student – student number: Alina Wagner – 5635616
main mentor – second mentor: Dr. Alessandra Luna Navarro - Dr. Eleonora Brembilla

# Reflection

1. **how are research and design related?**

This thesis “Decision-making framework for enhanced thermal resilience of façade-retrofits” investigates a novel framework for the design process of façade-retrofits, which aim for providing thermal comfort during current and future heat waves.

Thereby, the final design of the retrofit is based on the research conclusions altogether: based on a comprehensive literature review, resilience indicators are defined, which introduce the novel method of assessing thermal resilience in façade design during certain disruptive stages. A sensitivity analysis provides further information on the most influential façade variables per resilience indicator. Postprocessing the results, it can be concluded on certain façade variables to be considered, improving the overall performance of the façade or the performance during a certain stage in the extreme heat period.

Thus, the thesis proposes a methodology on how to design based on comprehensive research on the most influential parameters of the façade’s resilience to heat waves. Concluding, research and design are closely linked, with the design as the outcome of the workflow procedure.

2. **how is your graduation topic positioned in the studio?**

The building skin, with its important role at the intersection between the outside and inside environment, strongly influences the indoor environmental quality. However, even though, the design of facades increasingly considers energy and resource efficiency, the design is based on the local typical weather data, resulting in the loss of performance during shock conditions. The extremes of the future however require careful consideration of future challenges, on building- and façade level.

Within the Building Technology Graduation Studio, the thesis is related to both: “Façade and Product Design” and “Climate Design”. The former, focused on the innovation regarding the building skin and its related components. Thereby, design methods for building envelopes are reconsidered, and novel typologies, materials and fabrication techniques are developed. “Climate Design” concerns building climate systems including their energy performance and building installation while putting special attention on user comfort and health.

This thesis rethinks the required methodology for providing appropriate retrofits with sufficient thermal performance in extreme heat. This is in alignment with both, the overall objectives of the “Façade and Product Design” studio, as well as the “Climate Design Studio”.

3. **How did the research approach work out? Did it lead to the results you aimed for?**

In the start of the research process, only the general research objective of evaluating how to assess a building’s thermal resilience during periods of extreme heat is defined. After an extensive literature study, the research approach has been further defined. The inductive research approach leads to then identifies the research gap: the main goal of the further development of the research has been to develop an index combination, that can be used on one hand as a decision-making framework and proposedly also as an evaluation tool for the design of retrofits.

Hence, after deciding on resilience indicators, the building performance simulation methodology has been developed. Applied on a case study building, the outcome is materialised to a retrofit for the specific location of Munich.

The simulation methodology is an extensive process; however, it gives promising results that can be analysed in a reasonable way, providing useful information for the actual design. However, as an evaluation tool, the developed indices need further investigation.

4. **to what extent are the results applicable in practice?**

The methodology of the design process can be used in practice. The procedure can be seen as a guide for decisions, considering the local hazard to heat waves.

However, the actual design of the retrofit would change depending on local building requirements, the outcomes of the analysis of the most important parameters to consider, the building's current state, the programme, occupancy, etc.

Also, the developed final index for the assessment of the building's thermal resilience during current and future heat waves needs further refinement until commonly applicable. The separate resilience indicator indices work as an indication method, but not when used altogether as a rating tool. Hereby, further research is required to normalize the indices appropriately.

5. **to what extent has the projected innovation been achieved?**

The innovation of the thesis lies in the inclusion of multiple resilience indicators, as well as the use of predictive weather data when assessing thermal resilience.

Including multiple resilience indicators during the design process of a retrofit has been shown to be beneficial. The results give a clear indication of which façade properties to consider when optimizing for the façade's performance in one of the resilience stages. They also capture the important realization of contradictory parameter values in different stages of the disruptive period, fulfilling the resilience criteria.

The consideration of predictive weather data as part of the evaluation index needs to be examined in further research. However, also here, the innovation is in the concept to include future weather data in the overall methodology.

6. **does the project contribute to a sustainable development?**

Yes, definitely. Resilient retrofits can contribute significantly to a more sustainable development. In fact, resilience and sustainability are closely linked concepts; both aim to ensure liveable conditions while dealing with current and future challenges.

Thermal resilient retrofits can reduce the need for mechanical cooling, also in future climate conditions. Thus, the energy consumption is reduced.

The developed approach considers carefully what kind of retrofit interventions are needed, which improves a more careful usage of resources, as no materials are used wastefully.

When considering future climate conditions, resilient retrofits improve their adaptive capacity, making them long-term solutions that require minimal revaluation after several years. This reduces the need for additional retrofitting efforts, resulting in material and time savings, thereby enhancing sustainable development.

7. **What is the impact of your project on sustainability (people, planet, profit/prosperity)?**

Improving the thermal resilience of buildings through an improved design process of thermal resilient retrofits can have a positive impact on sustainability in terms of people, planet, and prosperity.

First of all, improving the performance of the building skin during heat waves leads to increased, more comfortable living conditions indoors. The building achieves again a protective function, by reducing the heat hazard level on occupants. Thus, the risk of heat-related diseases is reduced by also improving the overall well-being of the occupants.

With the investigation of the recoverability of the design of the retrofit, the focus can also be put on the night-time recovery. Better sleep conditions are proven to improve occupants' productivity, as well as their personal resilience to heat wave conditions during the day.

The proposed design process is efficient when it comes to the sustainable consumption of materials and resources. Different variants are investigated, leading to the most ideal scenario for the desired outcome in the current and future conditions. Hence, the resulting retrofit reduces the material consumption for further re-retrofitting in future circumstances.

The process aims to reduce the need for mechanical cooling. Even though, depending on the climate, mechanical cooling potentially is still necessary. However, by improving the thermal resilience of the façade in heat wave conditions, the building's energy consumption is reduced.

The reduced energy consumption, and the efficient use of materials, also have an economic benefit. Energy and building materials increase in value and in price due to more and more conscious consumption and the realization of their finite character. Thus, responsible consumption also leads to financial benefits.

With the positive impact of thermal resilient retrofits on the population, the planet, and economics, they do enhance sustainable development.

8. **what is the socio-cultural and ethical impact?**

When commonly applied, the improved thermal comfort standard of buildings during heat waves can affect the socio-cultural environment positively. More comfortable living and working environments contribute to better health, productivity, and overall well-being for occupants, leading to improved quality of life.

With the focus on reducing the heat load indoors in a passive way, the design approach can help fight energy poverty. Energy-efficient buildings, reduce energy costs and thus make a comfortable living more affordable for residents. Thus, enhancing thermal resilient retrofitting supports the long-term mitigation of energy poverty, helping occupants who struggle to afford adequate cooling.

Heat waves are especially dangerous for the more vulnerable part of the population. The approach to introduce an easier workflow of designing for improved building resilience during heat waves, aims to include the objectives in common retrofitting processes. Thus, commonly applicable, the goal would be that social inequalities do not prevent access to retrofit options, providing safe and comfortable living conditions for everybody.

9. **what is the relation between the project and the wider social context?**

   In a wider social context, the project aims to reduce the overall risk of the population suffering from extreme heat. Heat waves count globally as one of the deadliest of occurring weather events. With an immense impact on human health and the increasing dependency on active cooling systems, thousands of deaths are related to heat waves. Especially within the vulnerable groups of the population like the elderly and children, a high morbidity is recorded during heat wave periods. With increased morbidity being the most dangerous impact of heat waves, extreme heat is also influencing productivity and the general well-being of human beings. Improving the thermal resilience of facades during heat events therefore means to improve the general quality of life, but, in the most extreme cases, to save lives.

10. **how does the project affect the built environment?**

    A more resilient built environment means providing secure and comfortable living space that can resist failure, reduce the impact of climate-change-related challenges, and in case, improve the recovery. This includes multiple aspects, tackling extremes of the future: floods, cold snaps, earthquakes, and heat waves.

    This project addresses one of the most important aspects: heat waves are already and will affect the built environment worldwide. However, to improve its impact on the built environment of the future, the consideration of the total risk of all kinds of local hazards is necessary.

    The approach, as presented in the thesis, is important as a thought-provoking impulse. It should be further elaborated on detailed multi-hazard assessments which can potentially improve the overall resilience of the built environment.