon footprinting
Relevant Studies:
- Udas, E., Wölk, M. and Wilmking, M., 2018. The "carbon-neutral university"–a study from Germany. International Journal of Sustainability in Higher Education.

What are you going to learn from this project: building performance modeling, interacting with the university stakeholders who manage the campus, planning for carbon neutrality.

39. Business models for residential retrofit in Belgium: a critical assessment of key archetypes

The comprehensive retrofit of residential buildings has significant potential to reduce carbon emissions and provide additional health and economic benefits. However, in Belgium, much of this potential is yet to be realized. This study will investigate how the concept of 'business models (BMs) can be a powerful tool for understanding the challenge of improving energy performance and reducing carbon emissions in residential buildings. Through a review of contemporary literature and semi-structured interviews, the study describes and compares distinct BM archetypes: the Energiesprong market model, atomized market model, one-stop-shop, energy services agreement, and managed energy services agreement. These models range from the traditional approach to highly innovative energy service contracts. The study further illustrates how Belgium and the EU market for retrofitting residential buildings are beginning to trial the more innovative BMs. These emerging BMs are characterized by increasingly industrialized processes and integrated supply chains, a holistic customer offering and single point of sale, long-term energy-saving performance contracts (ESPC), and integral project finance.
Available Dataset: Medium ★★★
Partnerships: Guirec Ruellan
Relevant Standard(s):
Methodology: Qualitative Research: Literature review and interviews
Relevant Studies:
-Brown, D., Kivimaa, P., & Sorrell, S. (2019). An energy leap? Business model innovation and intermediation in the 'Energiesprong'retrofit initiative. Energy Research & Social Science, 58, 101253.
-Brown, D. (2018). Business models for residential retrofit in the UK: a critical assessment of five key archetypes. Energy Efficiency, 11(6), 1497-1517.

40. L'élaboration d'une étude sur le phénomène des ilots de chaleur urbains

Face aux enjeux en matière de changements climatiques, les politiques urbaines s'efforcent avant tout de réduire les pressions à la source. Le présent etude a pour objet l'élaboration d'une étude sur les îlots de chaleur urbains (ICU) afin d'en déterminer les causes (directes et indirectes) et les facteurs aggravants et de proposer des actions et recommandations concrètes que la Ville de Bruxelles pourrait mettre en œuvre afin de limiter ce phénomène. Les mécanismes à la base de ces impacts sont néanmoins complexes et leurs effets réels, en milieu urbain, généralement peu connus. En pratique, ceux-ci dépendent de très nombreux facteurs (taille de l'espace vert ou de l'élément verdurisé, densité et volume de la végétation, caractéristiques du feuillage, configuration spatiale des lieux, radiation solaire, vents dominants…). Par ailleurs, la végétation urbaine peut également être à l'origine d'impacts négatifs sur la qualité de l'air (piégeage des polluants sous le dôme de feuillage, émissions de composés organiques volatiles, pollens allergisants). Les gestionnaires urbains sont souvent confrontés à un manque d'informations scientifiquement fondées concernant notamment les mécanismes à la base de ces phénomènes, l'ampleur des impacts attendus ou encore, les conditions ou « bonnes pratiques » à intégrer dans les aménagements afin d'optimiser leur impact local sur les fortes chaleurs et/ou d'éviter d'éventuels impacts négatifs. Cette étude s'inscrit dans ce cadre et devrait permettre d'identifier les causes des îlots de chaleur urbains et disposer de recommandations/solutions précises d'aménagement afin de limiter leurs impacts. L'objectif de cette mission consiste à identifier 10 zones d'étude pilotes touchées par le phénomène des ICU sur le territoire de la Ville de Bruxelles, d'en déterminer les causes et facteurs aggravants et de proposer une série de mesures et d'actions d'atténuation à mettre en œuvre pour pallier ce phénomène.

Available Dataset: Medium ★★
Partnerships: Mk Engineering et Ville de Bruxelles
Relevant Standard(s):
Methodology: Mixed approach
Relevant Studies: