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Towards Bridging the Climate Resilience Gap in Building Assessment Systems: An Integrated Framework for the German Built Environment

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To my beloved son Elias and his generation,
This thesis is dedicated to you – the inheritors of our planet's future. May this work serve as both a cautionary tale and a beacon of hope, offering a blueprint for a positive future. It is a future that you, with wisdom and courage, have the power to reshape in a better order than the one we left for you.
With all my love and hope for a brighter, better and nature reconciled world

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Abstract

Climate change is a pressing global challenge that has already made a significant impact in Germany, with a marked increase in extreme weather events over the past century. Addressing climate change adaptation has become a matter of utmost importance. Within this context, this research aims to explore, analyse, and propose solutions for the integration of climate adaptation measures into the German building sector.

The underlying hypothesis driving this research suggests that the current German building performance and rating systems inadequately incorporate climate change adaptation and fall short in numerically evaluating building resilience to climate change. Therefore, to bridge this gap, there is a need for a dedicated numerical climate resilience assessment framework and rating system that capture the interconnected nature of the built environment and align with both international standards and German building practices. Therefore, this research starts by exploring the interplay between climate change and buildings, considering policy perspectives ranging from global to German and Bavarian context. Based on this foundation, the research proceeds to examine how have buildings historically adapted to the climate and assesses the degree of inclusion of climate change adaptation provisions in contemporary German building rating systems, with focus on the energy efficient, sustainable, and smart building rating systems. In addition, the research extends its scope to examine "operational" climate change adaptation and resilience rating systems at both the building and urban scales. The resilience rating systems are analysed and compared in terms of their hazard coverage, alignment with established norms, cross-scale considerations, and accounting method. Through this analysis, the research aims to identify adaptation gaps in the existing rating systems.

Based on these insights, the dissertation shifts its focus to the development of a numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices.

To this end, the research presents a multi sectoral, cross scale urban resilience assessment framework named: Integrated Cross-Scale Urban Resilience Assessment Framework and Rating system (iQRe). The framework merges the IPCC AR5 risk assessment approach with the generic multi-criteria analysis methodology of a sustainability certification system (SB Method), creating a series of agile and quantitative climate impact chains that allow assigning a normalized numerical value to each of the 3 components needed to assess the climate risk (Hazard, vulnerability, and exposure). The developed framework and assessment method is tested on three case study buildings in Bamberg, Germany.

The application of the methodology underscored complex nature of adaptation topics and the necessity of coupling the technical adaptation measures with the stakeholders' administrative responsibilities and the end-user knowledge and expectations. Crucially, the findings from applying the framework identified that the level of maintenance of the existing systems and the level adaptation knowledge, or 'adaptation literacy', among stakeholders are key enabler for the success of adaptation solutions.

Zusammenfassung

Der Klimawandel ist eine drängende globale Herausforderung. Die Anpassung an den Klimawandel ist von höchster Wichtigkeit. In diesem Kontext zielt diese Forschung darauf ab, die Integration von Klimaanpassungsmaßnahmen in den deutschen Bausektor zu erforschen, zu analysieren und Lösungen vorzuschlagen.

Die zugrundeliegende Hypothese dieser Forschung legt nahe, dass die aktuellen deutschen Gebäudebewertungssysteme die Klimaanpassung unzureichend berücksichtigen und bei der numerischen Bewertung der Gebäuderesilienz zu kurz kommen. Daher besteht die Notwendigkeit eines speziellen, quantitatives Bewertungssystems für Klimaresilienz zu entwickeln. Somit beginnt diese Forschungsarbeit mit der Untersuchung der Wechselwirkungen zwischen Klimawandel und Gebäuden vom globalen bis zum deutschen und bayerischen Kontext. Auf dieser Grundlage untersucht die Forschung, wie Gebäude sich an das Klima angepasst haben, und bewertet das Ausmaß der Einbeziehung von Klimaanpassungsbestimmungen in gegenwärtigen deutschen Gebäudebewertungssystemen. Der Schwerpunkt liegt dabei auf energieeffizienten, nachhaltigen und intelligenten Gebäudebewertungssystemen. Durch diese Analyse zielt die Forschung darauf ab, die Berücksichtigung der Klimaanpassung in den bestehenden Bewertungssystemen zu messen.

Der Forschungsumfang erweitert sich um die Untersuchung von bestehenden Klimaanpassungs- und Resilienzbewertungssystemen sowohl auf Gebäude- als auch auf urbaner Ebene. Die Systeme werden hinsichtlich ihrer Gefahrenabdeckung, Ausrichtung an etablierten Normen und Bewertungsmethoden analysiert und verglichen. Basierend auf diesen Erkenntnissen, verlagert die Dissertation ihren Fokus auf die Entwicklung eines numerischen Bewertungssystems für klimaresiliente Bauten, welches sowohl mit internationalen Standards als auch mit deutschen Baupraktiken im Einklang steht.

Zu diesem Zweck stellt die Forschung ein multisektorales Resilienzbewertungssystem vor, das als Integrated Cross-Scale Urban Resilience Assessment Framework and Rating System (iQRe) bezeichnet wird. Dieses Rahmenwerkzeug kombiniert den Risikobewertungsansatz des IPCC AR5 mit der generischen Multi-Kriterien-Analysemethodik des iiSBE Systems und schafft eine Reihe von quantitativen Klimaauswirkungsketten, die es ermöglichen, jedem der 3 Komponenten zur Bewertung des Klimarisikos (Gefahr, Vulnerabilität und Exposition) einen normalisierten numerischen Wert zuzuweisen. Das entwickelte Rahmenwerkzeug und die Bewertungsmethode werden an drei Fallstudien in Bamberg, Deutschland, getestet.

Die Anwendung der Methodik unterstreicht die Vielschichtigkeit der Anpassungsthemen und die Notwendigkeit, technische Anpassungsmaßnahmen mit den administrativen Verantwortlichkeiten der Stakeholder sowie den Bedürfnissen und Erwartungen der Endnutzer zu verknüpfen. .

Contents

List of Figures

List of Tables

Glossary

Term	Definition
AR5	The Fifth Assessment Report
ARI	Average recurrence interval is unit that give the average time between hazards of a certain size. a 100-year ARI flood is flood happing once every 100 years
Forcing	physical process that drives climate on the Earth through a number
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
RCPs	Representative Concentration Pathways
GMST	Global mean surface temperature
KWRA 2021	Klimawirkungs- und Risikoanalyse für Deutschland 2021 (Climate Impact and Risk Assessment 2021 for Germany)
Dry day	Are days with rainfall totals of less than 1 l.m2
GMST	Global mean surface temperature
Tropical night	Is the day with the Tmin >= 20 °C
Hot day	A host day is the day with Tmax >= 30 °C
UHI	Urban Heat Island effect
Strom surge	rising of the sea due to wind and atmospheric pressure changes associated with a storm
Mio	Million
DAS	Deutschen Anpassungsstrategie an den Klimawandel (German Strategy for Adaptation to Climate Change)
LfU	Bayerischen Landesamt für Umwelt (Bavarian State Office for the Environment)
BayKIS	bayerischen Klimainformationssystem (the Bavarian climate information system)
BayKLAS	Bayerische Klima-Anpassungsstrategie
rain erosivity	Soil erosion due to the kinetic energy of of raindrop impact, runoff from snowmelt, or water applied with an irrigation system rainstorm.
PV	Photovoltaic
UN	United Nations
KSG	Bundes-Klimaschutzgesetz (German Climate law)
StMUV	Bayerisches Staatsministerium für Umwelt und Verbraucherschutz (Bavarian ministry for environment and consumer protection)
Forcing	physical process that drives climate on the Earth through a number

GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
RCPs	Representative Concentration Pathways
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climate signal	long-term weather trends and projections that can be traced back to the influences of climate change
Days with alternating frosts	Mean annual number of days with maximum Air temperature > 3 °C. and a minimum air temperature < -3 °C
Heating days	Mean annual number of days with mean Air temperature < 15°C
Cooling days	Mean annual number of days with mean Air temperature > 18,3°C
heavy rain days	Mean annual number of days with a Total precipitation > 25 mm
R- Factor	Erosiveness of precipitation
Sensitivity	the degree to which a system is affected, either adversely or beneficially, by a climate-related signal
PCTL	Percentile
HVAC	Heating, Ventilation, and Air Conditioning

1 Introduction

"Never have the nations of the world had so much to lose, or so much to gain. Together we shall save our planet, or together we shall perish in its flames".
John F. Kennedy, Address Before the general assembly of the United Nations, September 25, 1961

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Human induced climate change is a global concern for the past 50 years [3]. The scientific community has since then voiced the importance of collective action to fend off this threat[4]. Today, the climate change seems to be an unavoidable challenge and a certain reality[5]. This is reflected in the IPCC latest report that concluded that the mean global temperature is **likely to increase beyond the 1.5 °C mark by 2040** even if all the promised GHG reductions of the 2015 Paris agreement are meet by 2030[5]. This alarming fact led the United Nations experts to rank climate change as the greatest existential threat to humanity[6].

One of the reasons for this grim prediction is related to the fact that over 60% of cities are already at risk to one or more natural disasters, and the number is constantly growing[7]. This is particularly significant given the shift of human habitation from rural to urban areas over the last century [8]. placing human settlements, urban environments, and cities at the heart of this threat [9]. Indeed, the built environment and cities occupy a unique position in climate challenge, being both a major contributor to the causes of climate change [10, 11] and uniquely vulnerable to its impacts. Hence, the urban environment is placed at the forefront of the world's efforts to combat and adapt to the looming changes in the Earth's climate[12].

Throughout history, the success or failure of any city has been rooted in successful application and adjustment of the set of laws and norms that governed the interplay between the human built environment and their surrounding natural environment [13]. However, as the climate is expected to change significantly in the coming decades, buildings and the overall built environment will face great risk. They will be challenged to cope with climatic and weather conditions they were not originally designed for. This makes it crucial to re-examine and adjust building performance requirements accordingly.

Local climate has historically been, and will continue to be, a central driving force in shaping the built environment. It significantly influences the design of our buildings and cities, and largely dictates their performance requirements. The building performance requirements and rating systems have evolved over thousands of years in response to technological, social, economic, and environmental factors into six distinct generations, starting from the historical generations such as from (0.0 shelter,1.0 Safe, 2.0 Sanitary) into the contemporary generations that appeared post-1970s (3.0 energy-efficient, 4.0 sustainable and 5.0 smart), each of which developed its unique path in handling and adapting to surrounding climate[14].

In the light of the ongoing climate crisis, it is widely acknowledged that this challenge is best met through an integrated approach[15, 16]. Both adaptation (actions taken to prepare for and adjust to current and future effects of climate change) and mitigation (measures aimed at reducing GHG emissions and land use alterations) should be enforced across multiple time horizons, spatial scales, and administrative sectors[17, 18].

However, existing literature shows a marked bias towards mitigation in current building performance requirements[19, 20]. Several factors contribute to the neglect of the inclusion of climate adaption. For one, the relatively recent emergence and inherent complexity of climate change adaptation and resilience issues, compared to mitigation measures [21]. This is often compounded by the localized nature of the adaptation measures in contrast the universal mitigation actions.

Although mitigation measures and adaptation actions can be complementary, leading to improved building performance across both areas[22-25], these dual benefits are not always fully realized. In fact, if not carefully considered, they can result in maladaptation or underperforming mitigation efforts [19, 26]. The complexity, differing objectives of both approaches limit the dual benefits that can be gained [23]. Additionally, progress in building resiliency remains largely ambiguous, hard to put in clear numbers [19] in comparison to the measurable progress made in mitigation, which uses quantifiable units measuring progress toward zero carbon (CO2-eqv).

Reviewing the majority of current building energy efficiency and sustainability rating systems, like LEED, BREEAM, and DGNB, show that they clearly prioritize mitigation strategies over adaptation[27-29] and fall short of offering the user a numerical quantification of the resilience performance of a building[29, 30]. The same is true of recently introduced smart building rating systems. Furthermore, these systems typically focus on a single urban scale, with minimal consideration for the interdependencies between a building and its urban surroundings.

A building with a platinum sustainability rating will only prove its worth only if it remains accessible and functional during and after a disaster [31]. This means that not only the building specific functions must remain useable but also the wider interconnected urban sectors vital for the building and its users such as transportation, communication, energy and sanitary systems must continue to function, and the supply of essential goods must be maintained[31]. The $19 billion damage the city of New York suffered in 2012 by the storm Sandy represent a bitter and tragic lesson to that regard as both sustainability certified and uncertified buildings were equally damaged[32].

These facts point out to clear gap in the domain of climate adaptation in the existing building performance requirements. Namely, the ambiguous and unclear inclusion of adaptation measures in existing building performance requirements and rating systems as well as the lack of holistic, multisectoral and multi scale adaptation rating system can help to guide users, planners, and policy makers to address and gauge the resiliency gap. Bridging this gap requires development of holistic mitigation and adaptation strategies that address multiple spatial and sectoral scales of the built environment. This research project is an attempt toward bridging these adaptation gaps in Germany's building performance requirements and rating systems and to develop an integrated, holistic, and cross scale approach that allow to assess and rate urban adaptation to climate change.

1.1 Research Problem

Climate change has already begun to make its mark in Germany, with the annual average temperature having risen by over 1.6°C in the past 120 years, and showing no signs of slowing down [33]. Particularly in Bavaria, the annual average temperature has already increased by 1.9 °C[34]. The impacts of these changes in the climate are already being felt both nationally and regionally. For instance, the damage caused by heavy rains, hail, and stormy weather tripled in 2021 compared to 2020, reaching over 12.5 billion euros[35]. the building and construction sector suffered an accumulated monetary loss of about € 98 Billion (when adjusted for inflation) from 1980 to 2018 due to flash floods and heavy precipitation, with over half of these damages occurring between 2008 and 2018[36]. These facts and signs represent a strong a wake-up call for stakeholders to intensify their efforts towards a decarbonized and a climate adapted built environment. By doing so, they can not only secure a better future, but also have the potential to expand the German economy by 2.5% by 2070 [37].

Despite the urgency of the adapting to climate change and the introduction of climate change adaptation provisions into the German building code since 2011 [38], the field of building design and urban planning in Germany has largely followed the global example and gravitated more towards mitigation efforts over adaptation actions.

This is evident in the German government's and EU Commission's approaches to reach climate change targets in the building sector by reducing the carbon footprint of buildings during their operational lifetime[39, 40]. While mitigation measures associated with energy-efficient buildings may have some positive impact on the building's adaptation to climate change, these positive impacts remain, as per the German Strategy for Adaptation to Climate Change (DAS) report, uncertain [41].

Moreover, there is still a massive delay in updating the national DIN norms and standards to accommodate for the new challenges the climate change exerts into the building sector. It is estimated that there are over 3.300 DIN and ISO norms that are related to the building and construction industry [42]. The German Federal Environment Agency (UBA) indicates that as of 2021, only 11, or about 0.01%, of the German DIN norms have been updated to include climate change and adaptation provisions[43].

While recent initiatives like the Qualitätssiegel Nachhaltiges Gebäude – QNG (Sustainable Building Quality Seal) launched as part of the German government's climate protection plan 2030, have aimed to shift the focus from energy efficiency to broader sustainability requirements, there are still limited provisions for climate change adaptation within these systems[27-29]. For instance, climate adaptation performance in the national DGNB system has a marginal impact on the overall building score [30].

Moving from Sustainable to smart, we observe that smart buildings has been proven to be an economically viable climate mitigation option [44] due to their ability take advantage of temporal and spatial scales that extend far beyond the building user and the building physical boundary [45]. However, there is a limited overview of the inclusion of climate adaptation provisions into smart building rating systems and their contribution towards a resilient built environment. This can be attributed to the fact that smart building rating systems are relatively novel and have only started to emerge in the past 10 years [46].

Additionally, the inclusion of climate change adaptation provisions in existing regulations and rating systems, particularly in the energy-efficient, sustainable, and smart building rating systems, remains vague as most systems do not put clearly defined adaption performance requirements for calamite impacts Therefore, the adaptability of buildings to climatic impacts remains speculative, as these rating systems were not primarily designed to measure resilience or adequately prepare buildings for climate change-related impacts. Although these systems are currently spearheading global and national efforts to combat climate change in the building sector, they lack a comprehensive and cross-sectoral approach to addressing the interdependencies and potential cascading effects of climate change impacts within urban environments[19]. Addressing the climate hazards holistically require balancing the climate mitigations efforts with the climate adaptation actions throughout the three urban scales (building, neighbourhood, and district) in a continuous and integrated manner [47].

These deficiencies highlight the urgent need to supplement existing rating frameworks with an integrated cross-scale urban climate adaptability assessment framework rating system and to update regulations and rating systems to incorporate climate adaptation provisions [24, 48].

1.2 Research Objective, scope, and Limitation

This dissertation aims to addressing the research deficiencies highlighted in chapter 1.1, by conducting detailed examination of the current state of climate change adaptation in the building performance requirements in Germany and specifically Bavaria, assessing the size of the existing gap in the performance requirements and rating systems, and offering insights into how it can be effectively bridged via developing an integrated urban adaptation assessment framework and rating system. The inclusion of regional aspects (federal state of Bavaria) in the analysis is necessary because the three case study buildings are located within federal state of Bavaria. Hence, the dissertation objectives are:

- Offer a summary of the global, national (Germany), and regional (federal state of Bavaria) climate change policies and targets in place to avert this threat. Furthermore, the dissertation will encapsulate recent climate change trends and observations, alongside their ramifications at global, national, and regional levels.
- Closely examine the contribution of the built environment to climate change, along with the impacts and risks that the built environment is facing due to climate change in the near and long-term future at global, national (German), and regional (Bavarian) levels.

- Present an overview of the main response strategies used to cope with climate change, followed by a qualitative analysis of the methods and strategies implemented across the five generations of building performance requirements for managing climate and building interactions.
- Conduct a numerical descriptive investigation aimed at rating the inclusion (either directly or indirectly) of climate change adaptation measures within the existing German and international performance requirements for energy efficient, sustainable, and smart building rating systems. This investigation will identify and suggest potential corrections for gaps in current building performance requirements.
- Review existing operational (market ready), change resilience assessment frameworks, comparing them in terms of scale of application, assessment output as well as their compatibility with the general risk assessment approach of the IPCC.
- Develop and Integrated Cross Scale Urban Resilience Assessment framework and rating system which allow to assess and enhance resilience across different urban scales: buildings, neighbourhoods, and districts.
- Test and evaluate the developed framework and rating system to three case study buildings in Bamberg, Germany. These buildings, which serve as youth centres, will provide practical examples for demonstrating the system's functionality, effectiveness, and limitations.

However, this dissertation recognizes the limitations and constraints inherent to this research:

- Although the study aims to provide a comprehensive analysis of integration climate change adaptation measures in building performance requirements, it acknowledges the fast-evolving nature of climate change science and the continuous advancements in building rating system, adaptation measures, which may lead to the emergence of new strategies after the publication of this dissertation.
- Topics such as social justice and socio-economic benefits are not covered in this dissertation. Despite their importance in the general realm of sustainability and resilience, they extend beyond the scope of this study.
- The examination of energy and sustainability rating systems are limited to the German rating systems recognized by the QNG for residential buildings only – as of early 2023- which are: DGNB NKW 13.2, BNB V1.0 and NaWoh V3.1. These systems are expected to be updated in the near future (2024).
- The case studies are geographically specific to Bamberg, Germany, and focus on one type of building usage (youth centres), which may limit the transferability of some findings to other regions with different climates, urban characteristics, socio-economic contexts, and building usages.
- The developed framework and rating system is tested on one spatial scale only, which may limit its immediate applicability to other spatial scales. The system and its application in different scenarios need further exploration and validation.

- The study does not investigate the economic and social feasibility of implementing the developed framework and rating system or the potential market barriers to its adoption. These factors are important considerations for real-world application and merit further research.

Despite these constraints, this study strives to contribute to the ongoing efforts to improve building performance requirements and rating systems for a more resilient and climate-adaptive built environment.

1.3 Research Hypothesis and Questions.

Based on the above-mentioned defined problems and research gaps in the domain of climate adaptation in the building and urban sector, this study proposes the following hypothesis: Current building performance and rating systems in Germany inadequately incorporate climate change adaptation and fall short in numerically evaluating building resilience to climate change. A dedicated numerical climate resilience assessment framework and rating system that capture the interconnected nature of the built environment and align with both international standards and German building practice can over come this shortcomings and supplement existing frameworks.

Answering this hypothesis is guided by the following two main questions:

A. How do buildings adapt to impacts of the climate, and to what extent contemporary (post 1970s) performance and rating systems in Germany integrate climate change adaptation measures?

B. What would be the key features and methodologies of a dedicated numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices?

Addressing these questions will provide insights that either support or challenge the initial hypothesis, contributing significantly to the development of the next generation of building and urban rating and assessment systems in Germany.

2 Bridging the Resiliency Gap: Dissertation Design and Structure

"Don't seek the truth; only cease to cherish the opinion".
Seng-ts'an. The Hsin-Hsin Ming poem, 6th century A.D.

2.1 Research Methodology and Research Design:

This dissertation project employs a research methodology that integrates principles of design thinking[49, 50],suitable for developing innovative and creative solutions for strategic multi sectoral issue [51]. The methodology progresses through four key phases: Problem Discovery and Framing, Problem Analysis, Solution Generation, and Solution Testing and Evaluation as follows:

Problem Discovery and Framing: This phase involves gaining an overview of global, German, and Bavarian climate policy and understanding the implications of climate change. It also focuses on exploring interplay between climate change and buildings, considering perspectives ranging from global to German and Bavarian contexts. This phase sets the foundation for understanding the broader climate change context and its specific implications for the built environment.

Problem Analysis: In this phase, qualitative and descriptive analysis methods are employed to examine the strategies and measures used in building performance requirements to adapt to the climate. Assess the inclusion of climate change adaptation measures in contemporary German building rating system, identify the gaps or shortcomings in the existing requirements and rating systems. Furthermore, existing climate change adaptation and resilience rating systems for the building and urban scale are analysed in terms of their hazard coverage, alignment with established norms, cross scale consideration and rating method.

Solution Generation: Building upon the findings from the previous phases, this phase focuses on the development of the integrated multi scale climate adaptation framework and rating system, which integrates qualitative insights with numerical assessments, The developed system aims to provide an integrated numerical rating system for assessing climate change adaptation in the urban environment.

Solution Testing and Evaluation: The developed framework and rating system is applied to three case study buildings in Bamberg, Germany. The application examines and evaluate the limitations, and applicability of the developed system in real-world scenarios.

Figure 1 illustrates the flow and progression of the research design, depicting how each phase builds upon the previous one to address the research questions and achieve the overall research objectives.

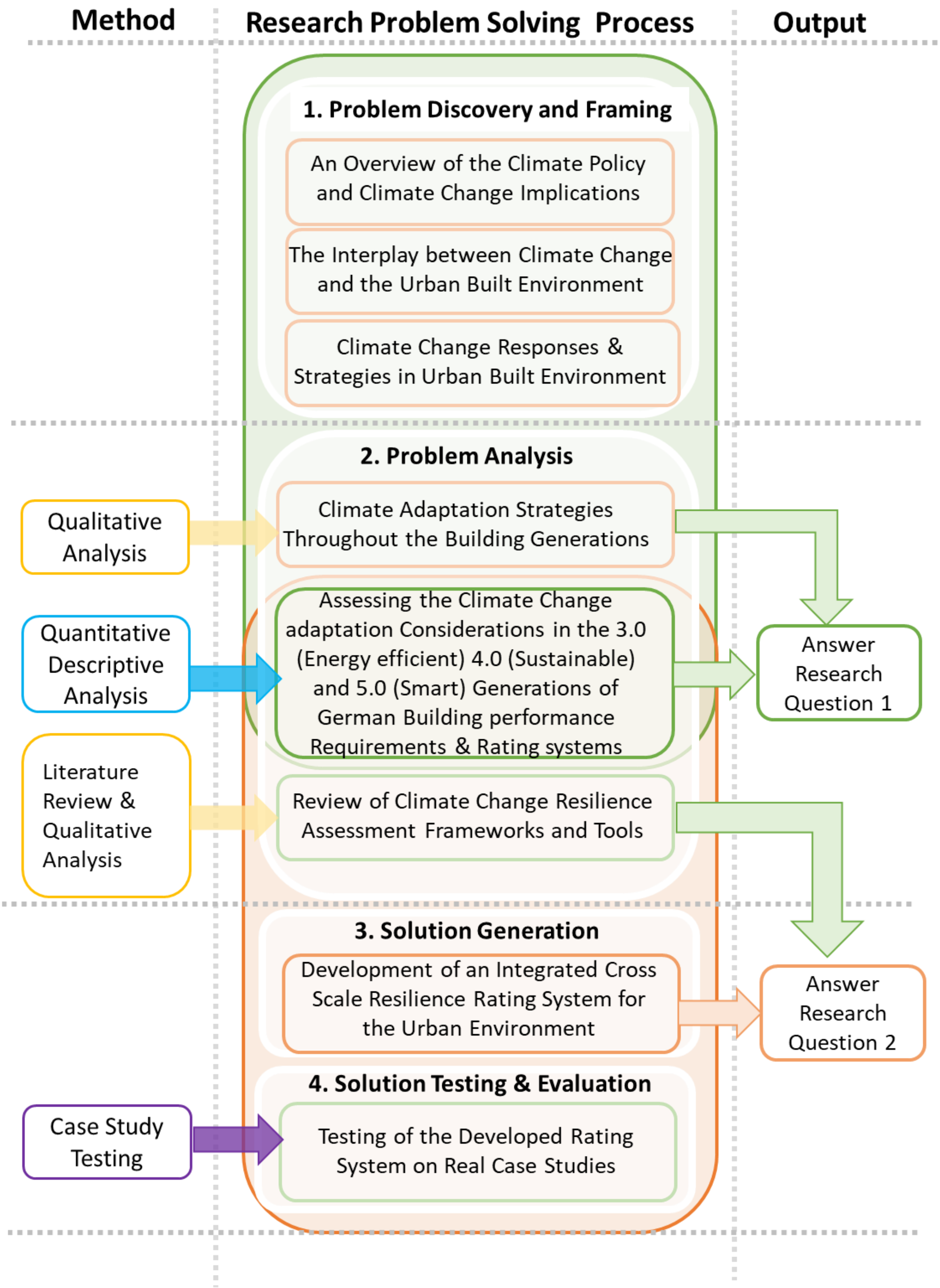


Figure 1: A schematic showing the design of the research project.

2.2 Dissertation Structure and outline:

This dissertation is structured in eight chapter that addresses the main topic: **Bridging the Climate Resilience Gap in German Building Assessment Systems**. It examines the implications of climate change on Germany's construction sector and highlight the urban sectors in which existing rating systems inequality incorporate climate adaptation provisions. Additionally, it proposes an integrated cross-scale rating system based on the risk assessment concept put forward by Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Chang (IPCC AR5) and its translation in the “ISO EN ISO 14091:2021 Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment” standard. The developed iQRe framework is then outlined and tested on three case study sites. As such the dissertation is organized as follows:

- **Introduction, Research Problem, Scope, and Limitation:** This chapter sets the context and rationale for the research. It presents the research problem and questions, hypothesis, and the study's significance. It helps readers understand the key research questions that the study seeks to answer.
- **Bridging the Resiliency Gap: Research Design and Structure:** The methodology chapter underpins the research approach and details the steps followed during the investigation. It gives the research its validity and reliability, helping readers understand techniques used in conducting this research, and the path used to fulfil its objectives.
- **From Policy to Reality: An Overview of the Climate Policy and Climate Change Implications:** This chapter offers an overview of climate policy, targets, and regulatory frameworks starting from the global view, then moving into the German and Bavarian scales. It adds contextual knowledge about the policy landscape that shapes legislative environment and the real-world implications of climate change.
- **The Climate-Built Environment Nexus: The Interplay between Climate Change and Buildings**: Chapter five explores the relationship between climate change and the built environment. It provides crucial information on how buildings contribute to climate change and impacts globally, and the specifics for the German and Bavarian built environments and building sectors. It forms the basis for understanding the adaptation strategies required in building performance.
- **Gauging the Gap: Assessing Climate Change Adaptation in German Building Performance Requirements Across Multiple Building Generations**: This chapter offers a comprehensive assessment of climate change adaptation strategies in building performance requirements across different building generations. It provides a chronological and systematic understanding of the evolution of the climate adaptation strategies in the building performance requirements. The chapter combines qualitative and quantitative assessments of the direct and indirect inclusion of climate change adaptation strategies in the contemporary German building performance requirements. The findings of the chapter provide an answer to the first research question and set the scene for the second part.
- **Climate Change Resilience Assessment Frameworks and Tools: A Review:** This chapter conduct a review of various climate change resilience assessment frameworks and tools. It offers a comparative understanding of different approaches, which forms the basis for answering the second research question as well as the development of the urban resiliency framework and rating tool.
- **Addressing the Climate Resiliency Rating Gap: The iQRe Framework and Its Application on Three Real Case Studies**: This chapter is the heart of the dissertation This chapter presents the developed framework and its application assessing climate change resiliency in the built environment based on three real case study sites in Bamberg; Germany. The chapter attempts to links theory to practice, offering practical insight into how climate change adaptation strategies can be applied and evaluated in real-world scenarios. The findings of the chapter provide the framework need to answer to the second research question.
- **Closing the Gaps, Concluding the Journey: Views on Germany's Building Performance Requirements for the Post 2° era**: The final chapter draws the research together, providing a synthesis of the findings and summary of the answers found for each research question. It also puts forth recommendations for further research into the building performance requirements in a post-2°C scenario.

3 From Policy to Reality: An Overview of the Climate Policy and Climate Change Implications

"The greenhouse effects have long time consequences, if you don't worry about them now, it is too late later on and we are passing on extremely grave problems for our children"
Prof. Carl Sagan, testifying before Congress in 1985 on climate change.

Life on Earth is a testament to, and a gift from, its climate, providing the essential conditions that guide the survival, evolution, geographic spread, and extinction of countless species. In contrast to weather that can change by the hour, climate is about the long-term prevailing weather condition in certain location. This climate system is a delicate, solar-powered system; its intricacies are dependent on the equilibrium of solar radiation energy. This balance is subject to disruption from both natural phenomena such as volcanic eruptions and anthropogenic influences including changes to land cover and heightened greenhouse gas emissions[52] leading to change in the climate. A relation that was first discovered in late 19th century by Arrhenius [53]. The consensus in the scientific community today acknowledges a significant tilt in Earth's solar energy balance, predominantly driven by a steep increase in anthropogenic factors such as rapid alterations to land cover and escalating emissions of greenhouse gases (GHG) [52].

This shifting climate is perceived by many as humanity's greatest existential threat [54]. Addressing, averting, and understanding its consequences have become primary objectives in global conventions and policies in the past 30 years.

This chapter aims to offer a synopsis on the global, national (Germany) and regional (federal state of Bavaria) climate change polices and targets in place that aim to avert this threat. In addition, it will encapsulate recent climate change trends and observations, alongside their effects at global, national, and regional levels.

3.1 Climate change policy: An overview of Global climate targets and regulatory frameworks

The recognition of the daring consequence of the human action on the climate started to came to light in the scientific community late 1950s [3]. Nevertheless, it wasn't until the late 1980s that serious steps were taken at the global arena[55] leading to the establishment of The Intergovernmental Panel on Climate Change(IPCC) [55]. In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) commonly known as the "the Earth summit" was held in 1992 in Rio de Janeiro with the objective **"to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system**[4]. [56]. Many climate conventions known as COP (Conference of the Parties) followed afterwards with limited global effect. The COP 21 held in 2015 in Paris can be viewed as an exception. COP 21 resulted in into the adoption of the Paris agreement which superseded the Kyoto protocol and established the **world goal of limiting the mean global temperature to below 2 °C mark above pre-industrial levels**[57].

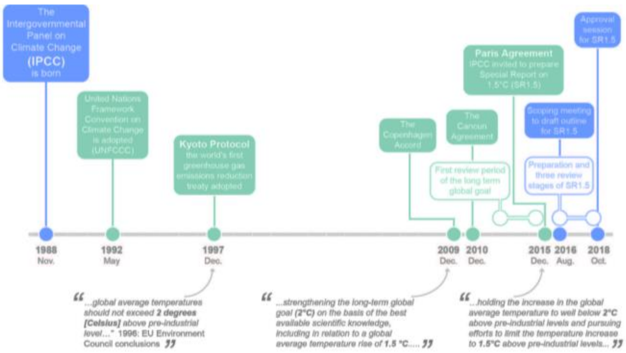


Figure 2: Timeline of notable climate policy agreements and global warming targets[57]

3.1.1 The German Climate Change Policy and Targets

Following the Paris agreement of 2015, Germany acted swiftly and adopted in 2016 a national climate change action plan that correspond to the Paris agreement and European climate targets. These targets where then further tightened with in introduction of The Federal Climate Change Act (Bundes-Klimaschutzgesetz) or (KSG) in 2019 in which the country pledged to reduce its carbon output by at least 55% relative to 1990s values. However, in March 2021, the Federal Constitutional Court deemed that reduction targets are insufficient and present a breach to the state obligation to protect life and physical integrity in the state[58]. Hence, the German **climate targets were amended again in 2021 setting a GHG emission reduction target to 65% in 2030 and by 88% in 2040 relative to the levels of 1990**. Furthermore, the KSG aim reach climate neutrality by 2045 and negative GHG emission from 2050 onwards [59]. To achieve this ambitions targets, the KSG Act splits the GHG emission targets between the following major GHG emission source sectors which are: energy, buildings, transport, industry, agriculture, waste and other. For each of these sectors the KSG allocate an annual GHG emission budget up to the year of 2030 as illustrated in Tabell 1[59].

Table 1: KSG Permissible annual emission budgets for the years 2020 to 2030 per sector

emission budgets per sector in (million tonnes of CO_2 eqiv.a)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy	280		257								
Industry	186	182	177	174	165	157	149	140	132	125	118
Buildings	118	113	108	102	97	92	87	82	77	72	67
Transport	150	145	139	134	128	123	117	112	105	96	85
Agriculture	70	68	67	66	65	63	62	61	59	57	56
Waste and Other	9	9	8	8	7	7	6	6	5	5	4

3.1.2 The Bavarian climate protection offensive

The Bavarian Climate Change Act of November 2020 was amended in November of 2021 to follow the same emission targets of the Federal Climate Change Act. As a result, Bavaria has set itself the goal to reach a 65% reduction in GHG emissions by 2030 relative to the GHG emissions of 1990 and to **become climate-neutral state by 2040**[60].

To achieve the Bavarian state climate change targets the Bavarian cabinet adopted climate protection offensive [60] which consist of a five-point plan with around 40 measures. The climate offensive plan is based on three main pillars: **the reduction of greenhouse gases**, **the adaptation to the consequences of climate change and boosting the research and development**.

3.2 Climate Change: Observations and Implications

The Intergovernmental Panel on Climate Change (IPCC) is the world climate change assessment centre. Since its establishment in 1988 , the IPCC released a number of assessment reports about the state of climate change starting with the first report in 1990s [3]. The fifth assessment report published by the IPCC in 2014 documented **an increase in the global mean surface temperature (GMST) by over 1°C in comparison to early 1900s** and the trend is increasing[61]. The IPCC report concluded that the observed changes in the climate are primarily induced by the human activities (anthropogenic forcings) that accelerated in the past 100 years [61]. This includes the excessive release of GHG due to the over reliance on fusile fuel as the primary energy source as well the rapid change in land use and landcover due to deforestation and urbanisation [5, 52, 61]. The IPCC Sixth Assessment report which was partially published by the time of writing (April 2022) concluded that the mean global temperature is **likely to increase beyond the 1.5 °C mark by 2040** even if all the promised GHG reductions of the 2015 Paris agreement are meet by 2030[5]. Therefore, the IPCC call upon the world to prepare for the unfolding of new climate system in which the weather extremes would occur more often[5].

To forecast the climate's future, the IPCC uses simulation models based on four Representative Concentration Pathways (RCPs) scenarios. The RCP2.6 scenario assumes that CO2 emissions will decrease and reach carbon neutrality by 2100, limiting the GMST rise to below 2°C and sea level rise to 40cm[61]. The RCP3.4 scenario is an intermediate scenario with less strict mitigation efforts, projecting a 2.2°C GMST rise and a 56cm sea level rise by 2100, which is the most likely scenario according to recent publications[62]. Next is the **RCP pathway of 4.5** W m^{-2} , which predicts that the GMST will rise to 3°C by 2100leading to a remarkable increase in of sea levels and wide spread extinction of flora and fauna[61]. According to Deloitte, the world can face an **economic loss of about US$178 trillion between the years 2021 and 2070** in case RCP pathway of 4.5 became a reality [63].

The last RCP is the **RCP pathway of 8.5**. This pathway basically represent the worst-case scenario as it is expected that the earth GMST well go north of 5°C making life on earth unbearable [61].

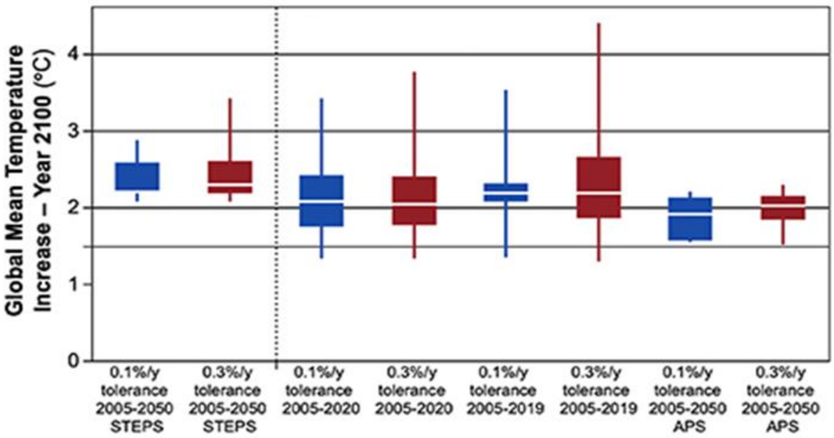


Figure 3: Expected increase in the GMST by year 2100 under the RCP 3.4 path[62]

Regardless of the RCP pathway humanity will follow in the future, the IPCC Sixth Assessment concluded that the climate change has already **caused a wide range of negative impact on vital human systems such as water security, food production, health, and wellbeing as well damages to urban areas and infrastructure**. The following figure (Figure 4) produced by IPCC Sixth Assessment report, illustrates the observed impacts of climate change on key human systems globally and regionally. The direction and trend of these impacts are represented by the symbols '+' and '-', where a '-' indicates an increasing adverse impact, and a '±' signifies that both adverse and positive impacts have been observed within a region or globally. The colours in the figure indicate the confidence level assigned by the IPCC (Intergovernmental Panel on Climate Change) when attributing the impact to climate change. Deep purple represents a very high confidence level, grey indicates low confidence, and white indicates insufficient evidence.

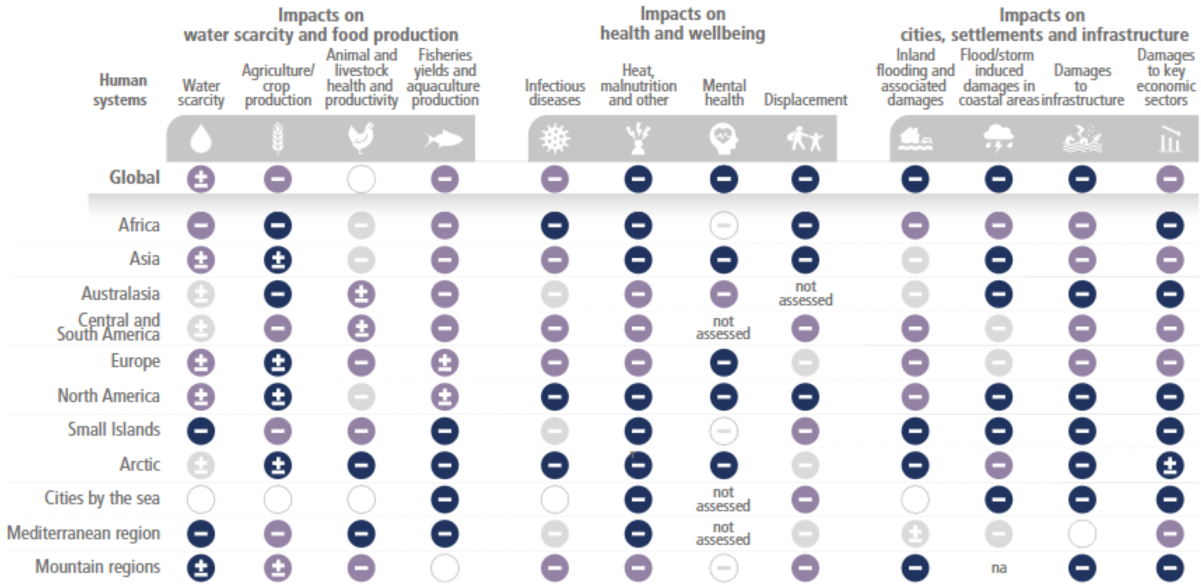


Figure 4: The IPCC assessment of observed global and regional impacts of climate change on human systems [61]

3.2.1 Climate Change Trends and Implication in Germany

The German Environment Agency published in 2021 its revised climate change impact and risk assessment for the federal state, abbreviated as KWRA 2021 [33]. The KWRA 2021 objective is to examine and evaluate the risks related to climate change in Germany and provide the state with the necessary basis for the further development of climate change adaptation actions and direct the climate change research in Germany. Table 2 provides an overview of the expected change in the in average values of climate singles in Germany.

Table 2: Expected change as per the in average values of selected climate signals for the whole of Germany for both the middle (2031 to 2060) and end of the century (2071 to 2100) compared to the reference period(1971 to 2000), as per the RCP8.5 scenario[33].

Selected climate signals	Average values reference period (1971-2020)	Expected change as per RCP8.5 in middle of century period (2031-2060)	Expected change as per RCP8.5 in end of century period (2071-2100)
Annual average air temperature	8.6 °C	+2.2 °C	+4.7 °C
Average air temperature in summer	16.6 °C	+2.3 °C	+5.0 °C

Average air temperature in winter	0.8 °C	+2.5 °C	+4.8 °C
Number of hot days per year	4.6 d	+10.3 d	+27.8 d
Number of tropical nights per year	0.1 d	+2.7 d	+16.2 d
Average annual precipitation	774 mm	+10%	+15%
Number of dry days	236.1 d	+11.9 d	+19.8 d

Regardless of the RPC path that is to dominate future, the KWRA 2021 confirmed that **Germany's annual average temperature has already risen by 1.6°C higher** from 1881 to 2020 and the trend continues (see figure 5).

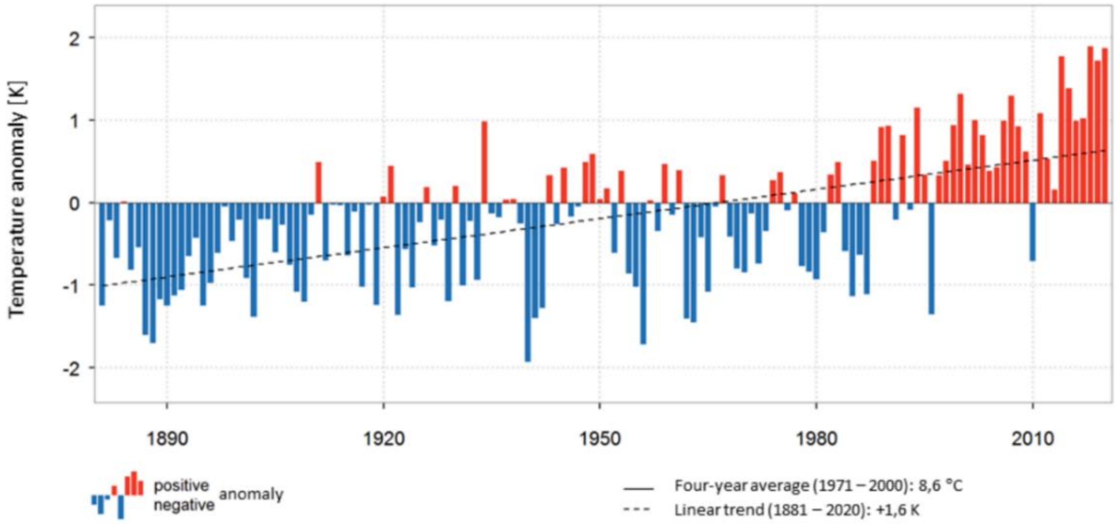


Figure 5: Deviation in Germany's annual average temperature between 1881 and 2020 from the reference period (1971-2000)[33].

The German weather service (DWD) confirms this increase as DWD data show constant increase in number of "hot days" (days with maximum temperature ≥ 30°C) registered across Germany. Similar trend is also observed in the number of "tropical nights" during which the temperatures do not drop below 20°C [41].

The effect of the increased summer temperature is felt mostly in cities and urban areas as the Urban Heat Island effect (UHI) exacerbates the temperature increase which **can reach up to 9 Kelvin** [41]. The trend is expected to increase in the future as the supply of green and recreational areas has been declining in recent years throughout Germany especially in metropolises and large medium-sized towns[41]. An increase in the GMST that is amplified with the UHI, and loss of green areas will expose urban areas and city dwellers to very hight heat loads that can impact both the personal health and the health care system alike. For example, the **heatwaves that occurred in 1994 and 2003, caused 10200 and 9600 fatalities** respectively[64].

Moreover, Germany is observing an increase in the number of registered allergic reaction cases and invasive insect species, which is attributed to the change in climate [41]. Freshwater resources are declining in Germany due to increasing periods of below-average groundwater levels and reduced spring and river discharges. Climate change, poor urban planning decisions, and unsustainable urban development practices are contributing to an increase in flood events [41]and storm surges[65]. Flash floods are becoming more frequent and causing significant damage to cities and urban areas [41]. For example, the 2016 flash flood in the town of Braunsbach caused over 112 million euros in material damage[66].

In general it is expected that the **German GDP might shrink by 0,6% annually between 2021 and 2070 in case the global annual mean temperature increased by 3°C** by the end of the century[37]. However, **in case if the decarbonization targets are achieved** by 2050, it is estimated that the **German economy can expand by 2.5 % by 2070**[37].

3.2.2 Climate change trends and implications in Bavaria

Similar to the KWRA, the Bavarian State Office for the Environment (Bayerischen Landesamt für Umwelt (LfU)) periodicity publishes it climate change impact and risk assessment for the Bavarian state .To account for the heterogeneous nature of the Bavarian climate, the LfU divides the **Bavarian state into seven climatic regions** based on their temperature and precipitation profile[34] as depicted in Figure 6 .

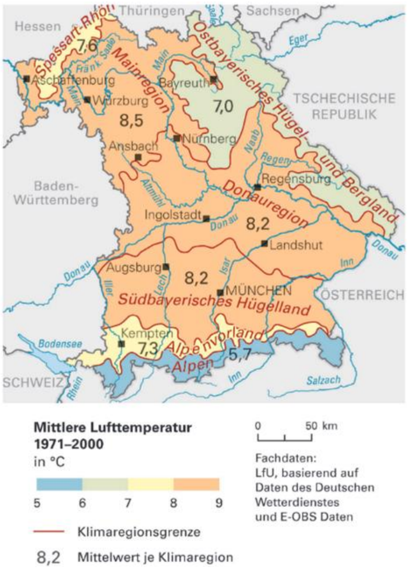


Figure 6: Map showing the georgical boundaries and the mean air temperature in each of the seven climatic regions of Bavaria[34].

The Bavarian climate report of 2021[34] confirms the warming trend observed nationally and globally. According to the statistical analysis of the mean annual temperatures, **a warming trend of +1.9 °C from the period of 1951to 2019 in the Bavarian state** is observed. As the GSTM continue to rise the LFU expect the following climate change impacts in Bavaria by 2050 to the following areas (see the figure 7) [67]:

- Cluster 1 (red): High flood potential and risk of damage to agriculture and transportation in alpine regions
- Cluster 2 (blue): Urban areas with high sensitivities to climate change, increased cooling energy demand
- Cluster 3 (green): Counties strongly affected by flooding in construction, industry, commerce, and transport.
- Cluster 4 (purple): Urban districts at high risk of flood-related impacts

- Cluster 5 (orange): Areas exposed to frost and climate change impacts in forestry.
- Cluster 6 (yellow): Agricultural areas at high risk of flooding.

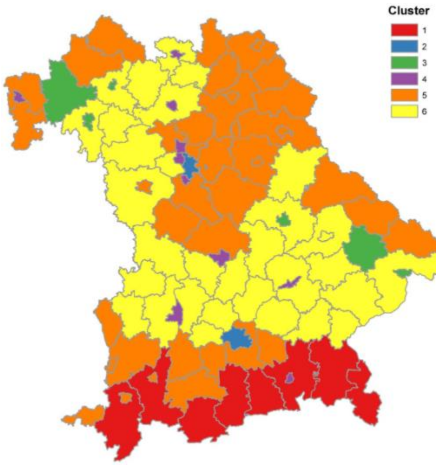


Figure 7: the LFU Map showing the six clusters and of the expected climate impacts in 2050 [67]

The Bavarian climate report of 2021 stated that extreme weather events such as heavy rain, hail, drought, or storms are becoming more often in Bavaria, which is causing significant human and material losses. For example, the damage resulted from unusual heavy rain and stormy weather in 2020 reached 415 million Euro[35]. This **number jumped to around 1.5 billion Euro in 2021 and the trend is expected to continue** [35]. Ernst Rauch from Munich Re blames three factors for the ever-increasing damage:

- First, the increase in the frequency and intensity of natural events.
- Second, the increase in material assets due to an increase in the building stock.
- And third, the sensitivity of the buildings shells due to the **wide spread use of external Thermal Insulation Composite Systems (ETICS/WDVS) which is making the building shell softer and susceptible to damage** [35].

To prepare the Bavarian state for the for the implications of the climate change, the Bavarian climate adaptation strategy of 2016 (BayKLAS) [68] **outlined 15 action fields in which climate change adaptation and mitigation measures are required to minimize the negative effects of climate change and seize possible development opportunities**.

The climate report of 2021[34] paints a rather dark picture about the expected effect of climate change on all the 15 actions fields all over Bavaria with effects such as decreased river discharges[69], low water levels[70], increased flood risk, and challenges for agriculture and forestry due to decreased rainfall and rising temperatures[71]. Climate change is also expected to negatively impact human health[72], as it can lead to an increase in cardiovascular diseases[73], eye diseases[74], respiratory diseases[75], mental illnesses [76], Allergies [77, 78], and the spread of infectious diseases [79, 80]. The climate change will lead to increased costs for transport[68]. The energy production and distribution are going to be strained as the **raising temperature would lead to a reduction in the PV systems efficiency** and the increasing fluctuation of wind speeds would also reduce the predictability of the amount of energy that can be produced from wind. Hence, increasing the burden on the energy network operator and the load management systems [81]. However, the climate change is expected to have a positive impact on the summer tourism sector. Nevertheless, one must keep in mind that the expected expansion of the summer tourism can lead to increased pressure on other clusters such as water, energy, health if the stainability and climate resilience principles are not followed rigorously.

The climate change is also going to increase the pressure on both private and global finances. Damages to private residential and non- residential buildings are expected to increase due to increase in extreme weather events. This will lead an increase in insurance rate of buildings[82, 83]. A topic that will be discussed in more detail in next chapter.

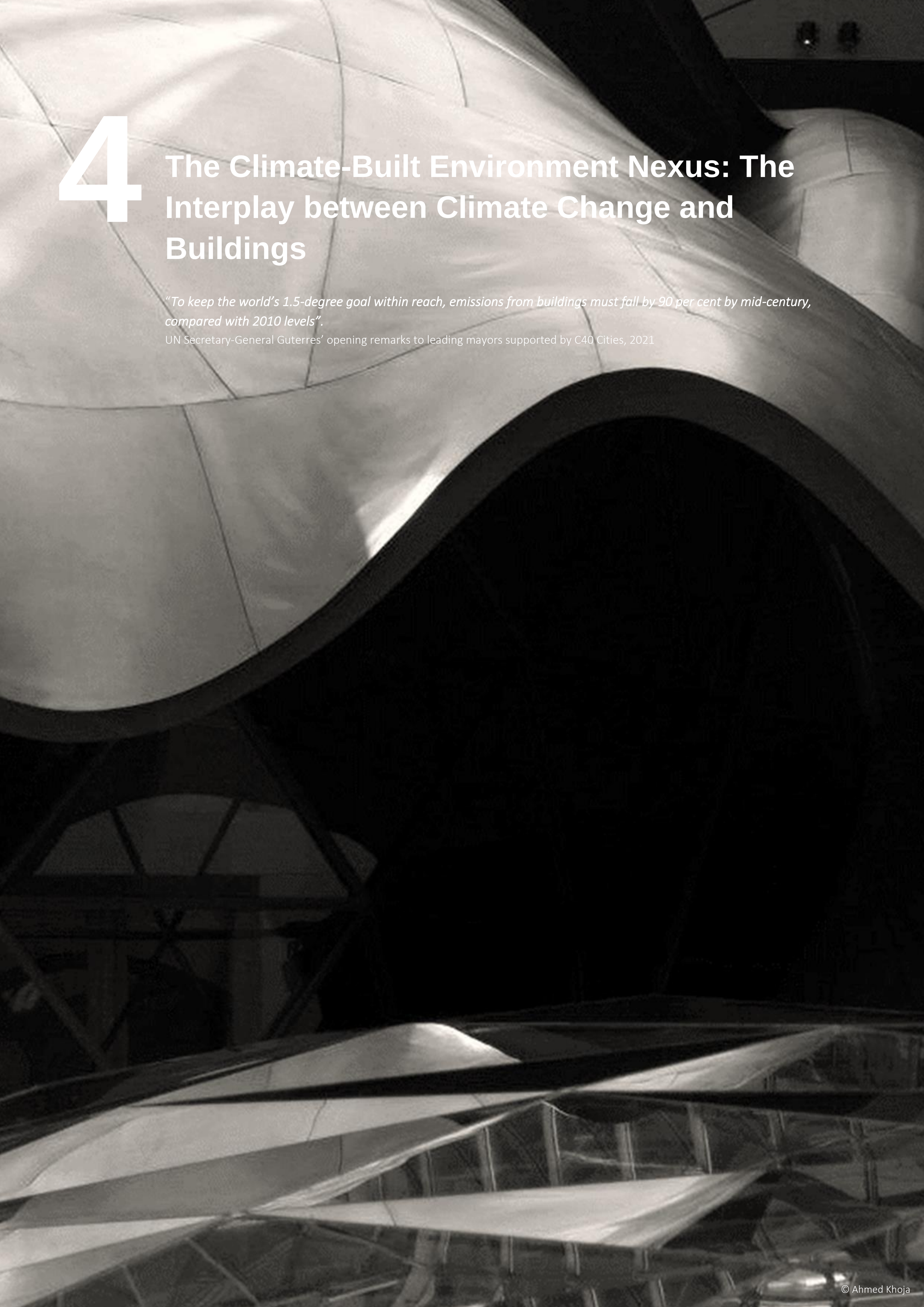
3.3 Chapter Insights and Key Findings

The review made in this chapter showed that the world is committed to stabilizing greenhouse gas concentrations to prevent the consequences of anthropogenic forcings on the climate system. However, despite that, recent IPCC observations showed that these efforts were insufficient to prevent global warming beyond the critical 1.5°C mark by 2040, which was the target set in the Paris Agreement. Germany and Bavaria have implemented aggressive climate policies with ambitious targets for CO2 reduction, but it is difficult to evaluate their effectiveness as they have only been in place for a short period of time. It is important to note that the effort needed to achieve the carbon neutrality target of 2050 is global and cannot be carried by single nations or regions. As it was pointed out above, it may already be too late to halt climate change and an equal focus should be on giving to adapt the upcoming era. The impacts of climate change are already causing irreversible damage to ecosystems and have negative effects on freshwater, health, and urban development. Although the situation appears gloomy, this is not a lost battle, but a wake-up call for stakeholders to intensify their efforts towards a decarbonized world. A goal that cannot just save lives and secure future but can also help expand the German economy by a wifty 2.5 % by 2070 [37].

4 The Climate-Built Environment Nexus: The Interplay between Climate Change and Buildings

"To keep the world's 1.5-degree goal within reach, emissions from buildings must fall by 90 per cent by mid-century, compared with 2010 levels".

UN Secretary-General Guterres' opening remarks to leading mayors supported by C40 Cities, 2021



City Planners have always considered the dynamic nature of environmental and climate conditions in their planning processes. However, climate change is intensifying these changes, making them more extreme, persistent, and rapid compared to past experiences. Consequently, the built environment is confronted with new and challenging climatic parameters for which it was not originally designed. This compromises the resilience of the built environment, leading to suboptimal performance in the face of climate change impacts. Furthermore, the limited and slow implementation of adaptation measures exacerbates the risks associated with climate change hazards [84]. Given the built environment's dual role as both highly vulnerable to climate change impacts and a significant contributor to its causes, it is expected to play a pivotal role in global efforts to combat and adapt to climate change [9].

Therefore, the objective of this chapter is to closely examine the contribution of the built environment to climate change and the impacts and risks that the built environment is facing due to climate change. The chapter begins with a global perspective on the issue in subchapter 4.1 and then narrows down its focus in remaining subchapters to the German and Bavarian built environments in order to provide a closer look at the contributions of to climate change and the climate change impacts that they are expected to deal with in the short- and long-run.

4.1 The Contribution of Built Environment to Climate Change and the Expected Impacts: A Global Perspective

The unique problem that climate change impacts bring with it, is that its impacts will affect a broad spectrum of the built environment physical and social sectors that are highly interrelated [85]. Thus, for the adaptation measures to be truly successful they need to be equally holistic incorporating many sectoral, spatial, and temporal scales. To better understand the impacts of climate change on the urban environment Chapter eight “Urban areas” of The IPCC fifth Assessment Report breaks down the built environment into fourteen “**Key urban sectors**” that are exposed to one or more climate change related impacts. They are: **Coastal zone systems, Human wellbeing, Ecological infrastructure**, **Water, waste water and sanitation systems, Green and blue infrastructure**, **Energy systems**, **Food systems and security**, **Transportation sector, Social and civil services Communication systems and Buildings, Structures, recreation areas and heritage sites**[85].

It is crucial to recognize that nearly all key urban sectors identified by the IPCC, which are susceptible to various impacts of climate change, are either located within or closely connected to the built environment. Buildings often serve as origins or destinations for these sectors, including water, energy, and transportation networks. Moreover, buildings are known to be significant drivers of climate change due to their high land use consumption, soil sealing effect, substantial resource and energy demands, and associated greenhouse gas (GHG) emissions[86]. Indeed, the estimates of the International Energy Agency (IEA) for **the year 2019, show that about 35% of the global final energy is consumed by the building and construction sector resulting in the emission 38% of global CO_2** emissions (see figure 8) [87].

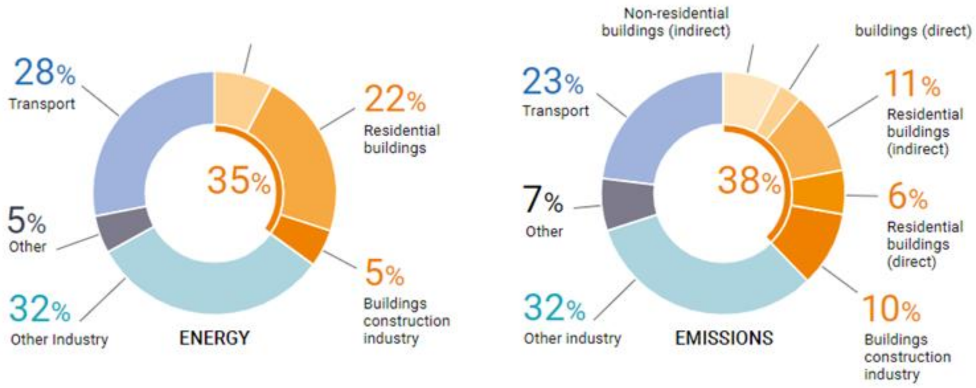


Figure 8: Global share of buildings and construction final energy and emissions in 2019[87]

Addressing the climate crisis challenges solely at the building scale would be insufficient. Buildings do not exist in isolation but are integrated components of the broader built environment. Therefore, effectively tackling climate change issues within the built environment necessitates the merging of various temporal, social, and spatial scales, as well as the involvement of diverse institutional actors that extend beyond the physical boundaries of individual buildings [88]. In fact, some scholars argue that achieving true sustainability and climate adaptability requires going beyond the spatial, social, and temporal limitations of the building scale[89].

Improving the sustainability of the built environment around the world is a key strategy to mitigate the climate change and to reach the UN Sustainable Development Goals. The global Greenhouse gas (GHG) emissions target foresee halving the global GHG emissions by 2030 and reducing it to zero by 2050 [90]. For the building sector this means avoiding 50% of projected energy consumption growth [91]. Given the fact that the majority of the existing building stock was built before the introduction of formal energy performance requirements [92, 93], and that over 75% of these inefficient buildings will still be in use post 2050 [94], buildings represent the largest untapped source to CO_2 reduction[95, 96]. In Europe, renovating the existing building stock is considered as the "*make or break"* element [12] in achieving the recently adopted Green Deal program goal of reaching a net zero GHG emission by 2050 [97]. Nevertheless, the IEA estimates of 2022 shows that building sector remains to date far from achieving the carbon neutrality target by 2050[98].

Beyond energy and emissions aspects, the building sector is also a major consumer of other vital resources that can directly or indirectly extrapolate the negative impacts of climate change. For example, 40% of global raw materials are consumed in the building and construction sector[99]. In the water sector, the building and construction sector consumes about 17% of water resources [99]. Similarly, 30% of solid global waste is generated from the building construction and demolition sector[100]. Thus, the building sector can, when treated in isolation, exert an increasing pressure on many of the already fragile eco and man-made systems that are threatened by negative consequences of climate change.

Renovating the existing building stock and planning new ones with climate change mitigation and adaptation considerations in mind can have many socioeconomic co-benefits that extend beyond the building and construction sector[86, 101]. This fact highlights the multi sectoral nature of climate change in the building and construction industry. For instance, from a macroeconomic perspective, the investments in building renovations can generate higher tax income to municipalities and reduce unemployment. It is estimated that for each €1 million invested in the energy renovation of buildings between 11 to 19 new jobs are being created [102]. Moreover, a study by Copenhagen Economics estimates that the energy efficiency renovation can reduce outlay on government subsidies as well as increase annual net revenue gains to the EU public finances by €30 – 40 billion by 2020 [103]. Improving the building energy performance can contribute significantly to improving the indoor climate conditions [104]. This, in return, would lead to fewer sick leaves, fewer hospitalisations and improved worker productivity as well as better chance for the building to withstand a warming climate and heatwaves[101]. Reducing and decarbonizing the building energy consumption, can lead to reduced local government expenditure on mitigating the outdoor air pollution and improved local revenues due to increased productivity[101]. The IPCC AR5 chapter 8 buildings provides a detailed overview of potential co-benefits and adverse side-effects associated with mitigation and adaptation actions in buildings[86]. This list can be viewed in annex 1 of this research.

The mentioned co-benefits examples highlight the cross-sectoral and cross-spatial nature of climate change. For the building sector this underpins again the importance of thinking beyond the building physical boundaries in temporal, spatial and sectoral sense when tackling the impacts of climate change on the building sector and the greater urban areas.

4.2 Climate Change and the German Built Environment and Building Sector: Contribution and Impacts

In Germany, the total GHG emission released from of the building sector during the construction, in-use, renovation and demolishing life cycle phase was equal to 362 million tonnes of CO_2 equivalent in 2014, which is about 40% of the total CO_2 emissions in the country [105]. The amount of CO_2 emissions emitted during the in-use phase alone was equal to 119.4 million tonnes of CO_2 equivalent or around 14% of the total emissions as per 2020 estimates [106]. Although this number represent an impressive 43% reduction of GHG emissions in comparison to the values of 1990[107], a further massive reduction of about 45% is needed to reach the government GHG target of 67 million tonnes CO_2 equivalent by 2030[59]. Its noticeable that 76% of these emissions are generated by residential buildings, while the rest (24%) is generated from commercial and military buildings[107]. This can be explained by the fact that about only 4% of the residential building stock was built after 2011[108]. Meaning that most of the residential building are built before the widespread implementation of the strict energy requirements of the Energieeinsparverordnung (EnEV) of 2007. Bearing in mind the relatively low retrofitting rate of the residential buildings that hover at around 1% annually, achieving the 45% CO_2 reduction in the building sector in the coming few years seems to be very unlikely [109]

The impacts of climate change on the German building sector are already being noticed. According to the report of the German environmental agency, extreme weather events such as flood, flash floods and heavy precipitation caused a damage of about€ 98 Billion when adjusted to inflation) during the period spanning from 1980 to 2018, of which more than half of the damages occurring in the last ten years[36].

To monitor the effects of climate change in Germany, the government lunched the German Strategy for Adaptation to Climate Change(DAS)[110]. The DAS monitoring indicator system comprises a total of 105 monitoring indicators, 56 of which describe the effects of climate change (impact indicators), 44 adaptation measures or activities and conditions that support the adaptation process (response indicators). For the building and construction sector, the DAS developed five impact and five response indicators. The five impact indicators designed to monitor the level of climate change hazards to buildings are:

1. BAUI1: Heat energy load in cities.
2. BAUI2: Summer heat island effect.
3. BAU-I-3: Cooling degree days (days with average. temperature above 22°C)
4. BAU-I-4: Heavy rain in the settlement area.
5. BAU-I-5: Claims in property insurance.

According to the DAS monitoring report of 2019, a negative development can be observed across all the impact indicators[41].

One the response or adaptation side, the DAS five response indicators are:

1. BAU-R-1: Recreation and green areas.
2. BAU-R-2: Green roofs on federal buildings.
3. BAU-R-3: Specific energy consumption of private households for space heating.
4. BAU-R-4: Subsidies for climate change-adapted construction and renovation.
5. BAU-R-5: Extended insurance against natural hazards for residential buildings.

The DAS reports a mixed picture about the development of the five response indicators in the building action field.

For the recreation and green areas indicator (BAU-R-1), the supply of such areas has been declining in metropolises and large medium-sized towns due to increasing population and densification.

The green roofs of federal buildings indicator (BAU-R-2) shows a positive trend, but the area covered is too small to make any significant contribution to the local climate.

The specific energy consumption of private households for space heating indicator (BAU-R-3) shows a decline in demand until 2014, but a rebound effect is observed with an increase in energy consumption since then.

The uptake of subsidies for climate change-adapted construction and renovation (BAU-R-4) shows a positive trend, but the report could not provide a conclusive assessment of its impact on fending of climate hazards.

Lastly, the extended insurance against natural hazards for residential buildings indicator (BAU-R-5) shows a positive trend, but the uptake is considered insufficient.

In General, The DAS report showed that the building stock exposure to damage resulting from flash foods, heavy rain, hail and storms has increased in the past years [41].

For the closely related action field of urban and spatial development, the DAS system uses the following six response indicators to monitor the effects of climate change on the urban planning and spatial development:

1. RO-R-1: Priority and reservation areas for nature and landscape
2. RO-R-2: Priority and reserved areas for groundwater protection / drinking water production
3. RO-R-3: Priority and reservation areas for (preventive) flood protection
4. RO-R-4: Priority and reserved areas for special climate functions
5. RO-R-5: Settlement and traffic area
6. RO-R-6: Settlement built up in flood risk areas.

The DAS 2019 assessment of the response indicators in the urban developed action field provides a heterogeneous assessment.

Both the RO-R-1 and RO-R-2 indicators show a reduction in the areas reserved for groundwater protection, nature, and landscapes. The development of the areas reserved for special climate functions, such as reducing heat island as assessed in the indicator RO-R-4, is still inconclusive. This is mainly due to the novelty of such areas in the urban planning practices. In contrast, a positive trend in observed in the remaining three indicators (RO-R-3, RO-R-5, and RO-R-6).

In addition to the indicators used in the DAS monitoring report, The German climate change risk analysis of 2021 [36] highlights the following impacts and hazards (consequences of climate change) to the action field of building and construction:

4.2.1 The Risk of Floods, Flash Floods, and Increased Ground Water Levels.

In Germany, river floods hold the highest potential of economic damage to the building sector [111]. In the cases of the floods and flash floods, basements are most commonly affected [112]. Furthermore, the type of materials used in finishing the buildings envelope can also have a great influence on the extent of damage caused by the flood for a building [113]. Climate projections indicate that damage caused by river floods could increase in future as a result of climate change in case no appropriate adaptation measures are enforced[114]. The German climate change risk analysis of 2021 classifies the risk of damage from flooding events to the building as middle risk in the time frame between 2031 to 2060 and 2071 to 2100. However, the risk is classified as high in case no appropriate adaptation measures are introduced [36].

4.2.2 Heavy Precipitation

Unlike flooding events that primarily pose a risk to buildings located near water bodies, damage caused by heavy precipitation can happen virtually anywhere. Over the period from 2002 to 2018, there were over 11,000 heavy rain events recorded, resulting in an estimated total damage of €6.7 billion and impacting approximately 1.6 million residential buildings. [36]. This highlights the widespread vulnerability of buildings to the damaging effects of heavy rainfall, regardless of their proximity to water bodies. The damage of heavy precipitation to buildings largely depends on the settlement urban structure, degree of soil sealing, the available reserve in the building and settlement drainage network, the building envelope finishing materials, the building base heights and the availability of roof overhangs which can protect the building envelope [112, 113, 115]. The German climate change risk analysis of 2021 categorizes the risk of heavy precipitation to the building as middle risk in the time between 2031 to 2060 and 2071 to 2100, as it assume that heavy rain events will intensify in the future due rising average temperatures [36].

4.2.3 Vegetation in Settlements

According to the German climate change risk analysis of 2021, the term "vegetation in settlements" includes all forms of green spaces and buildings in and around settlements such as parks, cemeteries, and street trees. It is a cross-cutting issue that affects many areas such as biological diversity, water, and human health. The climate change risks to settlement vegetation are classified as middle-risk in the time frame between 2031 to 2060 and 2071 to 2100, and high-risk if no appropriate adaptation measures are taken. The risks include man-made forcings and climate change impacts that can damage street trees and fragile nature of city trees due to limited space for root growth [116, 117] and poor air and soil quality[118]. Around 70% of street trees in Germany have limited resilience to extreme climatic conditions [119]. The risk is classified as high in case no appropriate adaptation measures are introduced [36].

4.2.4 Urban Climate and Heat Island

Urban heat island (UHI), is phenomena that results for closed isotherms that built up in and around an urban area and make it warmer than its surrounding rural area [120]. Low albedo building materials, increased built up surface area, urban geometry, high thermal capacity of paved roads, and certain air pollutants increase radiation absorption in the urban area and hence change radiation and energy balance, leading to the creation of the UHI effect [121-123]. UHI can lead to temperature difference between the city and rural area that can be as high as 12 Kelvin [124]. This can cause an increase in mortality risk by 50% in the event of heat waves and cause an overall decrease in the indoor and outdoor thermal comfort [125, 126].

The German climate risk analysis of 2021 concludes that the UHI risk expected to increase in the future due to building densification, higher population concentrations, increasing urbanization and lack of proper utilization of the urban green areas.

4.2.5 Indoor Climate

Indoor thermal comfort is usually defined as the occupant satisfaction with their thermal condition[127]. The range of indoor thermal comfort is usually measured based on the indoor operative temperature. Most building standards rate an operative indoor temperature between 20 and 26 °C to be within the thermal comfort range[128].

The vast majority of the existing building stock is ill-suited to provide proper indoor thermal comfort, especially in the summer as these buildings were mostly built before the introduction of strict energy efficiency ordinance of 2007 [108]. Moreover, the planner of the buildings does not take the expected future climate as well as UHI conditions into account [128]. As a result, an increased heat stress and worsening indoor air hygiene is expected, as the rising temperate will accelerate the release of hazardous substances ito indoor air and promote indoor mould growth[36].

4.2.6 Time for Construction Work

The impacts of climate change are expected not only manifest themselves through the occurrence of damage on buildings, the ecosystem and the inhabitants, but can also influence construction activities in Germany[129]. Climate change is expected to lead to reducing productivity, increasing the project duration, increase the construction cost and expose the worker to a higher health risk on the construction sites[129]. The German climate risk analysis of 2021 classifies this risk to remain low in the near and far future.

4.3 The Bavarian Built Environment and Building Sector.

The Bavarian building sector emitted about 25.7 million tonnes of CO_2 equivalent in 2021, which is about 34% of the state GHG emissions[130]. The state target is to halve this number by 2030 and to become a carbon neutral state by 2040 [60]. In the year 2018 the primary energy consumption of the building sector fell by about 7% in comparison to the values of 2010 and contribution of renewable energies to the final energy demand increased by 42% during the same time frame [130]. According to the 2018 statistics, only 287 thousand buildings were built post the 2011 date. This represents around 5% of the existing total building stock, which is about 6372 million buildings[108]. These figures are comparable to the situation on the federal level.

The BayKLAS strategy launched in 2016 (see chapter 3.2.2.2) aims to promote sustainable and energy-efficient construction that is adapted to the effects of climate change. However, it is observed that most of the effort outlined in the strategy is focused on energy efficiency measures rather than climate adaptation actions[34].

The BayKLAS includes a list of climate change-induced risks and nine climate adaptation measures for the building and construction sector that cover infrastructure and building adaptation in risk areas, as well as the implementation of roof and facade greening. The state is also developing computer-assisted climate analysis to enhance effective air exchange in cities and intends to incorporate assessments of heat island effect and flood exposure into land use planning regulations.

Efforts to reduce exposure to floods and heavy precipitation are reflected in the expansion of Article § 9 of the building law in Bavaria [131]. The leaflet "Flood and heavy rain risks in land use planning" published by the State Ministries for Housing, Building and Transport and for Environment and Consumer Protection provides a comprehensive list of flood and heavy precipitation adaptation measures [132].

In 2018, the Bavarian State Office for the Environment (LfU) initiated a research project to develop a system of 66 indicators for monitoring climate adaptation and impacts in Bavaria[133]. These indicators complement the existing climate monitoring in Bavaria and supplement evaluations of regional climate projections for the state. The LfU indicators cover the 15 action fields mentioned in the Bavarian climate adaptation strategy of 2016 and include a mix of impact and response indicators. However, due to missing information and data limitations, only 26 out of the 66 indicators are currently operational [133].

For the **action field of spatial planning**, the LfU system monitors two impact indicators but only one indicator for reservation areas for water supply is operational. The indicator results show an increase in reservation areas from about 120 thousand hectares in 2008 to about 140 thousand hectares in 2015. The indicator for regional green corridors to secure open space and improve the bioclimate and recreation conditions is not operational yet due to missing data.

For the **action field of urban development and land use planning**, the LfU system has developed one impact indicator and two response indicators. Only the response indicators are currently operational, showing that land use in Bavaria is stable at around twelve hectares per day, which is the highest compared to all other federal states [134]. The percentage of recreational areas in cities has in general increased slightly from about 7% in 1996 to almost 10% in 2016.

The action field of building and architecture is monitored with a single indicator, which refers to subsidies for climate change-adapted construction and renovation. However, the indicator **only takes into account measures that serve directly or indirectly to protect against heat in summer** and does not consider other state-specific funding programs that can provide a more holistic vision.

In 2021, the Bavarian Ministry for Environment and Consumer Protection (StMUV) published a guide for implementing climate protection measures in Bavaria [135]. The guide cites a **projected decreased demand for heating as the only positive side effect of climate change**, but also predicts a wide array of adverse climate change impacts that will affect the built environment in Bavaria. A summary of these findings is presented in Table2.

Table 2: list of adverse impacts due to climate change on the building and urban sectors [135]

Climate impact, hazard	Sector	Adverse impact
Increase in Temperature	Building	Increased cooling needs
		Worsening thermal and indoor air conditions
		Decreased productivity
	Urban environment and spatial planning	Increased cooling needs
		Increased water consumption and care needs for plants
		Change in type of plants
		Increased water, wastewater consumption and demand for green spaces and shaded places
		Increased levels of ozone pollution and respiratory illness risks
		Increased UHI in built up areas
Heavy precipitation	Building	Increased level of groundwater and increased risk to damage to building foundation and basement
		Damage to building due to backwater and damp
		Risk to inhabitant from groundwater and floods

		Flood damage to building
		Overload building drainage system
	Urban environment and spatial planning	Risk to the transportation, energy and water supply systems and buildings
		Overload of building and city drainage systems
		Risk of flash flood in densely built-up areas
		Increase in urban use conflict between urban development demands and climate protection needs
Drought	Building	Risk of soil settling damage
	Urban environment and spatial planning	Increased water demand for plants
		Increased replacement of plants
		Risk of malfunction of wastewater and wastewater treatment system due to lack of flushing water
Storms	Building	Increased risk of building envelope damage
		Health and injury risk to inhabitants
		Increased risk of damage to building roofing
	Urban environment and spatial planning	Increased risk of damage to buildings, infrastructure, transport and water and energy networks

4.4 Chapter Insights and Key Findings

Cities are the lifeblood of the global economy, but their crucial role comes with a significant environmental cost. They are responsible for over 70% of global greenhouse gas emissions, which makes them particularly susceptible to the impacts of climate change [10, 11]. Already, over 60% of cities with populations exceeding 300,000 are at risk from one or more natural disasters [7].

A key insight that emerges from the data is the centrality of the built environment to the climate change equation. Nearly all key urban sectors identified by the IPCC as susceptible to climate change impacts are either located within or intricately linked to the building part of the built environment. Buildings, in fact, often serve as either origins or destinations for various sectors including water, energy, and transportation networks. This highlights the significant role the built environment plays in climate change - a role that can no longer be overlooked.

The built environment consists of multiple sectors such as coastal zone systems, human well-being, ecological infrastructure, water and sanitation systems, green and blue infrastructure, energy systems, food systems and security, transportation, social and civil services, communication systems, and buildings, structures, recreation areas, and heritage sites. Each of these sectors faces varying degrees of risk from climate change impacts.

In the vast spectrum of the built environment, the building sector emerges as a primary driver of climate change due to its high resource and energy demands, as well as significant CO2 emissions. This sector alone accounts for about 35% of the global final energy consumption and 38% of global CO2 emissions. In the German context, the later reach 40%.

It is important to remember that over two thirds of German building stock consist of inefficient and ill-adapted buildings that will still be in use post the 2050 deadline. This indicates that the existing building stock is the largest GHG reduction source and is similarly the one exposed to the highest risk.

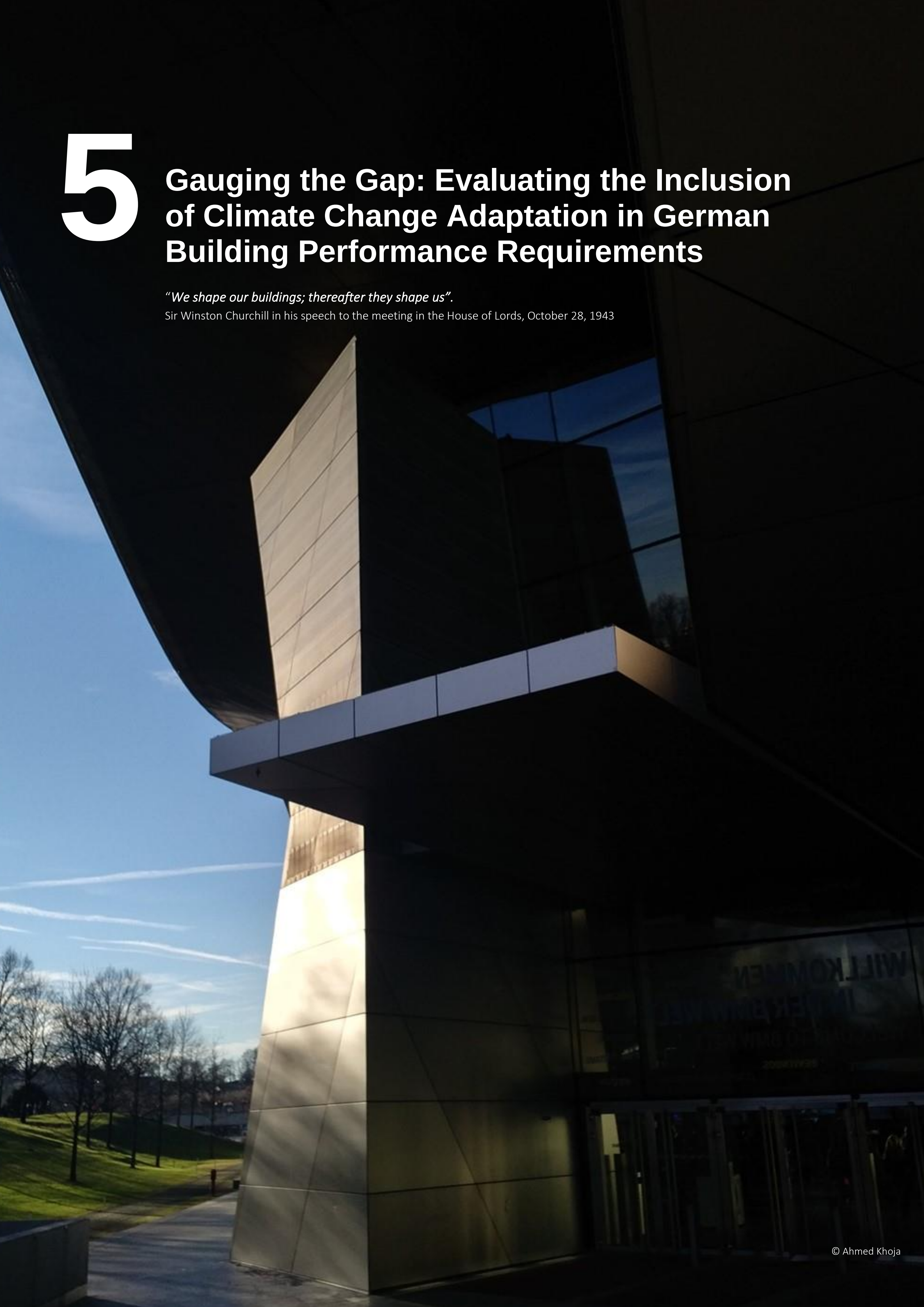
However, addressing the climate crisis solely at the building scale would be insufficient as buildings do not exist in isolation but are integrated components of the broader built environment. Effectively tackling climate change issues within the built environment necessitates merging various temporal, social, and spatial scales and integrating a wide array of institutional actors that extend beyond the physical boundaries of individual buildings.

The aim to cut global and local GHG emissions targets for 2030 and 2045 seems increasingly unattainable and the IEA's 2022 estimates indicate a significant gap in reaching these targets, underscoring the urgent need for immediate and effective action. Despite a 43% reduction in GHG emissions since 1990 that Germany managed to achieve, a further 45% reduction is needed to meet the government's GHG targets by 2030. The residential sector, being a major contributor and having a low retrofitting rate, presents a challenging path to reach the necessary reduction levels in the near future.

The impacts of climate change on the German building sector are increasingly apparent, as evidenced by significant damage caused by recent extreme weather events. Ongoing monitoring of climate change effects and responses in the building sector present a mixed picture of progress across various response indicators. The 2021 risk analysis underscores the urgency to address the risks of climate change to the built environment.

5 Gauging the Gap: Evaluating the Inclusion of Climate Change Adaptation in German Building Performance Requirements

“*We shape our buildings; thereafter they shape us”.*
Sir Winston Churchill in his speech to the meeting in the House of Lords, October 28, 1943



Scholars agree that the interplay of formal and informal law, coupled with robust social organization and efficient use of natural resources, are pivotal to the success of any city[13]. Throughout history the regulator bodies of cities drafted written rules or agreed on social norms that address the organization and functionality of the buildings in the city.

These rules governed two distinct aspects of the built environment. The first category of rules governs the shaping of the city. They dictate what is permitted to be built in a certain location or area of the city. In modern terms, these set of rules are usually called the city's zoning code or city planning law[136]. In essence, these rules are more related to answering the question of "what" is to be built and are concerned with regulating the buildings interaction with each other and with the greater built and unbuilt environment around them.

The second set of rules, which this chapter focuses on, dictates "how" a building should be built, establishing the building's performance requirements. These requirements have evolved over time in response to diverse technological, social, economic, and environmental factors. As illustrated in Figure 9 below, this evolution has resulted in the formulation of six distinct generations of building performance requirements , with each subsequent generation advancing upon the foundation established by its predecessor in an additive and hierarchical manner.[14]. These generations of performance requirements can be generally divided into two main groups: historical and current. The historical group contains the generations of building performance requirements that emerged at around 1800 B.C and lasted till about 1970 A.D. They include the 0.0 generation "shelter", the 1.0 generation "safe" and the 2.0 generation of building requirements the "sanitary". Post-1970s, a new generation of performance requirements supplemented with rating systems appeared which contain the 3.0 energy-efficient, 4.0 sustainable and the 5.0 smart. The 6th anticipated generation of regenerative, healthy, and positive buildings is not discussed here as its requirements are yet to take shape.

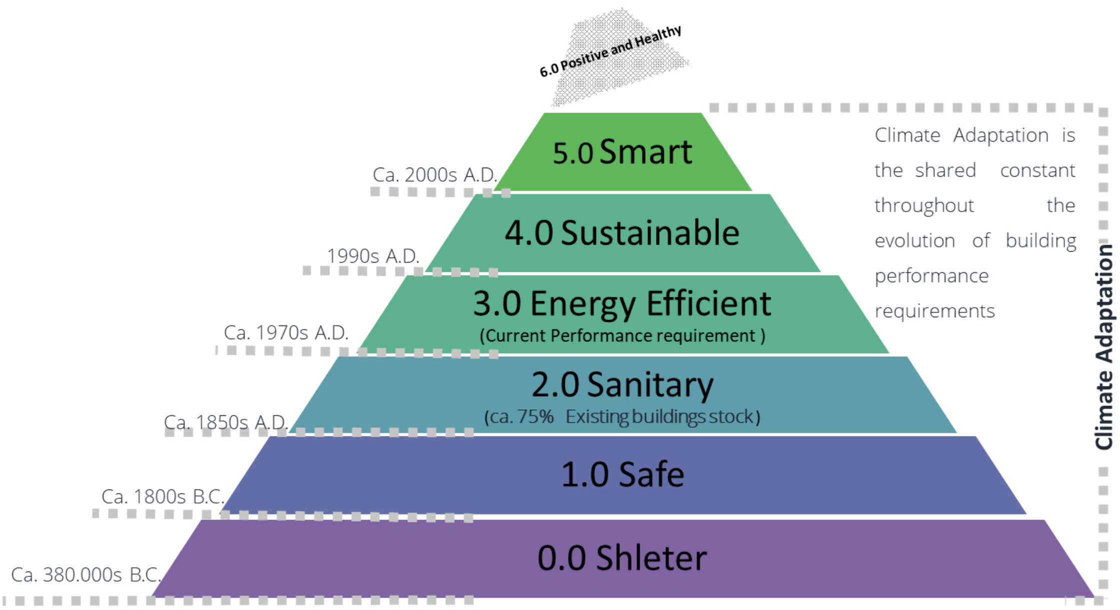


Figure 9: climate adaptation is the common dominator throughout the additive evolution of the building generations, adaptation from[14]

The prevailing climate significantly influences building design and operation, affecting aspects like location, form, material choice, room arrangement, openings, etc. Hence, as depicted in figure 9, the adaption to the climate and climate-related performance requirements are present throughout the evolution of the performance requirements. With technological and social advancements, each generation has adopted different methods to cope with and respond to the climate. However, as illustrated in Chapter 3, the climate is projected to change in the coming decades, with far-reaching consequences for a broad range of urban sectors closely intertwined with the existing building stock. Buildings erected in the recent past and those under construction today will face new climatic parameters and hazards they were not designed to handle.

Given this context, this chapter has a dual purpose:

- *Firstly, it aims to understand how the various generations of building performance requirements have addressed climatic conditions and responded to climatic hazards.*
- *Secondly, it seeks to gauge the extent to which existing German building rating systems incorporate climate change adaptation into their performance requirements.*

This exploration will focus on the current and operational building performance requirements and rating systems in Germany, i.e., the energy-efficient, sustainable (QNG-based), and smart generations of buildings. This investigation will form the foundation for answering the first research question:

A. How do buildings adapt to impacts of the climate, and to what extent contemporary (post 1970s) performance and rating systems in Germany integrate climate change adaptation measures?

To this end, the following three steps are taken:

In the first step a brief overview of the main response strategies used to cope with climate change is provided.

The second step investigates the climate adaptation methods and strategies employed in each of the five generations of building performance requirements.

The third step qualitatively assesses the inclusion (directly or indirectly) of climate change adaptation measures in the existing German and performance requirements and rating systems of the 3.0, 4.0 and 5.0 generations of buildings. The choice of using a qualitative assessment is two-fold:

I. The goal of the assessment is to assess the degree of inclusion in each system so to gain an understanding about the climatic hazards that are addressed by such system and the ones that are less addressed.

II. As adaptation solutions are local and context-specific, and since there is no universal benchmark to measure the effectiveness of each adaptation, a qualitative assessment, supported by scientific literature, is deemed more appropriate. It recognizes the complexity of the issue and allows for further enhancement and refinement as more knowledge becomes available.

The deployed descriptive assessment ranks qualitatively and numerically the degree of inclusion of climate change adaptation as either 'absent,' assigned 0 points; 'somewhat included,' assigned 1 point; 'Fairly included,' assigned 2 points; or 'well included,' assigned 3 points. The numerical assessment is chosen to facilitate ease of comparison and to clearly highlight the climatic hazards addressed. Table 3 provide the criteria upon which a performance requirement is either included or excluded from each of the above-mentioned categories.

Table 3: Scoring methodology to rate the degree to which adaptation to climate change are addressed in the existing German performance requirements of buildings.

Qualitative rating	Numerical Score rating	Rating criteria
Not applicable	N/a	There is no clear relation between the sector and a hazard
Absent	0	Is awarded when the performance requirements Lacks clear, specifically targeted adaptation measures for climate change impacts, or the measures are completely outdated and/or have no impact on the rating score.
Somewhat included	1	Is assigned to performance requirements that mention an adaptation measure, but description is vague or only partially addresses a climate hazard
Fairly included	2	Is awarded to one or more performance requirements adaptation measures are present, precise, yet they address climate change impacts only partially or may be somewhat outdated
Well included	3	adaptation measures are present and specifically address one or more climate change impact

The inclusion of performance requirement is considered absent, and award Zero (0) points are awarded when in the performance requirements, such as norms, rating requirements and guidelines, the provisions for climate adaption are either missing, totally outdated, or in the case of rating systems they are provided as mere recommendation without impacting the final rating of the building. For example, the indicator (Site 1.2.2 cycle paths) of the DGNB NKW system, while a valid measure for enhancing the resilience of the transport and mobility sector against climate hazards, does not directly impact the building's rating. Its fulfilment or lack thereof does not influence the final rating of the building. Therefore, no points are awarded as the indicator does not influence the system nor is it enforced.

In contrast, the full three (3) points are awarded when the performance requirements specifically integrate climate change adaptation into their standards. An example is the updated DIN 1986-Entwässerungsanlagen für Gebäude und Grundstücke Teil 100, which addresses the water and wastewater sector. It provides a detailed methodology for issuing a flood-proof certificate for building sanitary systems against flooding, considering expected changes in rain and groundwater levels due to climate change.

One (1) point, signifying a fair degree of consideration of climate change adaptation, is assigned to performance requirements that mention an adaptation measure, but either the description is vague or only partially addresses a climate hazard. For instance, §13 of the Gebäudeenergiegesetz (GEG) "Building Energy Act 2020" requires a minimum degree of envelope air tightness. Although studies show that achieving this requirement indirectly improves the building envelope's resilience against heavy precipitation by reducing the risk of water vapor condensation within the construction[137], it remains one of many aspects of adapting the building envelope to the hazard of heavy precipitation. Therefore, only one point is awarded.

Lastly the two (2) points are awarded to one or more performance requirements that are providing clear and precise guidelines that address adapting to the climate change impact but are either outdated or partial. Such as the case of DIN EN 752 (Entwässerungssysteme außerhalb von Gebäuden) intended to improve the resiliency of water and wastewater system against heavy rain, however, the values used for determining the precipitation levels are not based on the latest updated rain level prediction of German Meteorological Service) included in the KOSTRA-DWD-2020.

For the sectors of the building in which there is no clear relation between the sector and a hazard, such as the lack of relation between the climate impact of drought and building communication (mobile signal) or transport sector (parking places), this point is excluded from the total score and is denoted with n/a.

The German climate change risk analysis of 2021 [36] and the StMUV guide for the implementation of climate protection measures in Bavaria [135](see subchapter 4.2 and 4.3 respectively) has identified five climatic hazards that are shared by many locations and are relevant to the building sector, which are : floods and ground water rise, heavy precipitation , wind and storms, droughts, and heatwaves. As the adaptation reactions overlap and can serve to enhance the reliance against on or more hazard, the assessment is conducted separately to each hazard taking into consideration either individual or grouped performance requirements that address the hazard. Hence, double counting for the same hazard is not permitted and is only possible if the indicator or group of indicators address two sperate hazards. For the indicators that address the same hazard, the results will be based on the indicator that is assigned the highest score, i.e., (3) three points without aggregation. For each climate hazard, the assessment is made to the key urban sector that such energy, water, communication systems, etc that is addressed by a single or a group of performance requirements.

Furthermore, to prevent double counting and to clarify the areas of the building and types of hazards addressed by each rating system, the performance requirements are assigned to the building sector they closely address addressed, such as energy, water, communication systems, etc. The building sectors are divided into seven sectors: Structures (envelope), Water, wastewater and sanitation systems, green and blue infrastructure, Energy systems, Transportation and mobility, Communication systems, Human wellbeing, and organization. These are chosen in alignment with the urban sectors identified by the IPCC [85].

This alignment is justified du to the local and an integrated nature of climate adaptation issues. As can be noticed the majority of the key urban sectors identified by the IPCC that are at risk of one or more impacts of climate change can be found within or around a building and interact with it in various ways. For example, the IPCC's key urban sector of water and wastewater either starts or ends at a building and is represented by cost group KG411 and KG412 as per DIN 276:2018-12[138]. Similarly, the key urban sector of “structures” which on urban scale can be used to include buildings and other man-made objects, it can be again used on the building scale to describe the envelope and structural elements of the buildings that are covered in the cost group KG310 to KG360.

It's also noteworthy that a performance requirement can address the impact of climate change on a specific key urban sector but not others. For instance, DIN 1986 addresses the water and wastewater system of a building. Consequently, the building's water and wastewater system might be well-prepared for a flood event, but the energy systems might fail. The scoring matrix methodology used to rate the inclusion of performance requirement by breaking down the building by sectors and hazards is illustrated in table 4.

Table 4: Scoring matrix used in to gauge the inclusion of climate adaptation in existing rating systems, showing the highest possible score "Well included" (3 points) that can be assigned to each combination of urban sector and hazard.

Hazard / Building Sector	Flooding	Heavy Precipitation	Wind and Storm	Drought	Heatwave
Structure (Envelope)	3	3	3	3	3
Water, and sanitation systems	3	3	3	3	n/a
Energy systems	3	3	3	n/a	3
Green and blue infrastructure	3	3	3	3	3
Transportation and mobility	3	3	3	n/a	n/a
Communication systems	3	3	3	n/a	3
Human wellbeing and organization	3	3	3	3	3

The examples presented in Tables 5 and 6 demonstrate the application of this assessment method in evaluating the inclusion of climate adaptation considerations within existing performance requirements and the SmartScore rating system, which is utilized for assessing smart buildings (more detailed explanation in in chapter 5.7). The comments column in each table provides an explanation for the assigned score and, where applicable, cites the scientific articles that informed the assessment of the degree of inclusion.

Table 5: Rating of the 3.0 generation performance requirements adaptation to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, and groundwater rise		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	-	0	No updated Norm

Water, wastewater, and sanitation systems	DIN 1986-Entwässerungsanlagen für Gebäude und Grundstücke Teil 100: Bestimmungen in Verbindung mit DIN EN 752 und DIN EN 12056	3	The DIN 1986 standard details the methodology to produce certification for protection against flooding
Green and blue infrastructure	-	0	No updated Norm
Energy systems	-	0	No updated Norm
Transportation and mobility	-	0	No updated Norm
Communication systems	-	0	No updated Norm
Human wellbeing and organization	-	0	No updated Norm

Table 6: Evaluation of in inclusion of adaptation requirements in the SmartScore rating system to the impact of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	Drought can increase the risk of soil settling damage [135], A BIM model can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time after an exposures to climate hazard[239]
Water, wastewater, and sanitation systems	UF3:3 Water reporting	1	Having a solution to track the building's water consumption in real time can help

			reduce consumption [139]
Green and blue infrastructure	-	0	No Performance requirements
Energy systems	-	n/a	There is no direct risk at the energy sector of the building from the drought
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	UF6:4 Emergency alerts	1	building users can react to a potential drought alert[140]

5.1 Climate Change Responses Strategies in the Building Performance Requirements

The strategies used to combat climate change and its impacts can be broadly divided into two distinct, yet interrelated groups - adaptation focused and mitigation focused measures.

Climate adaptation measures describe actions and decisions taken by individuals, groups and governments that aim primarily to reduce and minimize the impacts of both slow onset and extreme climate hazards [19]. The IPCC defines climate adaptation as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities[141]. Climate adaptation focuses on increasing the building resilience to climate change through reducing the vulnerability of the system to adverse impacts of climate via three approaches:

A. Reducing the system sensitivity or susceptibility to harm (how far is the system affected by or responsive to a climate event)[142]
B. increasing the system capacity to cope and adapt to a new or existing climate condition via increasing the system's inherited potential to adapt to an adverse climate event[142];
C. minimizing or eliminating the exposure to the risk[143, 144]. This is done through reducing the amount of the valuable elements of the system located in an area that is at risk of impact or hazard[145].

Climate adaptation response in the built environment can be autonomous (natural, passive), strategic (active) or a combination of both[142]. Raising the house over pillars as in a stilt house to protect from flooding or maximizing the window opening in the direction of the prevailing wind to cope with heatwaves are examples of an autonomous or passive adaptation measure.

Figure 10: Reconstruction of stone age (4000 B.C) house, located in lake Constance (Germany)showing the building being raised on pillars to adapt water level rise and flooding. Other climate adaptation measures can also be observed.

Figure 11: An 18th century multi generation residential building in the old city of Jeddah (Saudi Arabia). Notice the high multi story wooden covered opening facing Northwest to allow for maximum air circulation and minimize direct solar radiation and glare.

The equivalent active adaptation measures to both above-mentioned climatic hazards would be the use submersible sewage lifting pump to cope with ground water level rise or to use air conditioning units to cool the buildings in summer months.

Figure 12: A submersible sewage lifting pump used in the basement of youth centre building to handle excessive rain events.

Figure 13:. A collection of air-conditioning unites covering the shop fronts in Singapore

It is important to note that the application of climate adaptations measures is not confined to a single spatial scale. Realising a holistic response to climate impacts constitute applying adaptation measures at various spatial scales staring from or ending at the building. One of the examples is organizing the buildings around narrow covered streets to protect the buildings and pedestrians from excessive heat and/or strong wind (See Figure 14). This cross-scale application of adaptation measures improves their effectiveness greatly.

The choice of the adaptation measure varies from one place to the another depending on the local climate conditions, available resources, and local knowledge. Likewise, the effectiveness of applied measure is also limited to local area of their application, so that an adaptation measure applied in one part of the city doesn't lead automatically to improvement of the climate adaptation of the whole city or other neighbouring places[19]. Unlike the adaptation measures, mitigation efforts are universal in the scale of their deployment. Mitigation strategies are basically the same regardless of the project location. Therefore, their success, or lack thereof, depend on their universal implementation by all parties [19]. Climate change mitigation measures started appeared in the mid-20th century in conjunction with realizing impact of the anthropogenic (man-made) forcing on the climate. Climate change mitigation measures aim to reduce current and long term man-made GHG emissions[19].

Figure 14: An ally in the centre of Freiburg (Germany). Notice the use of vines canopy as climate adaptation measures that serve both the urban scale and the building scale simultaneously.

Table 7: Main differences between mitigation and adaptation strategies, adopted from[19]

	Mitigation Strategy	Adaptation Strategy
Sectoral focus	Multiple	Sector specific
Spatial scale	Global	Local
Temporal scale	Long term	Short, Medium, and long term
Driver	Reducing global warming	
Monitoring	Relatively easy	Very difficult
Co-Benefit	Multiple	Limited

The climate change mitigation strategies can be organized in three categories which are: decarbonization, negative emissions technologies (NETs) and radiative forcing geoengineering. The latter is still at its theoretical stage of development at the moment and its application extends beyond the scope of the built environment [146] Therefore, radiative forcing geoengineering won't be further explored in this research.

The decarbonization techniques to climate mitigation constitute the most widely used approach [19]. The decarbonization techniques aim at reducing the GHG emissions via three principles.

Firstly, through switching to "relatively" low emitting CO_2 fuels such as switching from oil-based heaters to gas boilers [147].

Secondly, via increasing the energy efficiency gains of the building. This can be technically done by using passive elements, such as improving the building thermal transmittance by thermal insulation, or though deploying active elements, such as using a more energy efficient local or neighbourhood wide heating or cooling system. The building users can also be part of the decarbonization effort in which the user behaviour practices are improved via training or awareness campaigns to increase the end –user's utilization of the systems [147, 148].

Lastly, decarbonization can also be enhanced via increasing the uptake and deployment of renewable and zero emission energy systems to cover all or a part of the building energy consumption[146].

Despite the long and large deployment of the climate mitigation techniques over the past 50 years, recent studies cast doubts on the ability of the decarbonization approach alone to reach the required GHG reduction needed to stabilize the increase of the GSTM below the 2℃ mark [148-150]. Thus, it is expected that to reach the Paris agreement GSTM target, negative emissions technologies (NETs) alongside aggressive decarbonization measures would be needed[151].

The negative emissions technologies (NETs) include techniques such as direct carbon capture, afforestation and reforestation, bioenergy and land and water-based carbon sequestration. With the expectation of the land and water based carbon based sequestration, which can be partially applied at the built environment via increasing the green and blue infrastructure in and around the building[19], all other negative emissions technologies are space- and resource-intensive and are at an early stage of their development[146].

As both adaptation and mitigation strategies are inherently interrelated [19], it is often the case that application of one will influence, even if not intended, the performance of another sector. This interaction between both approaches is not yet widely well documented [152]. Nevertheless, it is important to take this interlinkage into consideration when deciding about the application of an adaptation or mitigation strategy. This connection can have positive synergistic effects, where a strategy improves both the building's ability to adapt to climate change and reduces its greenhouse gas (GHG) emissions. On the other hand, conflicts between adaptation and mitigation measures can occur. In these cases, prioritizing one measure may come at the expense of the other, leading to either maladaptation or underperforming mitigation[19, 26]. For example, it was found that the high levels of thermal insulation combined with low infiltration rates that are typical mitigation measures applied in zero energy buildings can significantly increase the risk of indoor overheating during the summer months [153, 154], hence worsening the building climate change adaptability to a heatwave. This conflict is a result of the fact that both the adaptation and mitigation strategies employ different approaches and strategic rationale.

5.2 Climate Adaptation in the 0.0 Building Generation: The Shelter

Buildings, as we know them, were firstly constructed by humans in around 380.000 BC [155]. These early structures had clear and basic functional requirements that correspond to the fundamental human need of a "shelter" [156]. The shelter is rather a complex requirement as it encompasses a shelter from weather, intruder, predator, etc. This primary functional user requirement was and will remain the dominant requirement to any permanent or movable human structure. After all, it is ranked as the first human need as per Maslow's pyramid of needs [157]

These structures that functioned primarily as 'shelters' existed long before the formulation of written building performance requirements and represent the zero generation of the building design performance requirements (0.0 building generation). This basically refers to any building that doesn't adhere to any formal performance requirement besides being a shelter. Buildings belonging to this generation can be found in the informal buildings of the unplanned areas of the city or urban space, typically lacking sanitary or safety provisions [158]

Like all other generations, this initial generation of buildings developed unique methods to adapt to the surrounding climate. However, to genuinely benefit from examining the climate adaptation techniques and strategies found in this generation, it would be more insightful to examine vernacular architecture rather than informal buildings. The vernacular architecture, which is the native science of building [159:4], has evolved over a long period time and managed to devise specific and pure (not influenced by the moder city) design solutions that address and adapt to the surrounding climate.

5.2.1 Vernacular Architecture Adaptation to Changing Climates: Principles and strategies.

The vernacular architecture evolved uniquely across different climate and geographic regions. Nevertheless, vernacular architecture applied similar set of governing principles to adapt to the climate and surrounding environment. In general, the Vernacular builders used two continuously evolving processes to adapt to climate change- a proactive and a reactive one[160]. The proactive processes are based on previous experiences and prevailing weather and climate conditions. Hence, the proactive processes are embedded in the building performance requirements and are reflected in site and culturally specific design responses that gave the architecture of specific region its distinct shape. They include room arrangements, openings, material, and roofing. Figure 15 and 16 provide an example of reflection of climatic performance requirements on the shape, material choice and arrangement of rooms of vernacular buildings in the Middle East.

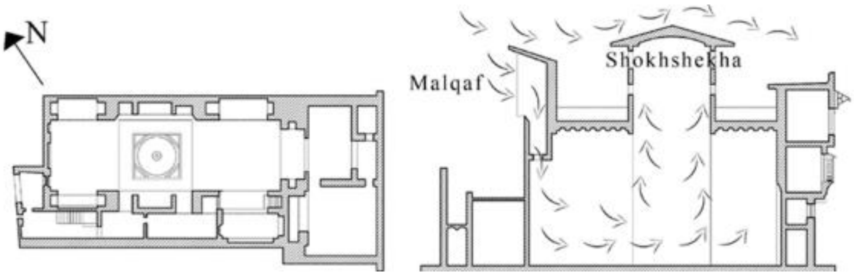


Figure15: The use of wind catchers is an example of proactive climate adaptation measures for hot weather in the Middel-Eastern vernacular architecture [161].

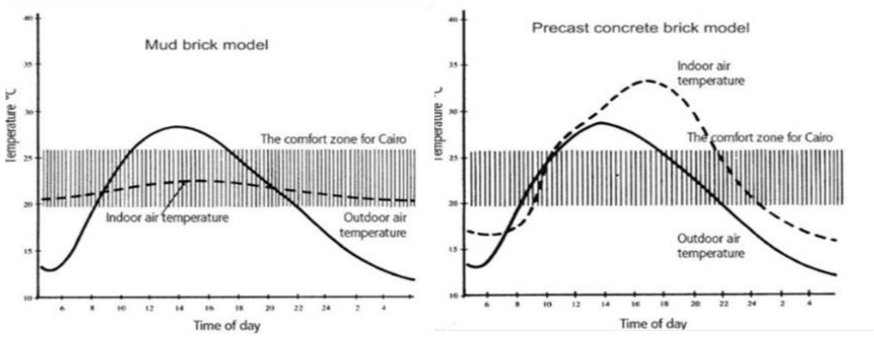


Figure 16: The clever combination of appropriate building materials and shapes leads to superior indoor air temperature in the vernacular building (on the left) in comparison to a modern concrete building (on the right)[162]

The second type of climate adaptation process found in the vernacular buildings is a reactive process. The reactive process occurs in response to a change in the climate means or after an extreme weather event such as a flood or a storm that the proactive measures proved to be unable to handle[160]. Such extreme events disrupt indigenous ecological knowledge and result in either the invention of a new proactive adaptation, which changes the perceived image of the older style, or in upgrading of the existing proactive measures to accommodate for such events in the future.

The constant development of the traditional Chinese roof curvature, sloping, pitch and the relation between the roof span and height that happened between 925 AD and 1504 AD presents a perfect example of how a reactive response turns into a proactive one to adapt to changing climate conditions[163]. As displayed in Figure 17, the roof span to height ratio (HSR) becomes steep in cold periods and then again softer and flatter in hot periods.

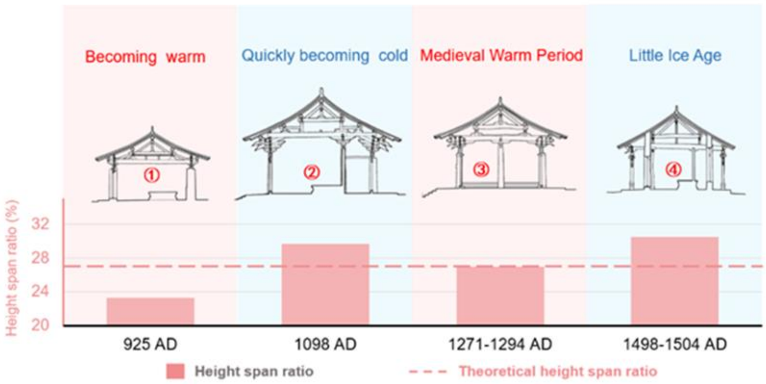


Figure 17: An example showing the change in the HSR as proactive measure to change in the climate conditions in the Longmen Temple in China[163]

The fact that vernacular buildings were able to integrate both proactive and reactive processes in their building techniques and adapt so swiftly to changing climate conditions can be attributed to the following five design principles.

Firstly, the vernacular buildings are rather simple constructions that can be assembled and disassembled with simple tools and manpower only. The construction is usually a collaborative work that can be accomplished in relatively short time and allows for a swift reconstruction and adaptation of the building[164].

Secondly, vernacular architecture is dynamic and evolving constantly to adapt to new situations[165]. These buildings were not designed to be permanent and inherently had a short lifespan[166]. This inherited weakness and agility is a result of the near exclusive use of locally sourced natural materials such as mud, straws, wood, and stones and simple joining techniques that had a short life span. As a result, maintenance becomes an integral part of the design process. The Cameroonian Musgum mud huts, illustrated in figure 18, provide an example of this integration of building maintenance in the building design. The ladders' shaped extrusions were used for constructing the building are also used for maintaining the hut envelope and are a distinct feature of the building form.

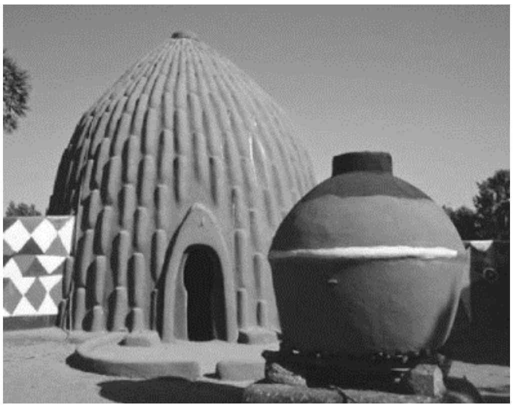


Figure 18: A typical Mugsum hut, notice the projected overlapping oval forms that surround the building and served as a ladder for reaching the summit of the hut. The ladders where used for both the construction as well as the maintenance of the structure[2].

Thirdly, in vernacular, as in nature, the form is treated as being cheap (easy to manipulate) while the material is expensive (hard and energy intensive to source). This resulted in forcing the vernacular builders to build their structures in a very efficient and effective shapes that maximize the utilization of the available materials to serve the desired climatic purpose [164].

Fourthly, a building in the vernacular was a collaborative community act in which the previous experiences, accumulated knowledge and building traditions were passed from one generation to the other. The local specific lessons learned reflecting local needs and adaptations were held and respected [165]. The building, being a community act also ensured that the erected building doesn't pose harm to other neighbouring buildings and fits well within the overall community interests[165].

Fifthly, the vernacular architecture was imbedded in the greater urban fabric to the degree that the boundaries of the urban scale and building scales were blurred and both planning scales are interwoven. This meant that both scales acted together as a single unit complementing each other[167, 168]. The effectiveness of this principle in providing appropriate climate adaptation was documented in the S. Al-Lyaly study about the interaction between climate, form and living patterns in the city of Jeddah Saudi Arabia[169]. In summer of 1987, S. Al-Lyaly measured the air temperature at a narrow ally in the old town of Jeddah and simultaneously at a modern built street just outside the old city walls.

When comparing the readings with the temperature readings from the meteorological station, he found that the maximum air temperature in the old city was about 2.0°C lower than the one recorded at the meteorological station and even 3.2°C lower than the reading measured in the modern street nearby. Taleb, D. and B. Abu-

Figure 19: A plan showing the location of temperature reading taken by Al-Lyaly in the old street(denoted by circle) and the modern street nearby(denoted by a triangle)[169].

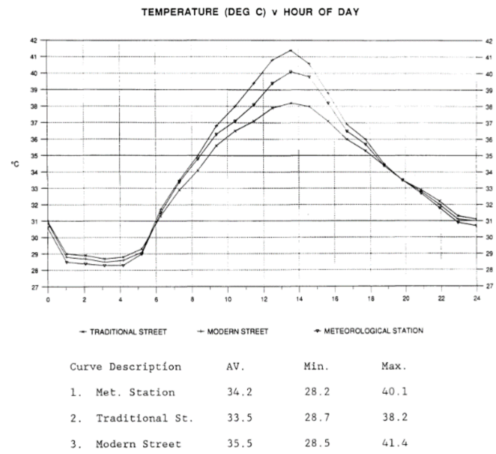


Figure 20: A graph showing the hourly temperature variation at the meteorological station, the traditional and modern street [169].

Hijleh [170]came to similar findings in their study about the effect of organic and structured urban configurations on temperature variations in Dubai, UAE.

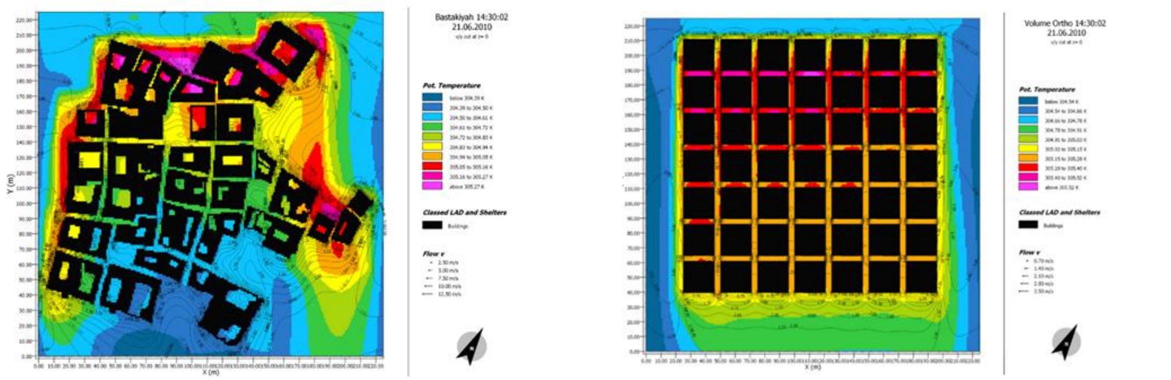


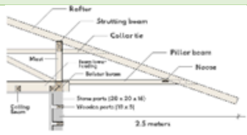
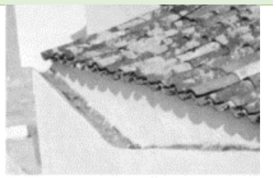
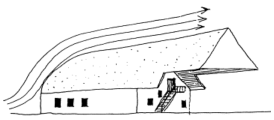
Figure 21: A study showing the superiority of vernacular urban fabric of Dubai (to the left) in comparison to a structured urban configurations (to the right) in reducing the UHI in the summer [170].

5.2.1.1 Climate Adaptation Examples in the Vernacular

In the context of climate adaptation techniques and strategies, vernacular architecture - representing the 0.0 generation of buildings - offers an exhaustive set of solutions for diverse climate adaptations. In fact, the vernacular architecture can be viewed as an unrivalled laboratory that demonstrates a broad spectrum of human responses to an equally diverse range of problems. These problems encompass culture, technology, resource availability, site-specific issues, climate, and much more [171:181].

The following tables are compiled to provide the reader with examples of vernacular adaptation solutions that at both the building and the urban scale. In sake of maintaining consistency, the climate change adaptation examples are organized according to climate change impact or hazard they address. Moreover, the selection of the climate change impact or hazard is made based hazard identified as relevant to the building sector in The German 2021 DAS [76] and the Bavarian StMUV guide [101] discussed in chapter 4.2 and 4.3 earlier.

Table 8: An example of vernacular adaptation measures to climate change impact and hazards applied at the building scale.

Climate impact / Hazard (from [36, 85, 135])	Examples of climate adaptation measures at the building scale	Example Image Source
floods, flash floods and increase in ground water levels	• Axile location of opening to allow for flood water to exit, • Raised attic to store food and use a safety hideout., • Use of the bamboo reinforced roof as safe place to gather in case of flood. • Building is raised above the flood threshold either on stiles or a retaining wall.	 [172] [172, 173]
Extreme precipitation	• Gentle pitched roof, • extended eaves, • gutters, • Use water absorbing roofing materials, • water resistant and water repellent façade materials, • green façade.	 [174] [174-176]
Drought and water scarcity	• Indoor water collection in ponds, • rainwater harvesting from the roof using a gutter system that led to cistern. • Sloping guiding the falling rainwater to the cistern.	 [177] [177]
Storm and wind hazard	• Narrow and aerodynamic shape facing the prevailing wind, • gentle pitched roof with minimal eaves, • courtyards as wind breaker, • low rise building.	 [178] [178, 179]
Heat and warming trend (Indoor climate)	• light coloured building materials, • reduced direct sun exposure via narrow openings and sunshades,	

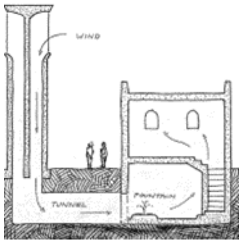
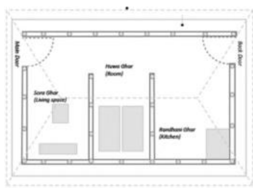
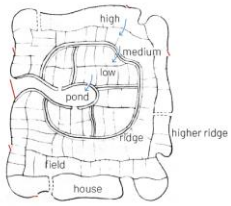
	• the use of building materials with the high thermal mass, • Use of high ceilings to increase air circulation, • increased air exchange through cross ventilation, • compact building, • Opening orientation toward the north façade • Water features • Taking advantage, the ground's thermal capacity by embedding building partially or completely under the ground • Use of dome shaped roof to provide partial shade and reduce solar gains through the roofs. • green façade.	 [180] [176, 180, 181]
Compound hazard	• Design with escape routes, • creating emergency safe gathering space, • deliberate failure points in the building structure • Flexible design and ease of assembly and disassembly	 [182] [182, 183]

Table 9: A summary of some vernacular adaptation measures to climate change impact and hazards applied at the urban scale.

Climate impact / Hazard (from[36, 85, 135])	Examples of climate adaptation measures at the urban scale	Example Image Source
floods, flash floods and increase in ground water levels	• Dual use of public space for excess water detention, recreation, and storage, • space between pavement to enhance permeability, • creating water ways and ditches, • lower land as flood catchment areas, • use of terraced gardens and cascading water system, • integrating agriculture to capture excess water, • use of dams and water gates to control water, • temporary fishponds in low land,	  

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raising the district building above the flood threshold,
constructing embankments,
constructing temporary emergency housing up hills.

</td>
<td>[184]
[184, 185]</td>
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<td>Extreme precipitation</td>
<td>

The use of Arcades,
Eaves,
Engawa (wet edge), raised porch around the building used to drain water under and away from building

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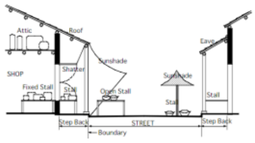
<td>

[186]
[186, 187]</td>
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<tr>
<td>Drought and water scarcity</td>
<td>

Rainwater harvesting in underground cistern or overground ponds,
Building reservoirs, aqueducts, wells, controlled water channels,
Collective water management
Use of tank-houses for water collections
Water storge in ice houses

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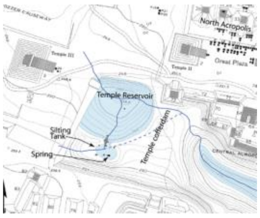
<td>

[188]
[188-190]</td>
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<tr>
<td>Storm and wind hazard</td>
<td>

Use natural or man-made wind breakers such as court yards, trees, and shrubs.
Embedding the buildings in the terrain
Organizing the building so that the elongated façade is parallel to the wind the direction

</td>
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[179]
[178, 179]</td>
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<tr>
<td>Urban climate and heat Island Heat and warming trend</td>
<td>

Use of narrow paths and dense urban patterns to reduce solar exposure and to provide mutual shading.
Covered streets and passages.
Orientation of building in the direction of prevailing wind and desired sun path

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[191]</td>
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	• Orientation of roads and path to create of wind channels. • Use of movable light-coloured fabric sunshades	[169, 181, 186, 191]
Compound hazard	• Homogeneous communities with shared responsibilities and ability to repair damage. • Avoiding construction in risk prone areas • Passing of local adaptation knowledge throughout many generations	 [173] [165, 173, 192]

5.3 The 1.0 Building Generation: The Safe Building

Article number 229 of the Hammurabi’s code set for the first time in human history a specific performance based design requirement for buildings, stating that “ *If a builder builds a house for a man and does not make its construction sound, and the house which he has built collapses and causes the death of the owner of the house, the builder shall be put to death” [193]*. His structural safety design requirement led to the emergence of a new generation of buildings that, by law, were more than just mere shelters like their predecessors; they had to be structurally safe, giving rise to the first generation of '1.0 safe buildings' [14].

The design performance requirements of the first-generation evolved to accommodate other safety aspects, particularly fire safety, in response to growing urban populations, societal complexities, and technological advancements.

The fire safety was first addressed in the Rebuilding of London Act of 1666. The act came as direct result of the great fire of London of the same year and is viewed by many scholars as the true origin of the modern building regulations [194, 195]. The 1666 Act is an example of a 'prescriptive building requirement', which outlines specific mandatory design requirements for buildings such as the total ban of wooden houses and thatched roofs and the introduction of buildings exclusively with brick walls in order to prevent spreading of the fire [196].

Similar regulations addressing the fire safety of buildings appeared in other places at around the same time such as the 1625 building code of new Amsterdam (now New York) in the U.S [197] and in Hamburg, Germany after its great fire of 1842 [198].

From climatic adaptation point of view, most of the climate adaptation strategies used in the vernacular, can be found in the safe generation of buildings, although more deliberate and better engineered. For example, Vitruvius spoke in length about the importance of creating climate adapted buildings to ensure the health and comfort of users and established design rules that considered the building location, site conditions, exposure to wind, solar and access to water and day light[199]. Ancient architects like Vitruvius and Faventinus had established a systematic approach to room placement in buildings based on solar exposure, aiming to maximize solar energy use in winter and minimize heat absorption in summer [199]. Figures 22 and 23 provide examples of the climate adapted Roman architecture.

The ancient Roman architecture teaching of adapting the building design to work in harmony with the surrounding climate conditions and available resources were adopted by early Renaissance architects such as Andrea Palladio, Vincenzo Scamozzi as well as other European architects of the 15th and 16th century[200].

Figure 22: A partial subterranean Roman domus in the ancient city of Bulla Regia in present day Tunisia show an example of roman climate adaptation for hot areas

Figure 23: Clay ventilation ducts used by the Roman engineers to cool the subterranean domus in ancient city of Bulla Regia in present day Tunisia.

For example, the use of underground ducts for cooling was widely utilized technology in the Venetian villas[201]. A study made by Ferrucci & Peron (2018), illustrated in figure 24, showed the excellent performance of the underground ducts in maintaining indoor room temperature at or below the 20 ∘C mark during the summer period[202].

It was in the early 17th century that the scientific approach to developing climate adaptation solutions dominated. European architects of the time began to utilize emerging measurement tools and technologies to develop more precise climate adaptation solutions, employing Newtonian-inspired tables to illustrate the effectiveness of their designs [203].

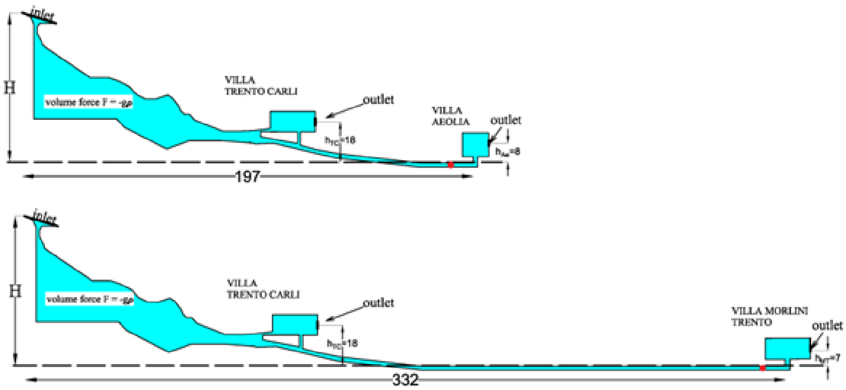


Figure 24: Schemes of the geothermal cooling systems used in 16th Century Villas in Costozza (Italy)[202]

Nevertheless, the general safety requirements, and the fire safety ones in particular, stood sometime in conflict with some of the traditional climate adaptation techniques that were inherited from the 0.0 generation of buildings or utilized by ancient architectures of 1.0 generation. For example, thatched roofs that expanded over the windows and provided sun shading and protection against heavy rain and hail were banned due to fire concerns [196]. Similarly, the wooden roofs were required to be hidden behind brick pediment [196]. The traditional and purposefully built narrow streets that provided shelter from wind and sun were expanded and the buildings were to adhere to clear propriety lines to enhance transportation and mobility in the city [198].

The onset of the Little Ice Age in Europe and North America during the early 15th to late 19th century might help explain the lack of interest in applying cooling climatic adaptations for summertime, as summers remained relatively mild during the Little Ice Age period.

Figures 25&26: The building regulations after the great fire of London banned the thatched roofs (to the left) and enforced the use of brick walls and brick parapets (image to the right)[204].

5.4 The 2.0 Building Generation: The Sanitary Building

The industrial revolution of the 18th century resulted in cities becoming the economic, cultural and social hub for human activities [205]. The industrial revolution exerted new social, economic and demographic pressures on the existing cities and the associated technological and scientific breakthrough of that period proved the building design requirements of the 1.0 generation to be obsolete[200]. The third cholera pandemic of 1840s fuelled the demand for new generation of buildings that ought to address the sanitary conditions of buildings and the wellbeing of their occupants[206].

The urgency of new sanitary performance requirements to stop the spread of diseases and improve the living conditions of the inhabitants led to the introduction of the Public Health Act of 1848 [207] and its follower - the Public Health Act of 1875 in the UK [208]. Both acts set a wide range of sanitary performance requirements on the building design such as the inclusion of toilets, sewers, controlled water supply, the right to natural light and ventilation [195, 209]. Similar building acts that focused on improving the sanitary conditions of buildings were introduced at around the same time in Germany and other western states[206, 210]. Hence, the 2nd generation of buildings “the sanitary building” was born.

The aesthetic, economic and social realities of the early 20th century coupled with the wide spread access to cheap construction materials, energy sources and utility networks, resulted in making the 2nd generation buildings almost totally dependent on active systems to adapt to their surrounding climate [211].

Figure 27and28: Examples of 2nd generation buildings showing extensive use of curtain wall systems and absence of external shading (to the left Bartningallee 9 building by Gustav Hassenpflug) and (image to the right Altonaer Straße 4–14 by Oscar Niemeyer) Both buildings were constructed as part of the Berlin Interbau of 1957

The architects of that time embraced the freedom the new construction materials and construction techniques available to them to create thin and light filled structures. The climate adaptation and occupant comfort and safety tasks were delegated to mechanical and civil engineers that can devise systems able to cope with varying climate conditions regardless of the location, risks or loads[211]. Mechanical ventilation, artificial lighting, instant hot water, and heating systems gradually replaced the passive climate adaptation techniques from previous building generations. Reyner Banham[212] sums up the lack of passive climate adaptation in the modernist buildings of the 20th century by saying "*As the progress of Le Corbusier's thinking shows, it would have been necessary to invent air-conditioning around 1930 had it not existed already*" .

Figure 28: A back alley in Jeddah, Saudi Arabia showing the overreliance on air conditioning and ventilation system that overtook the building back facades.

By the mid of 1950s, building laws and codes as the ones we are familiar with today, started to be widely enforced. In Germany, the German Federal Building Code (BBauG) appeared first in June of 1960. The Federal Building Code provides the legal basis for how land is to be used and set the framework for the minimum performance requirements buildings are to adhere to.

According to § 1, (4&5) of the 1960s Federal Building Code (BBauG), land use plans had to consider the social and cultural needs of the population, their safety and health, as well as the protection of nature and landscape[213]. In 1976, the BBauG was updated, and the goals of land use planning were expanded. Notably, § 1, Nr. (6) of the updated version of 1976 expanded the goal of the BBauG to ensure orderly urban development in accordance with the public good, contributing to securing a decent, humane environment [214].

The provisions for climate change adaptation first appeared in the building code amendments of 2011 [38]. However, these regulations are not applicable to the majority of existing buildings, as they were constructed before these laws were implemented[92, 93, 211]. It is estimated that more than 75% of these inadequately prepared buildings will still be in use after 2050[94]. Therefore, achieving a satisfactory level of resilience to climate change in building sector will depend on the comprehensive renovations of these structures.

5.5 The 3.0 Building: The Era of Energy Efficient Buildings

The inclusion of energy efficiency requirements in the building design started to appear in most Western building codes in the mid-70s as a direct response to the hard lessons learned from the oil export embargo of 1973 and the advances in the thermal insulation and cooling and heating technologies [215, 216]. While early 1950s and 1960s Scandinavian building codes required the introduction of thermal insulation and double glazing, these requirements were intended to improve occupant health and comfort rather than to enhance the energy performance of buildings[216].

Germany introduced its first prescriptive energy code, the Wärmeschutzverordnung (WSVO) , in 1977[217]. The energy efficiency requirements have since evolved through several iterations, setting ever stricter limits on the building’s energy expenditure. Starting from the 2010 onwards, improving the energy efficacy of the building stock and reducing its carbon footprint spearheaded the German and the European effort in reaching the climate targets in the building sector. As noted in the (EPBD) of 2010 [218] that emphasized the role of the building sector in achieving the EU's 2020 and 2050 climate change targets for the first time [219].

As per the EPBD of 2010, the building sector is tasked with achieving these targets through reducing building GHG emissions, increasing the share of renewable energy, and enhancing the overall energy efficiency of buildings[218]. Moreover, the EPBD 2010 directive instructed all member states to ensure that all newly built public building built after 2018 are nearly zero energy buildings and that all other buildings type built from 2021 onward are nearly zero energy buildings. The EU commitment to limit the global warming at the 1.5°C above industrial level as agreed in the Paris accord [57] and the IPCC call on the urgency to further reduce the global GHG emissions to reach the 1.5°C target [220] encouraged the EU to introduce in 2018 their long-term vision for a climate neutral content by 2050 in their Clean Planet for all strategic vision[221].

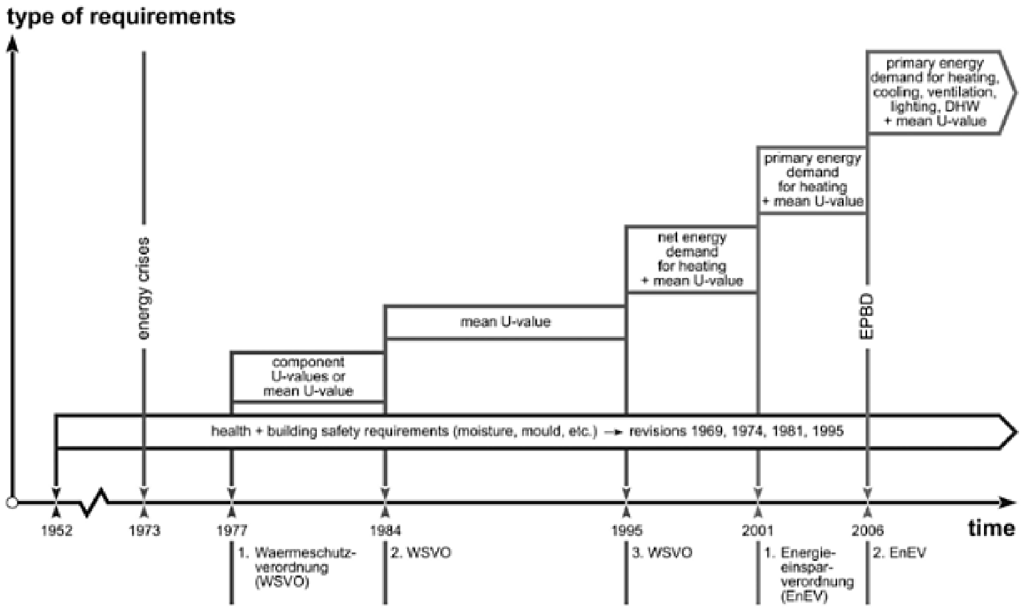


Figure 29. A time line showing the development of the energy efficiency requirements in Germany in conjunction of the development of safety and sanitary requirements of the 2.0 generation of buildings [222].

The Clean planet strategy highlighted the central role of decarbonising and renovating the existing building stock to achieve the Paris accord target. Moreover, the strategy mentioned for the first time the urgent need to have smart and zero emission building to achieve this target, hence, recognizing the deficiency of the nearly zero energy building strategy of the EPBD of 2010. However, the latest amendment of the EPBD (2018/844) maintained its commitment to the strategy of nearly zero-energy buildings, and not the zero-emission building [40]. Germany, the latest generation of building energy performance requirements is represented by the Gebäudeenergiegesetz (GEG) 'Building Energy Act 2020' introduced in late 2020[39].

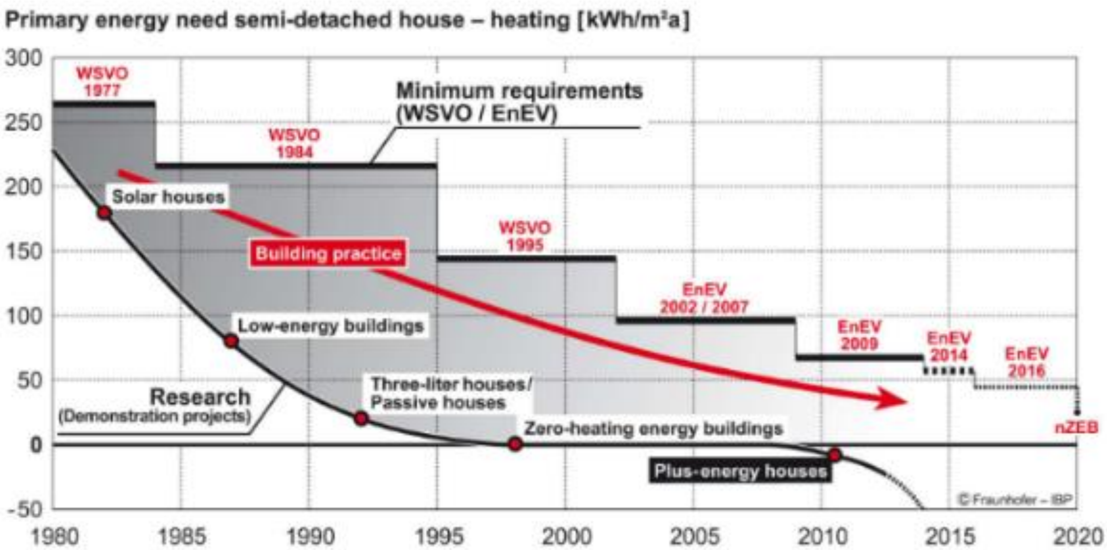


Figure 30: A time line showing the development of the energy law in Germany [223]

5.5.1 Climate Change and the 3.0 Building Generation: Strategies, Success, and Shortcomings

Energy-efficient buildings currently represent the minimum building design performance requirements mandated by law in Germany. That is, all newly built and deeply renovated buildings must adhere to this generation of performance requirements, which encompass the requirements of past generations (2.0 - the sanitary and safe building) and add energy efficiency aspects. Interestingly, this is the first generation of performance requirements that offers a rating system indicating the building's performance in a specific aspect (in this case, energy efficiency) against a benchmark.

In 2011, German building law was amended to include climate protection (mitigation) and climate adaptation as main objectives for the first time in paragraph (5) of § 1 (objectives, definitions, and principles of land use planning).

In practical terms the objectives of the German building law (BauGB)are enforced on buildings through a combination of ancillary rights (Baunebenrechte) such as the Gebäudeenergiegesetz (GEG) "Building Energy Act 2020" [39] and local building regulations (Bauordnungsrechts).

The Gebäudeenergiegesetz (GEG), or Building Energy Act 2020, requires all newly built and deeply renovated buildings to be nearly zero-energy buildings, where the operational energy expenditure of the building is drastically reduced to almost zero kWh/m². a (around 55 kWh/m². a), in alignment with national and EU carbon targets for 2030 and 2045 (2050 in the EU). Meeting this strict energy requirement is usually done via increasing the thermal insulation of the building shell, improving the efficiency of the HVAC systems, covering part of the energy demand with renewable sources and reducing the infiltration levels of the building envelope[216], as shown in figure 33.

Figure 31: A row residential buildings in Germany built post 2010 showing the typical features of design performance requirements of the 3.0 generation such as the use of solar PVs and solar Collectors on the roof, the relatively small openings, the external solar shading, and the extruded envelope insulation.

The absence of quantifying the carbon footprint of the used insulation materials and HVAC systems throughout their entire life cycle - from production to end of life - there is a significant risk that the GHGs saved by the building during its operation could be less than the amount of GHGs released during the production, construction, and disposal of these materials and systems [224-227]. Hence, rendering the climate change mitigation contribution of existing nearly zero energy buildings useless. This view is echoed by the International

Energy Agency's (IEA) assessment, which estimates that climate change mitigation targets can only be achieved by zero-carbon buildings, not by zero or nearly zero-energy buildings [228].

From a climate adaptation perspective, the high levels of thermal insulation and low infiltration rates required to achieve nearly zero energy standards can significantly increase the risk of indoor overheating during the summer months. This could exacerbate a building's vulnerability to heatwaves, thereby compromising its climate change adaptability [153, 154].

In terms of local building regulations, measures for climate protection and adaptation are often mentioned indirectly. For instance, the Bavarian Building Regulation (BayBO) incorporates protection against climate impacts indirectly in § 3 (General Requirements), § 11 (Protection against Impacts), and § 15 (Construction Types). These articles stipulate that all newly constructed or renovated buildings should adhere to the recognized rules of architecture and building technology (Anerkannte Regeln der Technik, aRdT).

Standard-setting bodies such as DIN (Deutsches Institut für Normung), CEN (European Committee for Standardization), and ISO (International Organization for Standardization) typically establish what is considered the recognized rules of architecture and building technology[229]. However, it is important to remember that the application of norms is voluntary and becomes legally binding only if a law explicitly refers to it[230].

Germany is known for having a wealth of standards and norms across various industries, and the construction industry is no exception. Marc Derichsweiler from the finance ministry of the federal state of Rhineland-Pfalz estimates that about 3,300 DIN, ISO, and EN norms apply to the construction industry[42]. Furthermore, professional associations like the Association of German Engineers (VDI) publish numerous recommendations and guidelines that help define the state-of-the-art in building technologies, thereby increasing the number of relevant norms and standards.

Searching for DIN norms that directly address climate change adaptation is a massive task beyond the scope of this research. However, the German Federal Environment Agency (UBA) initiated a research project titled "Adaptation standard: Analysis of existing standards for adaptation needs with regard to the consequences of climate change." This project investigated the extent to which the currently used DIN and other standards consider the impacts of climate change[43]. The study's final report found that only 11 out of approximately 34,000 DIN norms, or 0.003%, mention the impacts of climate change. Out of this small number, our research identified only seven DIN norms and VDI guidelines that directly address climate change in the urban built environment. The list of identified norms and VDI guidelines organized by the addressed hazard and spatial scale of application can be found in Annex 2. Considering the estimated 3,300 norms relevant to the construction industry, it can be said that only about 0.2% of existing DIN norms have been updated to include adaptation to climate change.

5.5.2 Evaluating the Integration of Climate Change Adaptation Considerations in the 3.0 Building Generation

A central aim of this chapter and the broader research project is to evaluate the degree to which climate adaptation are considered or integrated in the current German building performance requirements and rating systems. This assessment serves to highlight the existing gaps in these rating systems.

In this section the evaluation is made for the 3.0 generation of performance requirements and rating systems which are represented by design norms and guidelines issued by the DIN and VDI as well as the Building Energy Act of 2020 (GEG).

The evaluation is conducted based on the 4-point assessment system describe in the introduction of this chapter and range between 'absent,' assigned 0 points; 'somewhat included,' assigned 1 point; 'Fairly included,' assigned 2 points; or 'well included,' assigned 3 points. For more information refer to table 3.

The evaluation results are summarized in figure 32 and 33 and the points assigned to each hazard by each sector are detailed in Annex 3 . Based on the evaluation made, t is safe to say that the German 3.0 generation of building performance requirements scarcely incorporate provisions for climate adaption. For example, no updated norms or standards across the investigate seven building sector that put clear adaptation requirements for droughts were found. In contrast, we found that the hazard of a warming trend is in general fairly addressed. However, the analysis showed that this results is attained primarily due to the co-beneficial effect of thermal insulation and energy efficiency requirements . The hazards of heavy precipitation, storms, wind, and flooding events are also partially and insufficiently addressed.

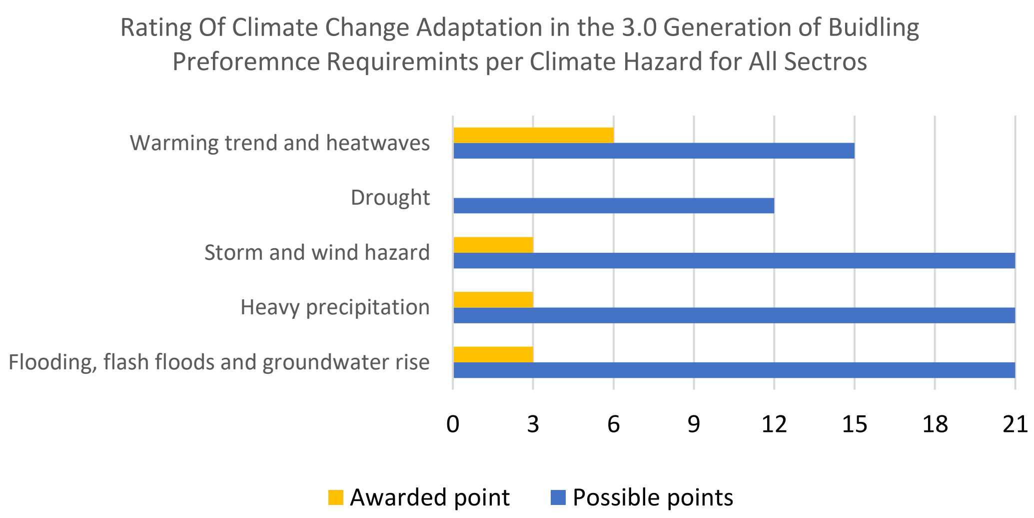


Figure 32: Results of the rating of the degree to which climate change adaptation are addressed in the 3.0 generation of building performance requirements broken down per key urban sector across the climate change hazards.

From the perspective of the building sectors, it was noticed that the norms related to water and wastewater systems show a very well incorporation of adaptation provision for floods and heavy precipitation. This can be partially explained in the light of the 2021 floods.

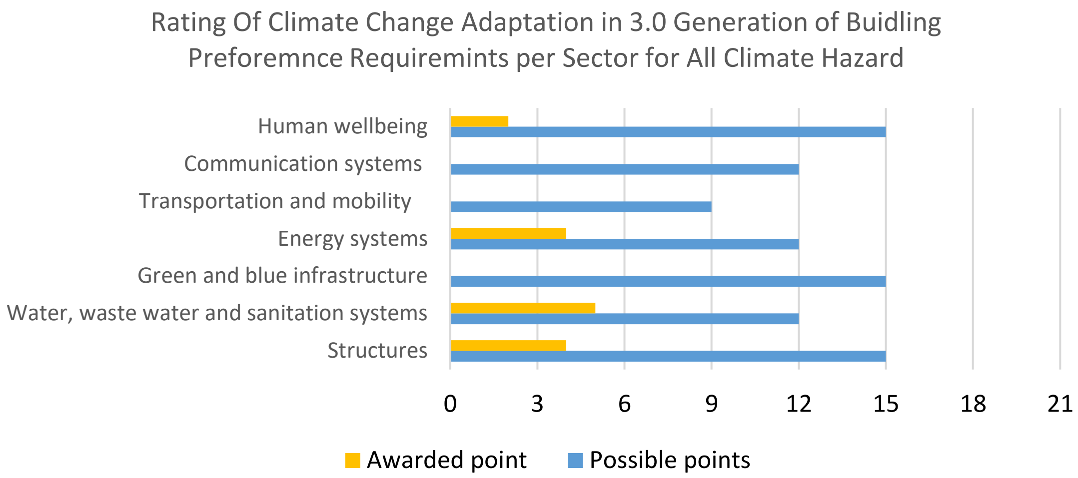


Figure 33: Results of the rating of the degree to which climate change adaptation are addressed in the 3.0 generation of building performance requirements broken down per climate change hazard across the key urban sectors.

In general, the results indicates that adaptation measures for climate-induced hazards are not adequately integrated into the 3.0 generation of building performance requirements. Yet again, Nonetheless, this observation isn't a measure of the efficacy of adaptation but rather an alert to the existing shortfall in recognizing climate change in the existing standards. It also underscores the limitations of energy-centred performance requirements in addressing the challenges posed by climate change.

5.6 From Green to Sustainable Building: The 4.0 Building Generation

In 1990, the British Building Research Establishment (BRE) published under the name Building Research Establishment Environmental Assessment Method (BREEAM) its environmental assessment for new office designs, hence becoming the world first assessment system for environmentally friendly buildings [231]. Over the years other national green buildings ratings such as HQE in France, LEED in the U.S and CASBEE in Japan started to appear and by 2010 over 600 such systems were in used all over the globe[232]. With the expansion of the scope of the rating systems to cover social and economic aspects next to the environmental aspects, the green buildings ratings evolved into the currently known sustainability rating system[232]. The use of such systems remains, however, largely voluntary.

Although the sustainable development paradigm differs substantially from the frameworks that measure and outline the climate change response, a dual relationship between both frameworks was recognized early on[22, 23] . Ideally the proposed frameworks in both domains - sustainability and climate change - should work in harmony, complementing each other’s objectives. However, due the complexity, differing objectives, and the multi-cross scale relation of each domain this is not always the case [23].

Sustainability systems in essence are more about promoting sustainable use of resources and mitigating climate change. Resilience is about reducing the vulnerability to climate change impacts through improving the adaptation and reducing the exposure to the risk[19]. As such the objective of each system differs greatly.

The use of measures to achieve one objective can inevitability help improve reaching the other. This conclusion is rather well reflected in the research of Felicioni et al.(2023) about finding the common ground between sustainability and resilience in the building sector[30]. In their study, it was shown that although adaptation to climate change is usually addressed in major sustainability rating systems, the weight of the climate adaptation topic and consequently its impact on the overall score of the building is rather marginal as noted by the dark red area in figure 34 below. Nevertheless, the study identified eight domains where the objectives of sustainability rating systems (mitigation) and climate change resilience (vulnerability reduction) overlap and enhance each other. This research proposes adding 'barrier-free design' as another performance requirement that addresses both sustainability and resilience objectives. Therefore, the domains where both systems overlap are:

1. Renewable energy generation
2. Water efficiency
3. Thermal comfort
4. Natural hazards assessment
5. Ease of material recovery and recycling
6. Daylight and ventilation
7. Access to quality transit
8. Site ecology
9. Barrier-free design (suggested to be added by this research)

Moving from a general overview to specific local insights, the following subchapter will investigate the extent to which three nationally recognized German sustainability rating systems incorporate climate change adaptation into their performance requirements. This will be evaluated using the same 4-point scale discussed earlier, in a manner like the method used to assess the integration of climate change adaptation of the 3.0 generation of building.

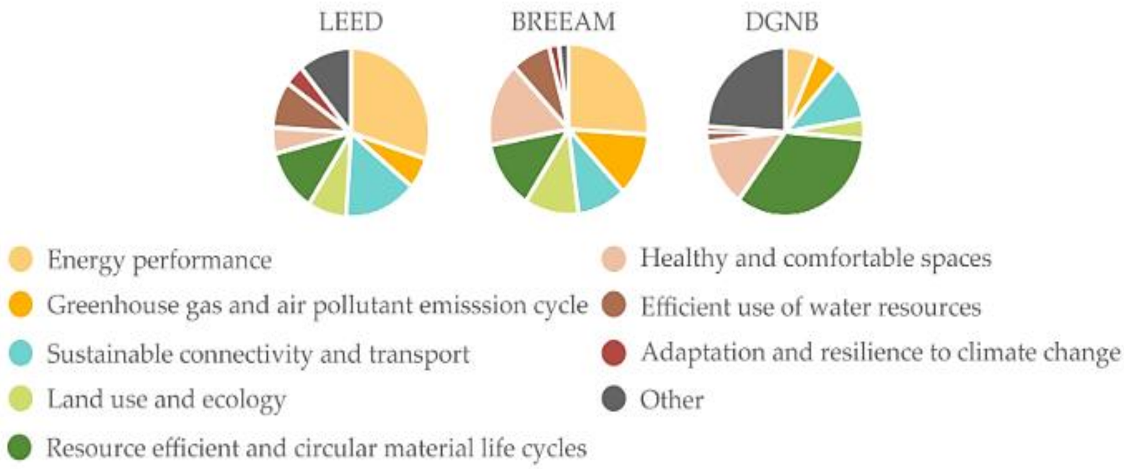


Figure 34: Overview of the topics addressed by three major sustainability rating organized according to sum of criteria weights in each system [30]

5.6.1 Evaluating Climate Change Adaptation Considerations in German Sustainable Residential Building Rating Systems

In 2011, the German Federal government committed itself to certify all newly built or renovated federal public buildings with the nationally developed Assessment System for Sustainable Building (Bewertungssystem Nachhaltiges Bauen – BNB). A decade later and as part of the government climate protection plan 2030 the Qualitätssiegel Nachhaltiges Gebäude –QNG (Sustainable building quality seal) was introduced. The QNG is not a rating system, but rather an umbrella seal for all nationally accredited sustainability certification systems.

Residential buildings that achieve the certain energy class and are certified by a sustainability rating system accredited by the QNG, are eligible for a range of lucrative funding and subsidies provided by the national KFW Bank under the KFN (climate friendly building) program.

At the time of writing (April 2023) there are only three recognized and accredited sustainability certification systems that can be used to fulfil the KFN class for residential buildings, which are:

A. The DGNB System Version 2018 (NWO18) and DGNB Neubau Kleine Wohngebäude (NKW 13.2)
B. The Qualitätssiegel Nachhaltiger Wohnungsbau (NaWoh V3.1)
C. Bewertungssystem Nachhaltiger Kleinwohnhausbau (BNK_V1.0) - (used to certify up to 5 dwellings)

It is foreseen that the QNG will introduce and recognize more systems for residential and non-residential buildings starting from 2024 onwards. Nevertheless, as these changes are happening rapidly, they won't be considered in this research, and the focus will remain on the above-mentioned systems used for small scale residential buildings. It is also worth mentioning that the three systems (DGNB NK13.2, NaWoh 3.1 and BNK V1.0) are not harmonized with each other. Hence, they cannot be directly compared.

In the following subchapters, the climate change adaptation considerations embedded in each of the abovementioned sustainability certification system is going to be evaluated using the methodology discussed in the introduction of this chapter. It's important to note that since fulfilling the requirements of the 3.0 generation is a prerequisite for a building to be certified using any of the QNG approved rating systems, the evaluation will not recount any measure already required in the 3.0 generation but add them to it. In this sense, if in either generation there is requirement that provide a more a more enhanced inclusion of adaptation measure is mentioned, the measure with the higher score will be considered.

5.6.1.1 Evaluation the Climate Change Adaptation Incluiosn the DGNB NKW (Neubau Kleine Wohngebäude), Version 2013

The DGNB system for the certification of single family and small residential buildings (up to 6 dwellings) was developed in mid-2015 by the DGNB (German Green Building Council) and is abbreviated as NKW 13. The DGBN NKW 13 uses basically the same rating template and logic used to the assess non-residential building, however, some new indicators are introduced to the system and the system weighting is adjusted to highlight areas that are considered more important for residential building.

The NKW 13 rates the buildings performance in 5 categories which are: environment, economy, social, technical, process and site. The DGNB NKW 13 system consists of 28 criteria that contain a total of 102 indicators.

In terms of the degree to which the DGNB NKW System incorporates climate change adaptation measures, the system shows a clear improvement over performance of the 3.0 generation. The improvement is more apparent when considering adding the DGNB NKW to rating requirements of the 3.0 generation requirements. Nevertheless, as can be seen in the figure 36 and figure 37 below, these considerations are far from being sufficient to holistically address all the climate change hazards areas and key urban sectors.

Interestingly, the DGNB NKW system demonstrates limited consideration of climate change adaptation in the communication and transport sector. This lack of enhanced consideration be attributed to the fact that fact that the system version used is already over 10 years old and the importance of the communication system might have been overlooked at the time of the system development. In the transport sector, the system contains a wealth of indicators that address transport and alternative mobility options, nevertheless, these considerations are largely descriptive and marginally affect the overall sustainability score of the building (less than 2%). Lastly both topics are at the very edge of the building scale and heavily interact with the broader urban scale. Conversely, the system shows high degree of inclusion of adaptation measures within the water and wastewater system. This can be attributed to the system addressing both the freshwater consumption, the reduction of wastewater as well as the use of grey water and rainwater collection systems. Moreover, the system showed an advanced consideration for the topic of the warming trend hazard. This is demonstrated in the system requiring a detailed thermal simulation to assess the occupant's thermal comfort. However, the requirements fall short of asking to run the simulation with weather data files that depict the expected climate conditions in 2050 as in the case of the European Level(s)system. Therefore, the only a "fair" rating with 2 points was awarded.

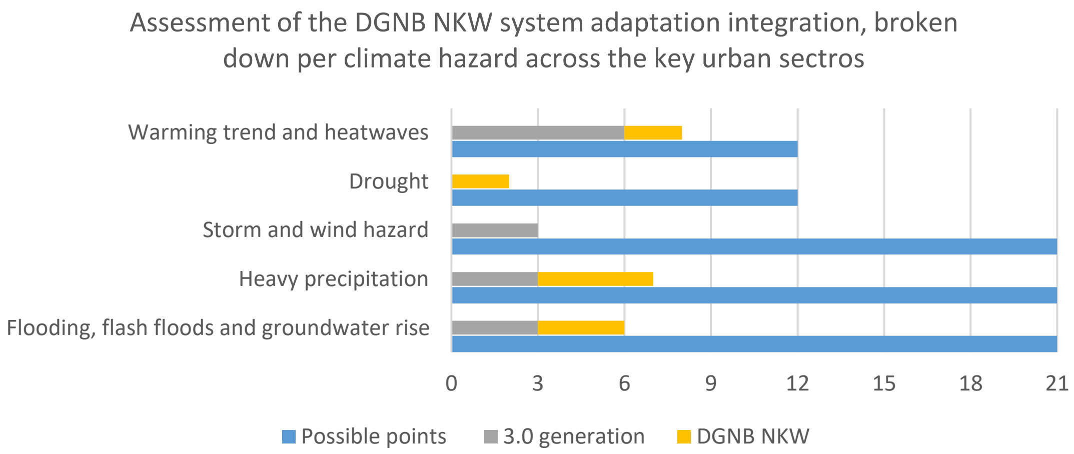


Figure 35: Assessing the degree to which climate change adaptation are addressed in the DGNB NKW system per climate change hazards across the key urban sector.

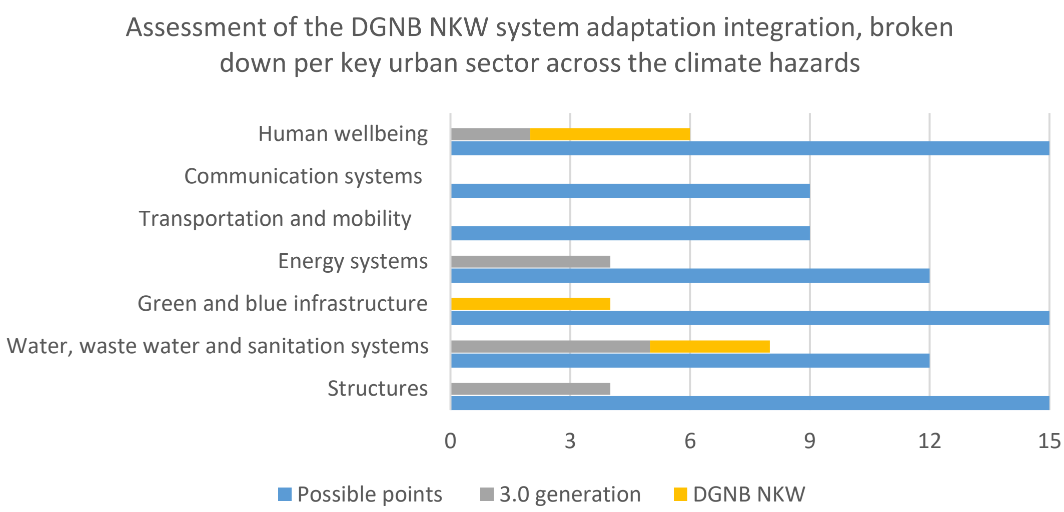


Figure 36: Assessing the degree to which climate change adaptation are addressed in the DGNB NKW system per key urban sector across the climate change hazards.

In total, the DGNB system showed a well-rounded consideration of the various impacts and hazards across most the key sectors A detailed overview about how this evaluation was made and the how the evaluation scores where assigned is provided in the annex 4 of this research.

5.6.1.2 Evaluating The Climate Change Adaptation Inclusion in the Bewertungssystem Nachhaltiger Kleinwohnhausbau (BNK_V1.0)

The Bewertungssystem Nachhaltiger Kleinwohnhausbau system (BNK) came to light based on several research projects conducted by Prof. Essig and her team at the Munich University of Applied Science. The BNK system was developed in the unvierstiy lab of Prof. Dr.-Ing. Essig in cooperation with representative from the construction and real estate industry and the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). In November 2015, The Building Institute for Resource-Efficient and Sustainable Building GmbH (BiRN) was founded as spin-off to manage the newly developed BNK system. Since then, BiRN acts as the BNK system scheme operator and certification body. The BNK system consists of 19 evaluation criteria that are hosted in four categories: Sociocultural and functional quality, Economic quality, Environmental quality, and Process quality.

In terms of the extent to which the BNK System incorporates climate change adaptation measures, it parallels the DGNB NKW system in exhibiting clear improvements over the 3.0 generation. While the BNK system has fewer indicators compared to the other two systems, it demonstrates a comparable amount of inclusion of adaptation provisions as to the DGNB NKW system. Although these considerations are a step in the right direction, they are far from being sufficient to holistically address all the climate change impact areas and key urban sectors as can be seen in the figure 37 and figure 38 below. Notably, as in the case of DGNB, the BNK system's consideration of climate change in the communication and transport sector is lacking, with both sectors almost entirely absent in the system. On the other hand, the BNK system shows a fair incorporation of adaptation consideration in the areas of water and wastewater systems, as well as drought impact, due to its focus on freshwater consumption and water system hygiene. The latter is not addressed in any other system. Nevertheless, the consideration of water system hygiene remained rather limited and only 1 point was awarded. In general, it can be said that both the BNK and DGNB system showed a comparable degree of inclusion of adaptation topics. The table found in annex 5 provide a detailed overview about how these scores were assigned and calculated.

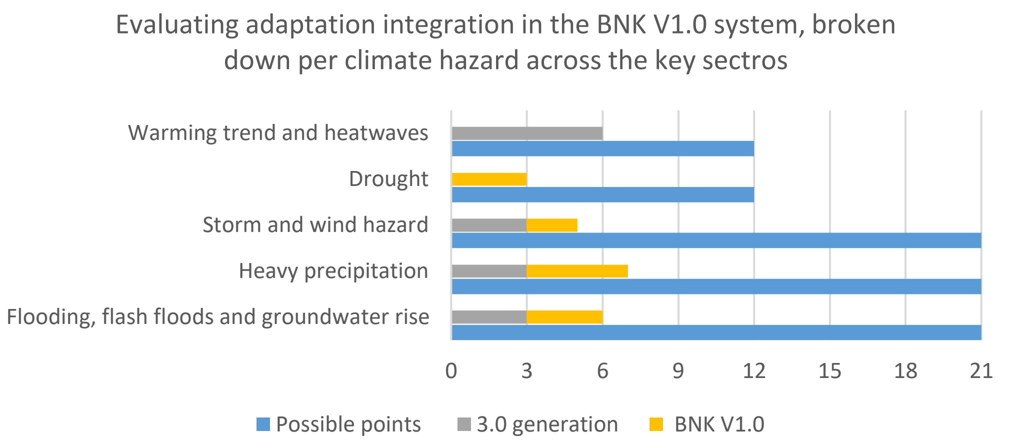


Figure 37: Assessing the degree to which climate change adaptation are addressed in the BNK V1.0 system per climate change hazards across the key urban sector.

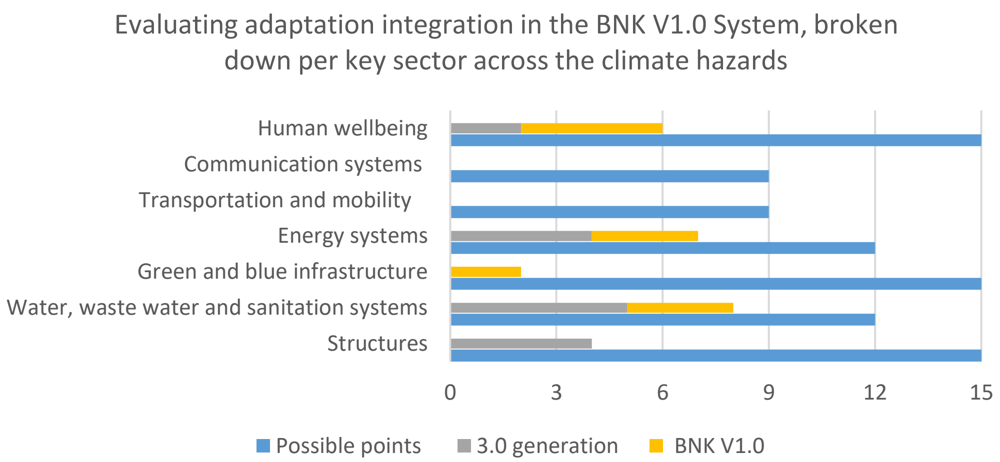


Figure 38: Assessing the degree to which climate change adaptation are addressed in the BNK V1.0 system per key urban sector across the climate change hazards.

5.6.1.3 Evaluating the Climate Change Adaptation Inclusion in The Qualitätssiegel Nachhaltiger Wohnungsbau rating system (NaWoh V3.1)

Similar to development of the BNK system, the NaWoh system was also developed based on the results of the Sustainable Housing (Nachhaltiger Wohnungsbau) research project that was funded by Federal Institute for

Research on Building, Urban Affairs and Spatial Development (BBSR). After the research project, The NaWoh association was created in 2012 via several real estate and professional associations and chambers. The NaWoh association is the NaWoh scheme operator and certifying body. The latest iteration of the NaWoh system (V3.1) published in 2020 covers 5 categories with a total of 70 evaluation criteria that are distributed as follows: 25 criteria in the living quality category, 17 in the technical quality category, 13 in the process quality category, 12 in the ecological category, and 3 in the economical quality category.

In relation to the degree of incorporation climate adaptation measures within the NaWoh System, the NaWoh showed a the highest level of inclusion of adaptation topics among all examined sustainability rating systems. The NaWoh system showed a well degree of inclusion of climate adaptation in regard to the climatic hazards of floods, heavy participation and storm and wind. In regard to the hazard of heatwaves, the NaWoh system does not require further mitigation measures that go beyond that was already required in the 3.0 generation. From the building's sectors perspective, its noticeable that the NaWoH system also demonstrated a fair to well degree of inclusion adaption measures except in the transport and mobility sector. Despite the impressive results achieved by, the NaWOh failed short of attaining the full three points due to two primary factors:

1. The system often refers users to adhere to building norms and standards that, in themselves, are not updated to consider climate change impacts, as outlined in subchapter 5.5.1.
2. The NaWoh system's requirements in regard to climate adaptation remain, as acknowledged by the NaWoh system itself, largely descriptive without a clear scoring methodology. See for example KPI, 2.4-2 Response to increased flood risk, 2.2.5 Durability and 2.2.6 Ease of maintenance/ retrofitting of building technical systems. Hence, both the user and the auditor lack a clear, unified method to judge the effectiveness of the applied adaptation measures. This challenge is rather a common problem faced by all sustainability rating systems. It can be partially explained by the novelty of the resilience rating systems and topics and the conflicting universal approaches of sustainability rating systems and climate change adaptation systems, a topic that will be explored in more detail in the next chapter of this research.

A detailed overview about the scores obtained by the NaWoh system and how these scores are reached is provided in the tables annex 6 of this research.

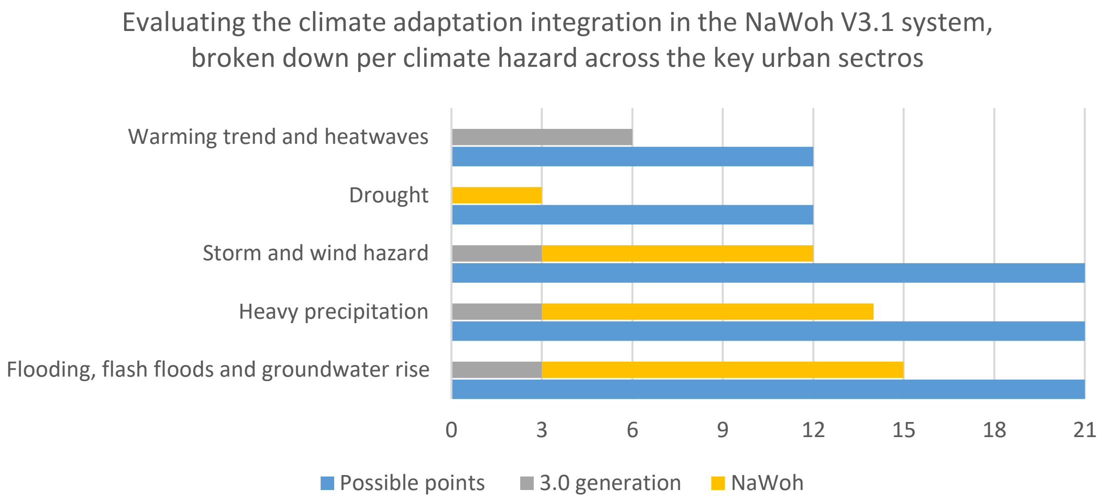


Figure 39: Assessing the degree to which climate change adaptation are addressed in the NaWoh V3.1 system per climate change hazards across the key urban sector.

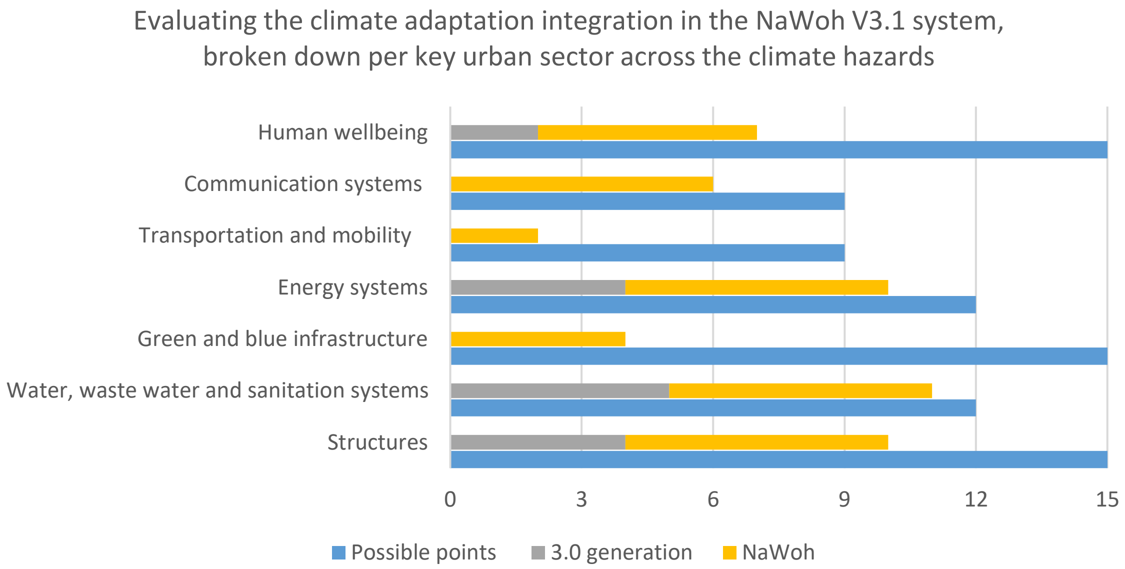


Figure 40: Assessing the degree to which climate change adaptation are addressed in the NaWoh V3.1 system per key urban sector across the climate change hazards.

5.7 The Smart Building

The twining between human and machine rapidly evolved from a cinematic fantasy in the early 20th century to a prevalent reality by the century's end. Computers' ability to store, manage, process, and communicate vast amounts of data in fractions of seconds initiated a new epoch in human history, known as the information age. The concept of leveraging on the power of computers and data networks to create a sustainable and climate aware urban environments was first introduced by Peter Droege in his winning design proposal for the Campus City Kawasaki competition in Japan in 1986[233]. As the computer power improved and the internet infiltrated every aspect of life, the smart city concept spread fast to cover every aspect in life resulting in the widespread automation of modern cities operations from mega infrastructure to individual buildings.

Currently, almost every aspect of life connected to the internet is eligible to bear the “smart” prefix. Hence, there is the smart grid, smart infrastructure, smart mobility, smart government, smart phones, and sure enough smart building. This fluidity in labelling things with the smart term makes defining a smart Building a bit of an elusive task.

Modern smart buildings trace their origins to the intelligent buildings of the 1980s [234]. However, while the 80s intelligent buildings were generally reactive in nature, the new smart buildings are proactive[234]. Smart buildings utilize the extensive amount of internal and external data collected through their sensors and internet connectivity to anticipate and prepare for events in the immediate or foreseeable future[234]. Moreover, smart buildings are capable of leveraging temporal and spatial scales that extend well beyond their physical boundaries to optimize the performance of both individual and surrounding buildings [45].

Currently, the global building sector in general, and European one in particular, is in the midst a complex transition from energy efficient and sustainable (3.0 and 4.0 generations) toward a sustainable and smart (4.0 and 5.0 generation) performance requirements. This transition is driven by a combination of various policies, regional and national energy and environmental goals, financial constraints, societal shifts, and technological changes. Moreover, the advancements of the 4.0 revolution, and fallout of the COVID-19 pandemic are shifting the building user expectations toward a more empathic and interactive buildings have put forward the immense potential of utilizing big data to enhance building performance as means to combat climate change [235, 236].

This transition towards smart building stock is observed at the policy level, which is evident in newly adopted amendments to the proposal of EPBD in March 2023 [237, 238] and the EU taxonomy of 2020 [239]. The careful review of the amendments made to the EPBD draft of 2023 [237] shows a clear departure from 3.0 energy efficient building requirement towards incorporation a much wider range of design requirement typical of the 4th generation of sustainable buildings (the use of life cycle assessment for calculating the energy and carbon footprint of building, putting emphasis on circular economy and the inclusion of provisions related to indoor air quality). Moreover, the recast of EPBD defines is objective §3 as to aid the EU transition toward a climate-neutral and smart cities. Therefore, we witness that the EPBD acknowledges in many of its amendment articles the crucial role of “smart “technologies to support and complement the EU 2030 and 2050 objectives. For example, the recast EPBD 2023 expands requirements for building to include smart meters, smart girds, smart charging, automation and explicitly mentions ‘the Commission’s Smart Finance for Smart Buildings’ (§47) [237]. Moreover, it is envisaged that introduction of an EU-wide rating scheme for the “smart readiness” of buildings will foster the transition to smarter buildings and “raise awareness amongst building owners and occupants of the value behind building automation” [238].

While the EPBD recast touches tangentially on the topic of climate adaption in the building sector, this topic is rather clearly addressed in the EU taxonomy regulation that came into force in 2020. The EU taxonomy serves as a fundamental pillar of the European Union's Green deal plan and transition towards carbon free building stock by 2050. Moreover, it spearheads the Union's effort to enhance market transparency and channel investments towards economic activities that are essential for the transition according to the objectives of the European Green Deal. Similar to the position adapted by the draft recast of EPBD 2023, the EU taxonomy foresee the benefits of inclusion smart building aspects such as the installation (or repair) of building automation and control systems, building energy management systems (BEMS), lighting control systems and energy management systems as well as smart meters to contribute significantly to climate change mitigation objectives [239, 240].

With this transition towards smart and sustainable building stock that is taking place in parallel to the first signs of changing climate, it is important to assess at this early stage to which extent the smart building rating schemes are incorporating provisions which support directly or indirectly buildings' adaptation to hazards of climate change.

In contrast to the well-established rating systems used for certifying sustainable and energy-efficient buildings, most smart building rating schemes are still in the research domain, with very few being operational (deployed in the market). Among these few operational rating systems, there is the Smart Readiness Indicator (SRI), SmartScore, WiredScore, and the Ready2Services (R2S) label.

The smart readiness indicator (SRI) was launched by the EU in late 2020 to work in tandem with the energy efficiency certification and is used to rate, as the name suggests, the smart readiness of buildings. The SRI is currently in its last phases of active testing and is expected to become part of the new amendment of the EPBD, anticipated in the late 2023.

The SmartScore rating system was launched in 2013 by the New York based company WiredScore. The SmartScore evaluates the buildings based on the integration of smart systems that enhance user experience, minimize costs, and promote sustainability.

WiredScore is a digital connectivity certification system that rates the digital the physical elements of the building necessary for paving the way for it to be smart. This includes the building infrastructure, mobile coverage, and wireless connectivity. Lastly, the Ready2Services (R2S) label developed by Certivéa and the Smart Buildings Alliance (SBA) with 35 certified buildings is claimed to be the most widely used smart building rating system in Europe. The R2S label is close in its objective to the WiredScore system. The R2S label focuses on readiness of a building to accommodate a multitude of digital services, to make it adaptive, pleasant to live in and able to interact with its environment.

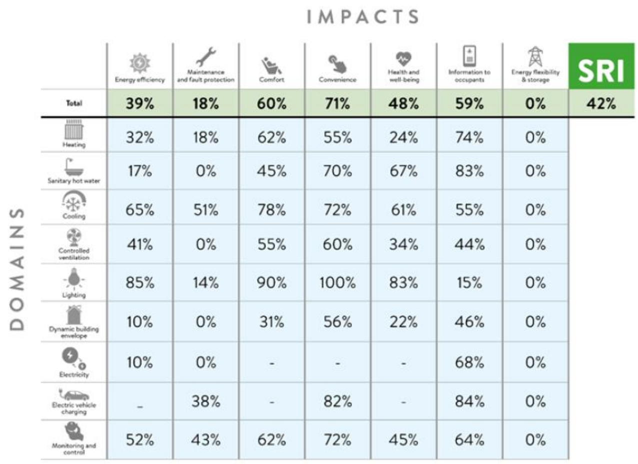
5.7.1 The Climate Change Adaptation Considerations in the Four Smart Building Rating Systems

In the subsequent section, each of the mentioned smart building certification systems will be evaluated, based on the degree of incorporation of climate change adaptation considerations within their performance requirements. The methodology applied here is identical to that used in evaluating the previous generation of rating systems (3.0 and 4.0), as discussed in the introduction of this chapter, and detailed in table 3.

In line with the approach utilized in subchapter 5.6.1, double counting of adaptation measures is avoided. In cases where a superior adaptation measure is mentioned in either the 3.0 or the 5.0 generations, the measure with the higher score will be considered. It is worth noting that measures arising from the 4.0 rating systems are not included, as they are generally not a prerequisite to attain smart building certification.

5.7.1.1 Evaluating the Climate Change Adaptation Integration in the Smart Readiness Indicator (SRI) System

Leveraging the ability of smart buildings to exploit temporal and spatial cross-scaling synergies for economic and environmental benefits, the EU introduced a voluntary smart building rating scheme, the Smart Readiness Index (SRI), in its latest revision of the EPBD [40] .Currently, it operates as an optional rating of a building's smart readiness [46]. The SRI score is a ratio that reflects the building's smart readiness in comparison to the maximum achievable smart readiness. The SRI consists of nine technical domains and seven impact criteria, encompassing heating, domestic hot water (DHW), cooling, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, and maintenance and control. Each of these domains is assessed in the SRI system for its impact on energy efficiency, maintenance, comfort, convenience, health and wellbeing, information to occupants, and energy flexibility and storage.



IMPACTS / DOMAINS

	Energy efficiency	Maintenance and fault protection	Comfort	Convenience	Health and well-being	Information to occupants	Energy flexibility & storage	SRI
Total	39%	18%	60%	71%	48%	59%	0%	42%
Heating	32%	18%	62%	55%	24%	74%	0%	
Sanitary hot water	17%	0%	45%	70%	67%	83%	0%	
Cooling	65%	51%	78%	72%	61%	55%	0%	
Controlled ventilation	41%	0%	55%	60%	34%	44%	0%	
Lighting	85%	14%	90%	100%	83%	15%	0%	
Dynamic building envelope	10%	0%	31%	56%	22%	46%	0%	
Electricity	10%	0%	-	-	-	68%	0%	
Electric vehicle charging	-	38%	-	82%	-	84%	0%	
Monitoring and control	52%	43%	62%	72%	45%	64%	0%	

Figure 41: Matrix showing an example composition of the SRI domains and impacts criteria and the aggregation mechanisms of the SRI system[241]

In terms of improving building resilience against climate change, most SRI indicators focus on optimizing energy consumption through a mix of energy monitoring, fault detection, energy demand forecasting, and communication with the external grid. Consequently, the SRI heavily relies on active system adaptation, which has its own inherent vulnerabilities. Nevertheless, when assessing the combination of SRI in addition the 3.0 generation requirements, as foreseen by the EU renovation strategy [242],results in a significant improvement in the building's inclusion of climate adaptation provisions. This more apparent in the hazard of heatwaves and in the energy sector, owing to the SRI system's focus on renewable energy generation and smart grid integration.

However, as demonstrated in Figure 42 and Figure 43, these considerations fall short from addressing all the climate change impact areas and key building sectors, such as drought and the resilience of the transport and blue and green infrastructure sectors. The system is generally complementing the existing requirements of the 3.0 generation with its very strong focus on energy efficiency and expand slightly on it by introducing adaptation relevant provisions for the communication sector. A detailed explanation of how this score was determined is provided in Annex 7.

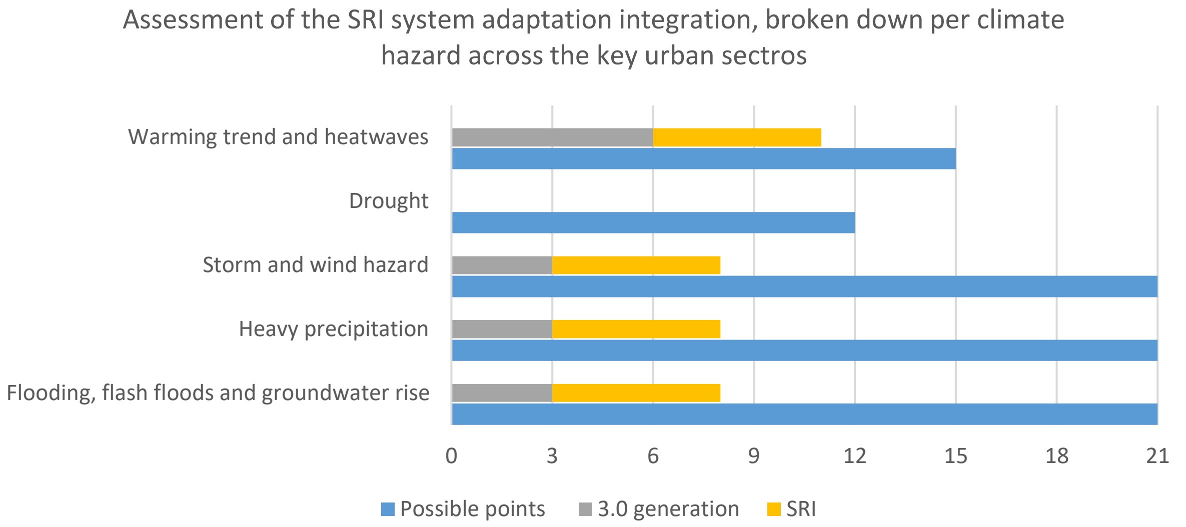


Figure 42: Assessing the degree to which climate change adaptation are addressed in the SRI system in combination with the 3.0 generation of building requirements broken down per climate change hazards across the key urban sector.

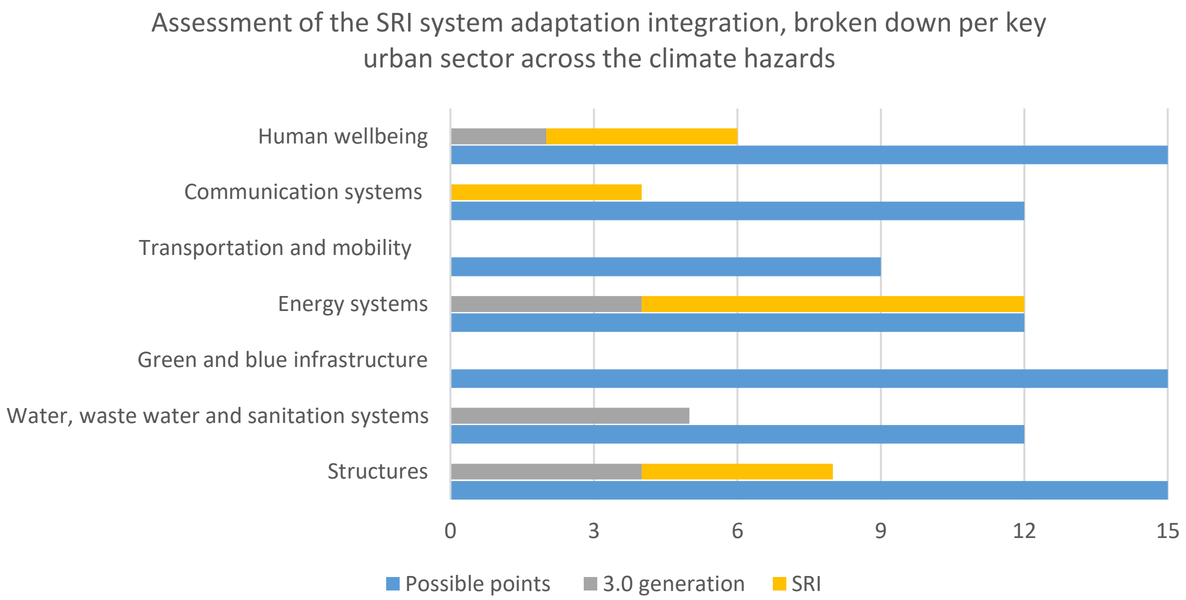


Figure 43: Assessing the degree to which climate change adaptation are addressed in the SRI system in combination with the 3.0 generation of building requirements broken down per key urban sector across climate change hazards.

5.7.1.2 Evaluating the Climate Change Adaptation Integration in The SmartScore assessment system

The SmartScore system, launched in 2021, with its current version V2.1, is tailored to rate the "smartness" of office buildings. The scoring system is divided into 3 main issues: user functionality (UF), Technical foundation (TF) and innovation (IN). The user functionality issue is composed of 6 categories that contain a total of 33 indicators. The technical foundation contains 22 indicators that are distributed over 6 categories. The innovation issue contains a single category and indicator.

Regarding the incorporation of climate change adaptation measures, the SmartScore, as the SRI system, shows a tendency towards the use of active systems to enhance building adaptation and resiliency. Nonetheless, coupling the SmartScore with the 3.0 generation requirements leads to an overall improvement in degree of inclusion of adaptation provisions.

As illustrated in Figures 44 and 45 below, the SmartScore covers a broad array of hazard and topics to varying degree of detail, the transport, blue, and green infrastructure sectors remain as with the vast majority of other investigated systems not addressed. A detailed overview of how this score was calculated is provided in Annex 8.

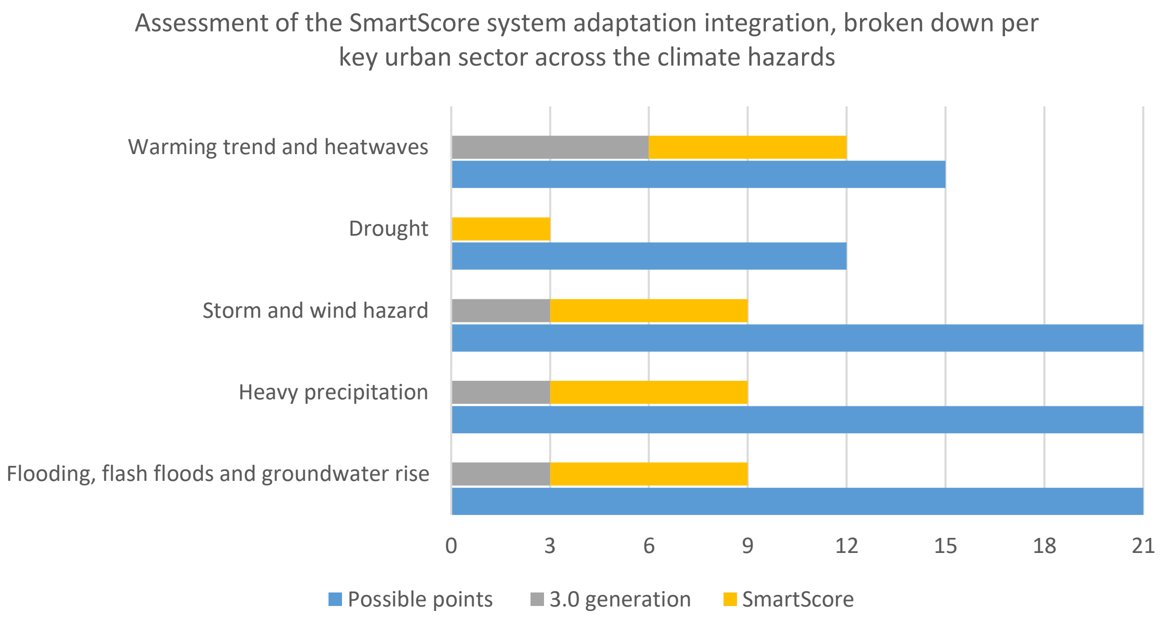


Figure 44: Assessing the degree to which climate change adaptation are addressed in the SmartScore system in combination with the 3.0 generation of building requirements broken down per climate change hazards across the key urban sector.

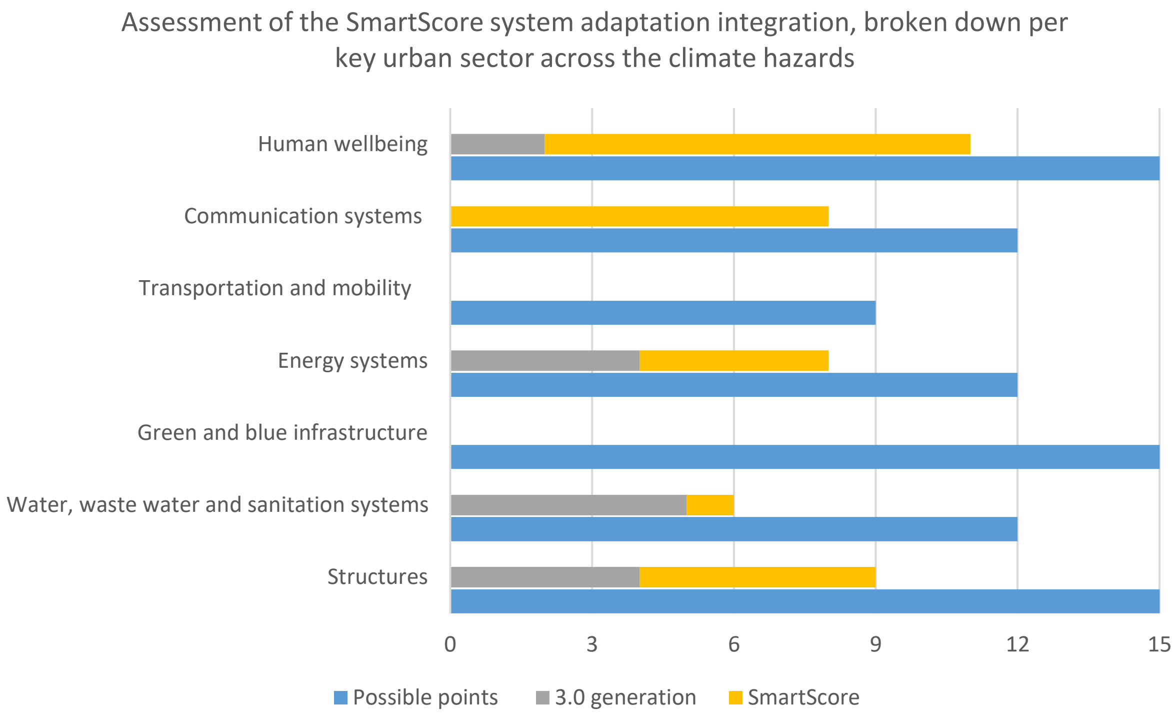


Figure 45: Assessing the degree to which climate change adaptation are addressed in the SmartScore system in combination with the 3.0 generation of building requirements broken down per key urban sector across climate change hazards.

5.7.1.3 Evaluating the Climate Change Adaptation in the WiredScore assessment system

WiredScore defines itself as a digital connectivity certification system that rates the digital and the physical elements of the building to ensure that it is future-proof[243]. WiredScore offers a range of rating systems that can be used to assess new development of office buildings as well as existing ones. For the sake of consistency, only the WiredScore criteria for newly developed building is going to be examined. The WiredScore is composed of 7 domains hosting a total of 27 indicators, that are divided as follows: mobile and wireless connectivity with 6 indicators, building infrastructure- point of entry containing 3 indicators, building infrastructure – telecommunication room with 6 indicators, Building infrastructure-risers covered by 7 indicators, electrical resiliency represented with 2 indicators, access readiness assessed via 2 indicators and lastly digital connectivity innovation with 1 indicator.

In terms of the degree to which the WiredScore system incorporates climate change adaptation measures, the system's focus primarily on the communication and energy sectors, which is expected due to the nature of the rating system. Nevertheless, the integration of WiredScore with the 3.0 generation requirements results in an overall enhancement in the integration of adaptation provisions at the building's scale, these is most clear in the energy and communication sectors. However, as illustrated in Figures 46 and 47 below, this improved integration falls short of covering all the climate change impact areas and key urban sectors to the same degree, with both the transport and bule and green infrastructure remaining unaddressed. A detailed overview of how this score was calculated is provided in Annex 9.

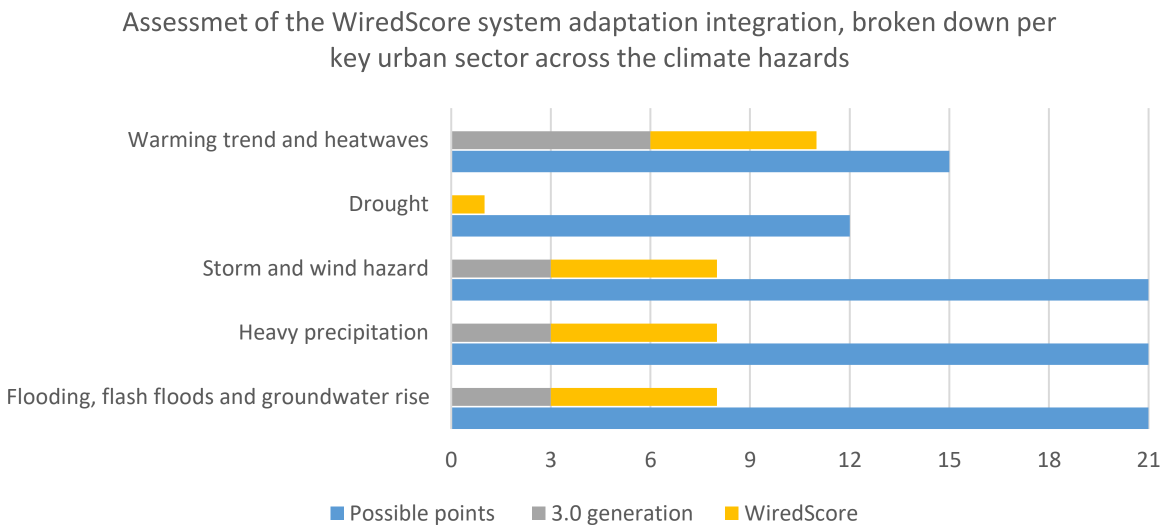


Figure 46: Assessing the degree to which climate change adaptation are addressed in the WiredScore system in combination with the 3.0 generation of building requirements broken down per climate change hazards across the key urban sector.

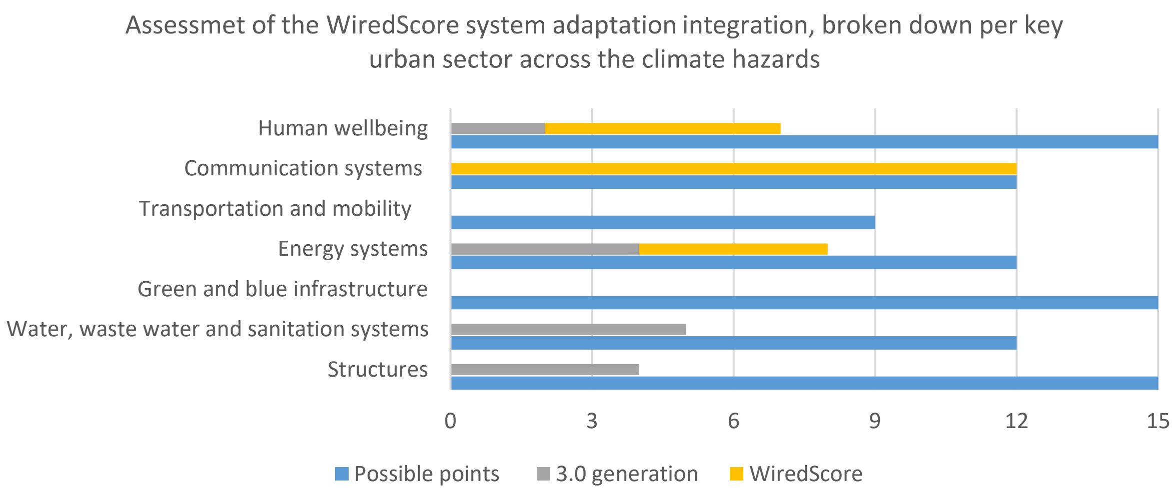


Figure 47: Assessing the degree to which climate change adaptation are addressed in the WiredScore system in combination with the 3.0 generation of building requirements broken down per key urban sector across climate change hazards.

5.7.1.4 Evaluating the Climate Change Adaptation in The R2S rating label

The Ready2Services (R2S) framework is primarily designed to certify non-residential buildings based on their smart capabilities and capacity to accommodate digital and connectivity services[244]. The goal of the R2S label is to equip certified buildings to be adaptive, pleasant to inhabit, and capable of interacting with their wider environment as an integral part of a Smart City. The R2S system covers six themes: one, titled 'Services,' is dedicated to the occupants and the building and contains a single category; two themes address governance, namely 'Digital Security' and 'Responsible Management,' the latter of which contains nine categories. The final three themes - 'Connectivity,' 'Network Architecture,' and 'Equipment and Interfaces' - focus on technical principles and collectively comprise eleven categories.

Despite the extensive catalogue of indicators of the R2S system, it scored the fewest points among all the rating systems examined across the generations. The R2S heavily focuses on the communication sector and active systems. The review of the systems indicators show that R2S system do not address the impact of heatwaves on communication systems and do not consider the possible combination of passive and active strategies to reduce vulnerability to climate change-related impacts. As with the other rating systems, the combination of the R2S with the 3.0 generation requirements results in an overall wider integration of climate adaptation in building performance requirements. The evaluation results summarized in figures 48 and 49 below, show the fusion between the energy efficiency and R2S requirements result in marginal improvement of the inclusion of adaptation topics. A detailed explanation of how this score was calculated is provided in Annex 10.

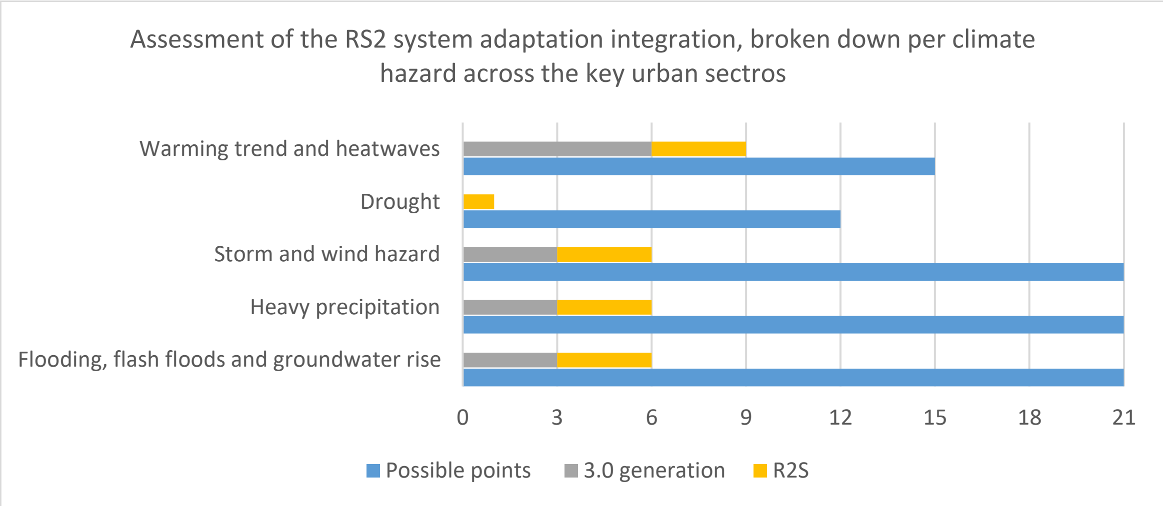


Figure 48: Assessing the degree to which climate change adaptation are addressed in the R2S system in combination with the 3.0 generation of building requirements broken down per climate change hazards across the key urban sector.

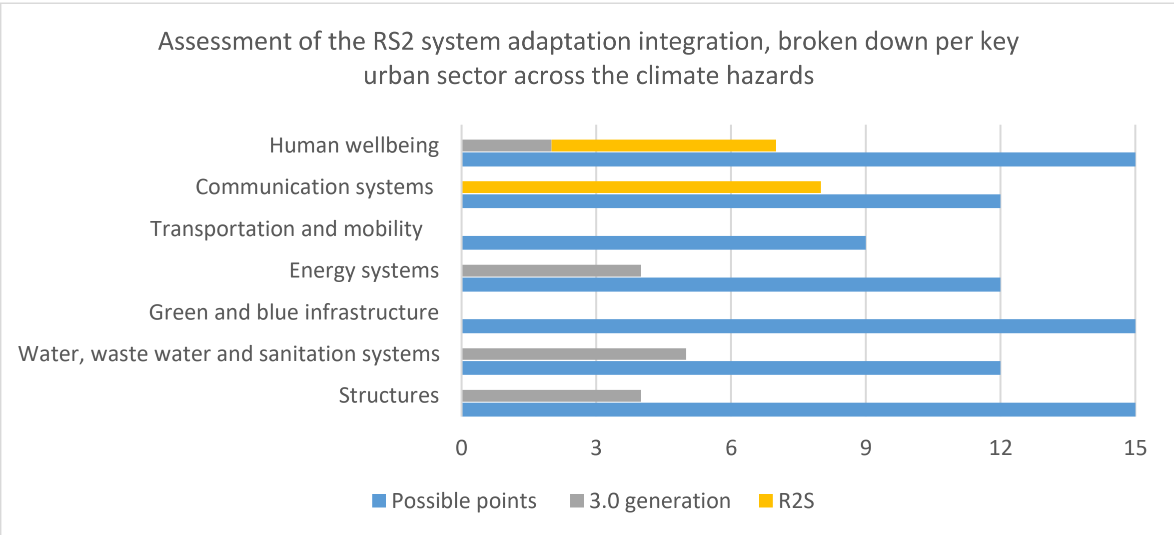


Figure 49: Assessing the degree to which climate change adaptation are addressed in the R2S system in combination with the 3.0 generation of building requirements broken down per key urban sector across climate change hazards.

5.8 Chapter Insights and Key Findings: An Answer to the First Research Question

The analysis conducted in this chapter explored the strategies and methods used in each generation of building performance requirements and rating systems to address and adapt to the impacts of climate and its associated hazards. An in-depth qualitative analysis, supported by a numerical scoring method, was carried out to measure the degree to which climate adaptation is addressed in each generation of building rating systems.

This analysis lays a solid foundation for answering the first research question: *How do buildings adapt to impacts of the climate, and to what extent contemporary (post 1970s) performance and rating systems in Germany integrate climate change adaptation measures?*

Regarding the climate adaptation strategies used in each generation of building performance requirements, the relatively good performance of the 0.0 generation of buildings in adapting to climate can be attributed to five design principles: simplicity and ease of construction, agile construction and integrated maintenance in design, efficient use of form and material, community collaboration and knowledge sharing, and the coupling between building and urban scale.

The trial-and-error approach employed in the 0.0 generation to develop climate adaptation solutions was gradually replaced with scientifically based methods in the 1.0 generation of buildings. However, due to social and technological developments, the performance requirements of buildings became more complex, and a trade-off between climate adaptation and other societal needs began to occur.

This trade-off is most apparent with the introduction of fire safety and transport requirements in the first generation of buildings. The outcome of this trade-off is reflected in the replacement of some building materials with superior climate adaptability in favour of those with better fire safety resistance, such as replacing wood-based houses with brick-based ones - a decision that still dominates the cityscape of most European cities. It can be argued that the onset of the little ice age that occurred between 1300–1850 AD masked the shortcomings of this approach in resisting and adapting to summer heatwaves.

Moreover, the safety and mobility requirements that appeared in the late period of the 1.0 generation of buildings negatively affected the climate adaptation performance of the urban morphology inherited from the 0.0 generation. The narrow and weather protected streets gradually gave way to wider straight streets better suited for civil defence, fire safety, and mobility requirements of the time, resulting in the decoupling between the building and its urban context.

This separation between buildings and their urban context became more pronounced during the 2.0 generation of buildings, which began to appear in response to the technological breakthroughs and societal needs accompanying the Industrial Revolution. The advent of the Industrial Revolution enabled wide access to cheap construction materials, energy sources, and utility networks, leading to 2.0 generation buildings becoming largely dependent on active systems for climate adaptation, with traditional passive systems largely neglected.

During the era of 2.0 generation buildings, spanning from the late 19th century to the mid-1970s, climate adaptation tasks were delegated to energy-intensive technical systems capable of handling climate conditions regardless of location, risks, or loads. The convenience offered by these technical systems resulted in a dependency on fossil fuels and other finite resources.

By the late 1960s, the negative side effects of overreliance on fossil fuel-based active climate adaptation systems started to become apparent. Alarms about anthropogenic climate change and the rapid depletion of Earth's natural resources began to surface in the late 1970s. In an effort to mitigate these negative consequences, the energy-efficient generation of buildings emerged, with a focus on reducing greenhouse gas (GHG) emissions and resource consumption. Today meeting the requirements of energy efficient generation of building is adopted officially in Germany and wider Europe and it represent the currently in-use generation of performance requirements and rating systems.

The shortcomings of the 3.0 generation in supporting holistic sustainable development were realized in the 1990s, leading to the appearance of sustainable building performance requirements. Today, with the introduction of the QNG quality seal, the performance requirements of sustainable buildings are on the verge of becoming the new mainstream generation of building performance requirements and rating systems in Germany.

In parallel, technological advancements and the proliferation of computing power and internet connectivity have paved the way for the introduction of smart buildings. Smart building rating systems complement the efforts of previous generations in reducing energy consumption and consequently the amount of GHG emissions by automatically adjusting the building system to its surrounding conditions and enabling cross-building exchange of information and resources. With the explicit mention of the SRI rating system in the EPBD and EU Taxnominy legislation, it can be concluded that the 5.0 generation of rating systems is also on the verge of becoming a mainstream generation of buildings.

Despite the world’s efforts of the past 40 years, the recent IPCC estimate show that the achieved GHG emissions reductions are not sufficient to halt the global warming below the 2℃ mark[9] and that a new climate is to be expected. Thus, the debate now is not about the occurrence of climate change but about its severity. This means that existing building performance requirements must adequately prepare buildings to adapt to future climatic conditions without compromising their ability to meet essential mitigation targets. Updating building norms to reflect the impacts of climate change is a monumental task. The study made by the German Federal Environment Agency (UBA) study showed the only 11 out of approximately 34,000 DIN norms, or 0.003%, mention the impacts of climate change[43]. Out of this small number, we found that only seven DIN norms and VDI guidelines directly address climate change in the urban built environment. Considering the estimated 3,300 norms relevant to the construction industry[42], only about 0.2% of existing DIN norms have been updated to include adaptation to climate change. Moreover, the building codes set the minimum performance requirements and not the optimal performance. The study made be the American National Institute of Building Sciences', showed that every $1 spent on climate resilience strategies in designing buildings beyond the provisions outlined in the 2015 International Codes (I-Codes), $4 can be saved in return [245]. Moreover, the study projected that such measures would prevent approximately 600 deaths, avert 1 million nonfatal injuries, and alleviate 4,000 cases of post-traumatic stress disorder (PTSD). In addition to the human and societal benefits, designing new buildings to exceed the provisions of the 2015 International Building Code (IBC) and International Residential Code (IRC) would have positive economic implications.

Admittedly, as shown in the analysis made in subchapters 5.5 to 5.7, a dual relation between climate mitigation efforts and climate adaptation strategies result– intentionally or not – increased integration of the topics related to improve building adaptability and resilience to the climate. Nevertheless, these considerations remain fragmented, mitigation biased and, the degree improved resiliency remain not yet clear. This conclusion is also reflected in the DAS assessment of the response indicator BAU-R-4 (See chapter 4.2).

The analysis exercise made in the subchapters 5.5.2, 5.6.1 and 5.7.1 attempted to revile the degree of inclusion of climate adaptation in the existing three generation of building performance requirements through a simple 4-point scoring scale. The results showed that performance requirements of the 3.0 generation of building rating system rather partially include climate change adaptation measures. The energy efficiency measures that aim to enhance the mitigation effort, have in many cases, a dual effect in which the climate adaptation is automatically addressed even if such result was not originally intended. Nevertheless, research showed that these improvements are still far from being holistic or sufficient. The adaptation to some eminent climate hazards such as drought is totally lacking and the key urban sectors of communication, green and blue infrastructure as well as mobility are not sufficiently addressed.

Supplementing the official requirements of the 3.0 generation with the requirements of sustainable building systems or smart building rating systems results in a significant improvement in the degree of inclusiveness of climate change adaptation (see Figures 51 and 52). The improvements are most apparent in climate adaptation requirements against the warming trend and floods. Nevertheless, the consideration of climate change adaptation against storm and wind hazards and heavy precipitation remains rather marginal, while adaptation to drought is completely insufficient. In terms of improvement to the key urban sectors, the picture is rather mixed. Sustainable building rating systems show a better degree of consideration for the water and wastewater system. The smart building assessment systems take more care in including the energy and communication sectors. However, in both systems, the inclusion of urban sectors of transport and green and blue infrastructure is very limited and, in some cases, totally missing.

From the three examined sustainability rating systems, the NaWoh V3.1 showed the highest degree of inclusion of climate adaptation considerations within its performance requirements. The other two analysed systems (BNK V1.0 and DGNB NKW) managed to collect far fewer points than the NaWoh system and showed comparable results to each other.

In terms of the 5.0 generation of buildings that are represented in this research by four Smart assessment systems, the SmartScore system showed the highest inclusion of adaptation measures and the R2S collected the lowest number of points. The WiredScore and SRI attained a nearly similar number of points.

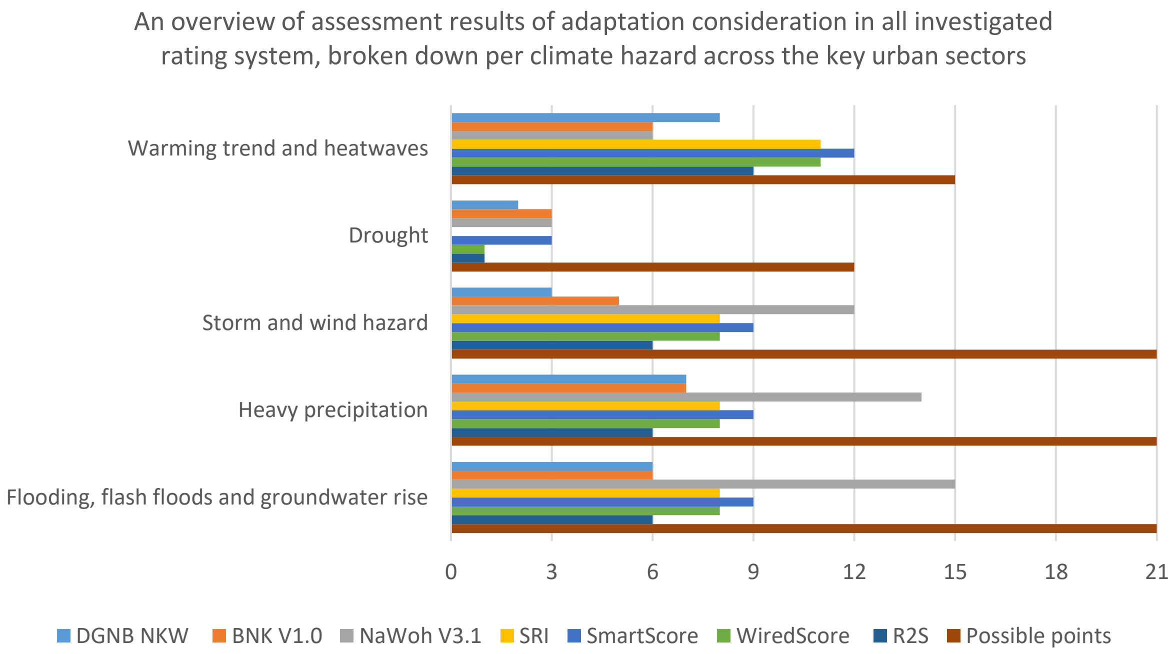


Figure 50: An overview of assessment results of adaptation consideration in all investigated rating system, broken down per climate hazard across the key urban sectors.

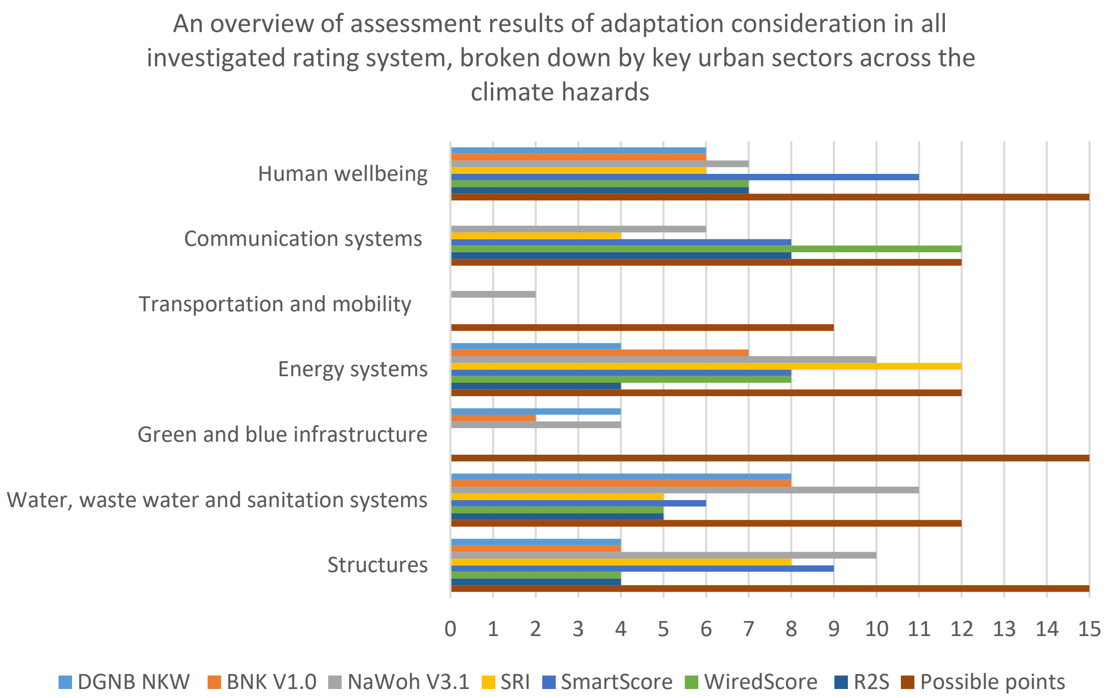


Figure 51: An overview of assessment results of adaptation consideration in all investigated rating system, broken down by key urban sectors across the climate hazards.

It could be argued that combining elements from the 3.0, 4.0, and 5.0 generations of building rating systems could result in achieving higher scores. However, this question was not explored for two reasons: First, the number of potential combinations of is rather high. Considering the possible combinations of 1 energy rating system, 1 sustainability rating system, and 1 smart rating system from the given 8 options (1 energy, 3 sustainability, and 4 smart rating systems), we obtain 12 unique combinations. If we consider that each of these combinations can be applied to each of the five investigated climatic hazards and the seven key urban sectors independently, the total number of evaluations escalates to 420. These systems combined consist of about 361 indicators. If they were to be evaluated within each of the 420 combinations, for each hazard and sector, then, the total number evaluation rises to 151,620 cases. This volume of evaluations goes far beyond the scope and capacity of this research.

The second reason relates to the fact that the assessment results made in this chapter are intended to provide insights into the degree of climate adaptation considerations integrated into the modern building performance rating systems. Hence, they do not claim to give a clear answer on how effective these measures are in improving the resilience of buildings and the wider urban environment to climate change impacts. This crucial question requires the use of a dedicated urban resilience rating system.

In conclusion, the analysis made in the subchapters 5.5 to 5.7 reveals four main shortcomings or gaps in the existing building performance requirements and rating system can be highlighted:

- **Firstly,** the performance requirements of the existing rating systems only partially consider climate adaptation. The existing building laws and design norms are not yet holistically updated or enforced to address climate change adaptation.
- **Secondly,** there is no widely adopted unified rating system in operation today that provides a holistic rating of a building's vulnerability and resilience to climate change impacts. The effect of this shortcoming is rather more apparent in the NaWoh V3.1 and DGNB NKW systems. Both systems mention the adaptation to climate impacts and hazards and propose indicators to measure them. However, they lack the means to clearly describe adaptation requirements or to quantify the effectiveness of the applied measures.
- **Thirdly,** the rating systems are spatially constrained to the building boundary itself and generally do not allow for coupling and tracing the effectiveness of climate adaptation measures applied to the building on the greater urban scale and vice versa or to expand the use of the same rating system at a greater urban scale. Adapting to climate impacts can be best achieved when the building as a unit and the greater urban fabric work in tandem, complementing one another.
- **Lastly,** the current generation of rating systems (3.0, 4.0 and 5.0) are designed to assess newly built buildings. However, as two-thirds of the building stock was built according to outdated standards that predominantly belong to the 2.0 generation of performance requirements (sanitary), addressing climate adaptation in this generation of buildings is key to the successful adaptation to climate change.

6 Climate Change Resilience Rating Systems and Frameworks: A Review

"The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads".

Ibn Al-Haytham. 10th century A.D.

Synergies between existing building performance rating systems and climate adaptation has been uncovered in the previous chapter. While existing building rating assessment methods excel in delivering a high-performance building in specific domain (energy, smart and sustainable), they fall short in providing a clear view of how achieving a high rating in one domain, would reflect on the building's resilience to climate change. This limitation leaves the assessment of the building's adaptability to climatic impacts up to speculation.

To their credit, the systems discussed in the previous chapters never claimed to be suited to measure the building resilience or prepare it adequately to a climate change related impact. Instead, they evolved in a different context, with different priorities. This highlights the urgency to supplement existing rating frameworks with a building climate adaptability rating system and framework that can effectively address this gap.

This gap in assessment methods isn't isolated to the building sector. Formal and informal structures for assessing climate change risk and resilience were virtually non-existent before the 1990s[246]. As awareness and understanding of climate change grew, so did the number of publications and initiatives focus on climate adaptation assessment. By the turn of the century, such publications had rapidly grown to thousands [246].

Broadly speaking, the climate change risk assessment structures can be divided into two distinct families, generic and sector specific. On the one hand, generic risk assessment structures establish a standardized method for assessing climate change-related risks, irrespective of the sector being evaluated.

On the other hand, specific risk assessment frameworks are tailored to individual sectors, utilizing the foundational concepts of generic frameworks while addressing the unique characteristics of the sector under consideration. Examples include frameworks to measure the climate change risk to the investment and finance sector, the insurance sector, the energy sector, the urban environment, and buildings sector. These assessment structures can be supported by climate change adaptation platforms, online toolboxes, adaptation solutions, and best practice repositories as listed in Annex 11 of this research.

This chapter serves as an introduction and platform for addressing the second research question: *How can an integrated urban resilience assessment framework and rating system be developed to effectively evaluate and enhance resilience across different urban scales, including buildings, neighbourhoods, and districts?*

To address this question, the research provides a brief review of existing generic climate change risk assessment frameworks and proceeds to review operational[1] climate change adaptation rating systems and frameworks specific to the building and urban sector. This review will highlight their strengths, shortcomings, and alignment with the established risk national and international assessment approaches. Based on this analysis, an integrated, multisectoral, cross-scale urban resilience assessment framework will be developed, discussed, and piloted in Chapter 7. This framework aims to bridge the spatial and sectoral gaps in the existing climate change adaptation frameworks.

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[1] operational climate change adaptation rating systems refer to rating systems that are currently (April 2023) in use and have been implemented in real-world applications.

6.1 Generic Climate Change Risk Assessment Rating Frameworks: An Overview

The conceptual risk assessment framework put forward by the IPCC Working Group II (WGII) in 2014 belongs to the family of the generic frameworks. The IPCC framework does not offer specific instructions for conducting a climate risk assessment but offer a conceptual framework. The conceptual framework is widely used as a basis for the climate risk assessment frameworks by many national organizations such as German Environment Agency [33], German Federal Ministry for Economic Cooperation and German development agency (GIZ) [247] and in the German, ISO based, DIN EN ISO 14091 - 2021-07 (Anpassung an den Klimawandel - Vulnerabilität, Auswirkungen und Risikobewertung) [248].

According to The IPCC AR5 framework, climate change-related risk refers to measuring the potential for consequences when something valuable is at stake, and the outcome is uncertain. This concept is quantified as the probability of hazardous events or trends occurring multiplied by the resulting impacts if these events or trends do occur. Climate change-related risk arises from the interaction between vulnerability (the susceptibility to harm), hazard (the presence of a threat), and exposure (the presence of elements at risk) [249].

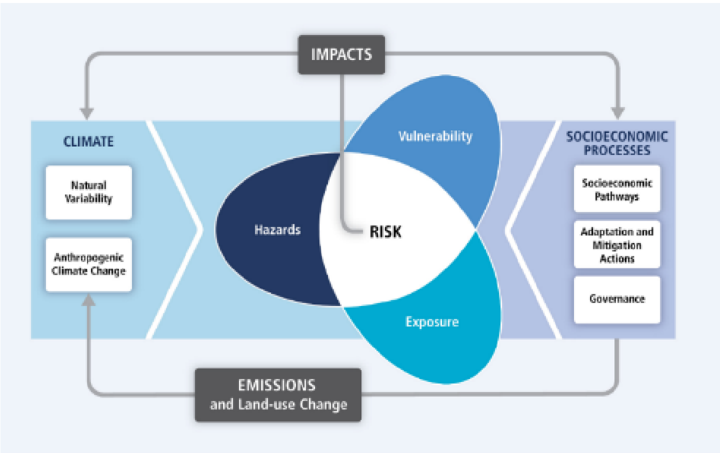


Figure52:The IPCC AR5 conceptual framework with climate change risk is a result of interaction between the vulnerability, hazard and exposure[249].

Accordingly, the risk is expressed mathematically as

$$R = f\,(H, E, V) \quad (1)$$

Where **R** is climate change related Risk,

H is the hazard and is defined as “the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resource”[249].

E is the exposure and the IPCC defines it as to "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected"[249].

V stands for the vulnerability and is defined as "the propensity or predisposition to be adversely affected"[249]. The vulnerability is dependent on two factors: (1) the system sensitivity and (2) adaptive capacity. The sensitivity refers to the system attributes that directly affect the consequences of a hazard and the adaptive capacity refers to how well is the system prepared to respond to the these hazards[250].

The American Federal Emergency Management Agency (FEMA) takes a slightly different approach to assess climate risk, expressed as:[251]:

$$Risk = Expected\ annual\ loss * Social\ Vulnerability * \frac{1}{Community\ Resilience} \quad (2)$$

In equation (2), risk is based on the interaction between expected annual loss, social vulnerability, and the inverse of community resilience [251].

Expected annual loss is calculated by multiplying an annual dollar amount by the exposure of buildings, population, and agriculture based on average or actual densities. Social vulnerability is an indexed value derived from 29 socioeconomic variables measuring a community's susceptibility to the adverse impacts of natural hazards. Community resilience is computed as an indexed value incorporating 49 indicators representing six types of resilience: social, economic, community capital, institutional capacity, housing/infrastructure, and environmental.

The FEMA approach simplifies the assessment by assigning risk scores ranging from 1 to 100 and categorizing them as very high, relatively high, relatively moderate, relatively low, and low risk. However, this system fails to capture indirect losses that cannot be assigned a simple dollar value, such as the long-term consequences of biodiversity loss, or migration of population. Additionally, the assessment of drought risk is limited to the agriculture sector, even though it can impact all three categories of expected annual loss.

The German Environment Agency used a unique methodology that is aligned with the IPCC AR5 in generating its climate change risk assessment (KWRA 2021) (see subchapter 3.2.1)[33]. The KWRA system applies the same general equation used in the IPCC AR5 to compute risk, but it extends the calculation to two-time units: the middle and end of the century with an optimistic and a pessimistic scenario. Figure 53 illustrates that the adaptation capacity coverage in the KWRA encompasses both system sensitivity and exposure, referred to as spatial exposure in the KWRA. The rest of the terminology remains consistent with the IPCC AR5.

The KWRA utilizes the concept of impact chains to systematically trace the cause-and-effect relationship between climatic factors and climate impacts (e.g., heat leading to health problems) and how vulnerability or exposure aspects of a system can increase or reduce the risk of climate change impacts (e.g., population age structure, presence of fresh air corridors, population density). Impact chains also demonstrate how adaptation actions can mitigate the risk of climate impacts. The KWRA assessment results are presented on a three-level scale of low, moderate, and high without additional criteria. The KWRA justifies the simplicity of this method due to the diversity and complexity of climate impacts and interaction.

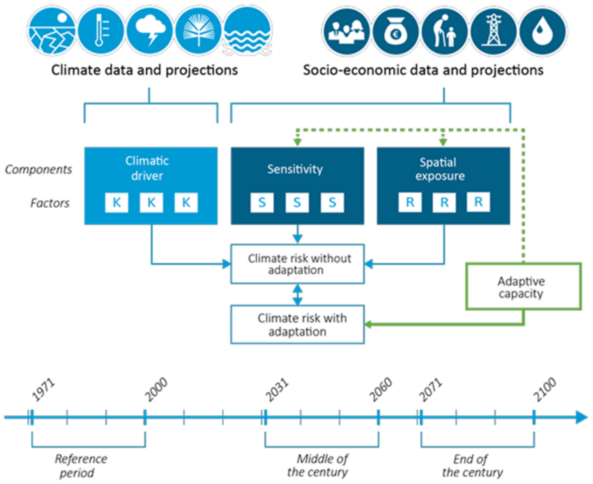


Figure53:The methodological risk assessment framework used by the KWRA 2021 [33].

The concept of utilizing impact chains in combination with the IPCC AR5 risk method is also employed in the GIZ vulnerability source book, as shown in Figure 55. The advantage of the GIZ vulnerability source book method is that it provides practical guidance on applying the AR5 risk assessment concept, as the Working Group II (WGII) of the IPCC does not offer specific instructions for conducting a climate risk assessment. Furthermore, the vulnerability source book method adapts the IPCC AR5 method from disaster risk reduction to the context of climate change adaptation that can be adapted to various scales and contexts, including different sectors (e.g., agriculture, water, health), geographical areas, and time horizons [250].The impact chains developed according to the GIZ method serve as visual representations of the potential impacts of specific climatic stimuli on a defined system, sector, or area of interest. They help to break down complex climate change impacts into manageable parts, thus enabling a systematic vulnerability assessment. Moreover, it allows to involve stakeholders throughout the process, to ensure that the assessment is relevant and responsive to local needs and conditions. As Illustrated in the figure 54, the key components of impact chains are:

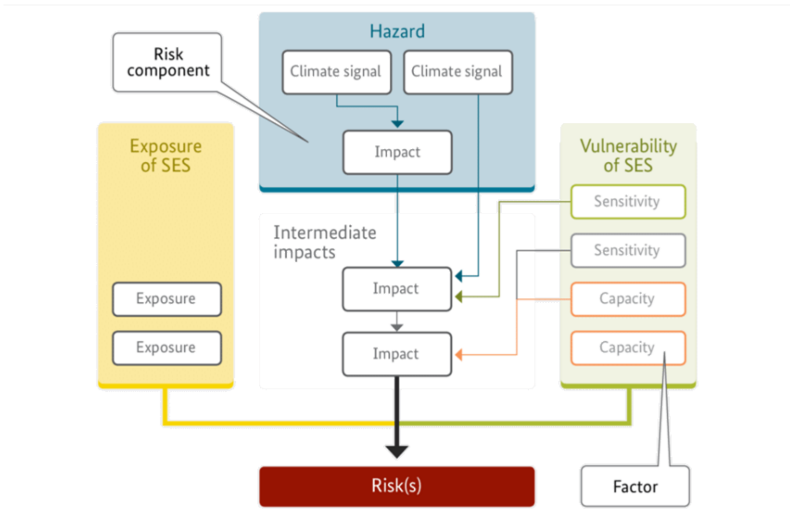


Figure54: The impact chain concept framework used by GIZ framework to assess the climate risk based on the IPCC WGII approach [252].

- **Climatic Stimuli (Climate Stressors):** These are changes in the climate that could potentially have an impact on the system of interest. They might include changes in temperature, precipitation, sea level rise, storm frequency or intensity, and so forth.

- **Biophysical Impacts (Intermediate Impacts):** These are the direct impacts that the climatic stimuli have on the natural environment. For example, higher temperatures could lead to more frequent heatwaves, while changes in precipitation could alter water availability.

- **Socio-economic Impacts (Final Impacts):** These are the impacts that the biophysical changes have on human systems. These impacts depend not only on the biophysical changes, but also on the vulnerability of the human systems. For example, changes in water availability could affect agricultural productivity, which in turn could affect food security.

- **Vulnerability Factors:** These include the factors that determine the susceptibility of the system to the impacts of climate change and its ability to adapt. These could be environmental, social, economic, or political factors. For example, the presence of robust irrigation systems could reduce vulnerability to changes in water availability, while high levels of poverty could increase vulnerability to changes in food security.

- **Adaptation Measures:** These are the strategies, policies, or actions that could be taken to reduce vulnerability or enhance adaptive capacity. They could include both 'hard' measures (like building sea walls or irrigation systems) and 'soft' measures (like changing farming practices or improving disaster risk management).

- **Indicators:** These are measurable characteristics that can be used to quantify and monitor changes in each component of the impact chain. They should be sensitive to changes in climate and the system, relevant to the decision-making context, and feasible to measure.

Each of these components are linked in a cause-and-effect chain, illustrating how changes in climate could ultimately lead to changes in human systems, and how these changes could be mitigated or managed through adaptation measures. The whole chain is, of course, influenced by broader context conditions and changes, such as demographic development, socio-economic trends, or broader environmental changes.

In conclusion, the different investigated climate risk assessment frameworks have their strengths and limitations. The IPCC AR5 Framework offers a widely accepted and adaptable method, based on a solid understanding of the interaction between hazard, exposure, and vulnerability. However, it remains too broad and generic and lacks detailed instructions for practical application. A limitation that is addressed to a great extent by the GIZ Vulnerability Sourcebook Method.

6.2 Frameworks and Rating Systems for Assessing Climate Change Resiliency in the Built Environment

Building upon the analysis of general climate risk assessment frameworks, this section focuses on exploring the existing frameworks and rating systems that are specifically designed for assessing climate change resiliency in the built environment. The objective is to review and analyse these frameworks and rating systems to gain insights into their methodologies, criteria, and effectiveness in measuring and enhancing climate change resilience as well as their alignment with the IPCC AR5 risk assessment approach.

The review will encompass a range of operational frameworks and rating systems that have been developed at different scales, from individual buildings to greater urban scales such as neighbourhoods and districts and to examine how the cross-scale relation between these spatial scales is treated. Gaining an understanding of the complex interdependencies between various spatial scales (individual buildings, neighbourhoods, and districts), is crucial as adaptation measures implemented at one scale can significantly impact the performance of others. A platinum or A+ rated building will only prove its worth if it remains accessible and functional during and after a disaster [31]. This means that not only the building specific functions must remain useable but also the wider interconnected urban sectors such as transportation, communication, and sanitary systems must continue to function, and the supply of essential goods must be maintained[31]

Additionally, the review will assess the extent to which these frameworks and rating systems align with DIN EN ISO 14091 - 2021-07 and IPCC guidelines, which are widely utilized in Germany across various urban and policy sectors. This investigation aims to ensure a harmonized and cohesive approach to assessing climate change resilience, not only within the built environment but also in other relevant sectors. Hence, contributing to more coordinated and integrated strategies for climate adaptation.

This analysis will serve as a foundation for the development of an integrated framework that considers the multidimensional and cross scale nature of climate change adaptation and provides a comprehensive assessment of resiliency across the built environment. Ultimately, the goal is to foster the creation of more resilient urban environment as a whole that can effectively adapt to the challenges posed by climate change and ensure sustainable and liveable environments for present and future generations.

6.2.1 Building scale

The literature review made by Felicioni et al. (2020) showed that there is a significant number of research papers and journal articles discussing the resilience of buildings and urban areas to climate impacts[253]. However, despite the abundance of academic publications, only a few operational systems are currently being used in practice. This research will focus on investigating four of these operational systems, namely: the LEED based RELi 2.0 rating system; the German GIS-IMMORISK tool; the Resilience-based Engineering Design Initiative (REDi™) Rating System, developed by Arup; and the Building Resilience Index developed by the World Bank.

6.2.1.1 The RELi™ 2.0 Rating System

The RELi 2.0 certification is directed towards newly built projects and utilizes a point-based system to determine a project's certification level. The mandatory 15 requirements are not assigned a point value and must be fulfilled as a prerequisite, while the optional credits have specific point values, providing flexibility for projects to aim for a certification level that suits their goal [254]. One of the unique features of the RELi 2.0 system is that it's designed to work in companion with the sustainability certification system LEED system. The assessment doesn't have a clear risk assessment approach and leaves that to be judged by the planners. Based on the declared climate change related risks the project can collect resilience point in eight categories that have a variable weighting: The system considers a wide palate of natural, man-made and climate change related hazards spanning from earthquake and volcanoes to flood, physical conflict, and epidemics. The system close alignment with the LEED system, focus on newly built buildings and lack of clear risk assessment approach limit its potential for being utilized in a German urban context.

Table 10: A breakdown of the RELi 2.0 system categories, indicators, and the weighting of each category

RELi 2.0 system broken-down by number of categories, indicators, and the weighting of each category

Category	Number of indicators	Weighting in %
Panoramic Approach	10	7.7%
Hazard preparedness, short-term hazard preparedness, Mitigation + Adaptation	6	3.2%
Hazard Mitigation + Adaptation	8	23.3%
Community Cohesion, Social+ Economic Vitality	9	23.6%
Productivity, Health + Diversity	8	9.7%
Energy, Water + On-site Food Production	9	17.3%
Materials + Artifacts	8	3.5%
Applied Creativity	4	11.8%

6.2.1.2 The IMMORISK Rating System

The GIS-ImmoRisk was developed in 2013 as part of the German Strategy for Adaptation to Climate Change to support decision making and action for investments in the face of growing climate risks and extreme weather events. The GIS-ImmoRisk is a geographic information rating system designed to help real estate owners, developers, and prospective buyers assess the risk of natural hazards such as heavy rain, earthquakes, and heatwaves on their properties.

The system provides both a risk assessment of individual properties and for portfolios and offers accompanying information and explanations of the expected hazards. Since 2023 the use of the system is compulsory for non-residential buildings that seek to be certified with a QNG compatible sustainability certification system[255].

The IMMORISK system provides the user with the possibility to choose the time reference for each hazard either using current weather prediction or future weather prediction that, depending on the type of climate hazard, can go up to the year 2100. The data on the current climatic hazard are based on measurements and analyses of the German Weather Service (DWD), which has provided corresponding statistical data from a time series of 1971-2008. The future climate is based on an ensemble of regional climate models provided by the Karlsruhe Institute of Technology (KIT).

The system describes the level of a climate and natural hazard for the location based on a color-coded scale that starts with very low (blue), then low (green), to average (yellow), increased (orange) and finally high (red).

To assess the hazard for building, the GIS-ImmoRisk webtool requires the user to input some basic information about the building such as the location, building type, the building state and the last year of renovation, the year of construction, area and number of over- and underground floors, window areas and orientation, type of building materials and roof shape which can be chosen from a drop down menu, as well as some basic questions about the energy system.

Through inputting this relatively simple list of building information, the system produces a comprehensive assessment of the risk situation of the property in a very short time. The risk is assessed quantitatively for hail hazard by stating a monetary amount that reflect the annual expected loss due to the climate hazard exposure as per the following[256]:

$$Risk\ (r,g,t)\ =\ Hazard\ (r,t)\ *\ vulnerability\ (g,t)\ *\ value\ (g,r) \quad (3)$$

Where r = is the location, g is the building and t is the time

The annual expected loss is then calculated as [256]

$$AEL = \int_{xmin}^{\infty} S\left(f(x)\right)W dx \quad (4)$$

Where f = probability of hazard, S: function of damage, xmin: Lower integration limit from which damage can be expected, x: hazard intensity and W: building value

For climatic hazards: heat, wind and storm, and heavy precipitation a qualitative risk assessment is provided. The qualitative risk assessment plots the probability of hazard occurrence in relation to the building’s resilience on spatial matrix and provides an indication to the probability of expected annual damage.

For the natural hazards such as snow load, forest fire, earthquake, flood, and lightning, only the hazard probability for the respective location is given. The drought hazard is not assessed.

The system doesn't take into account the impact of climate adaptation measures applied on the greater urban scale and doesn't offer the possibility to test the effect of applying adaptation measures on the expected monetary loss. Moreover, the system assesses only the expected annual damage or monetary loss to building structures and energy systems. As such, the expected risk on other vital systems such as water, human health, communication, etc. are not evaluated. Moreover, the user is constrained to a predefined scenario of the future climate and cannot freely choose a different Representative Concentration Pathways (RCP). Finally, it is not clear if the monetary risk values expressed in €/m² are inflation adjusted or not.

In conclusion, the IMMORISK provides an outstanding, easy to use webtool to assess a wide array of the climate change related risks to a certain area or building. However, it is rather not holistic or sufficiently integrated within the greater urban scale. Moreover, the tool is limited in providing guidance on the effectiveness and the type of adaptation that can be applied. Hence, the tool cannot be considered – neither does it claims to be - a holistic rating of the building's vulnerability and resilience to climate change impacts. The system application remains limited to provide a quick first step to assess the climate related risks at certain location.

6.2.1.3 The REDi resilience rating system

The Resilience-based Engineering Design Initiative (REDi™) rating system provides a comprehensive approach to design of resilience in the built environment. Created by Arup's advanced technology and research team, it offers a framework for owners, architects, and engineers to design structures that can withstand earthquakes, extreme storms, and flooding. As of February 2023, only REDi rating for extreme storms is available and other assessment systems are expected to be published soon.

The Arup's team shares the same view about the existing building codes as this research in which they admit that existing codes prioritize safety, not resilience. Meaning that even if people inside are protected during a disaster, the building and its systems can still be severely damaged. This results in high financial costs for demolition, repair, and restoration, as well as indirect costs such as lost business and decreased quality of life for communities[257].

The REDi Rating System aims to address this issue by promoting resilience-based design. It outlines design principles and planning criteria to help owners resume operations and maintain livable conditions quickly after a disaster. It also provides a method for evaluating the effectiveness of the design in meeting the desired resilience objectives.

The REDi™ framework provides three levels of REDi™ rating (Platinum, Gold, or Silver) that can be granted to newly built buildings. Regardless of the level of the rating desired, the building is to fulfill the necessary performance requirements in three resilient design and planning categories: Operational Resilience, Building Resilience, and Site Resilience. Operational Resilience is about contingency planning for utility disruption and business continuity. Building Resilience focuses on minimizing expected damage to structural, architectural, and technical building components through enhanced design. Lastly, site resilience aims to reduce risks from external hazards that may cause building damage or restrict the site access.

The central principles of the REDi™ Roadmap to Resilience are illustrated in the figure 55. The REDi criteria are performance based, in which the system outlines the performance to be achieved for each category but keeps the means of how the performance is achieved relatively open for the managers to decide.

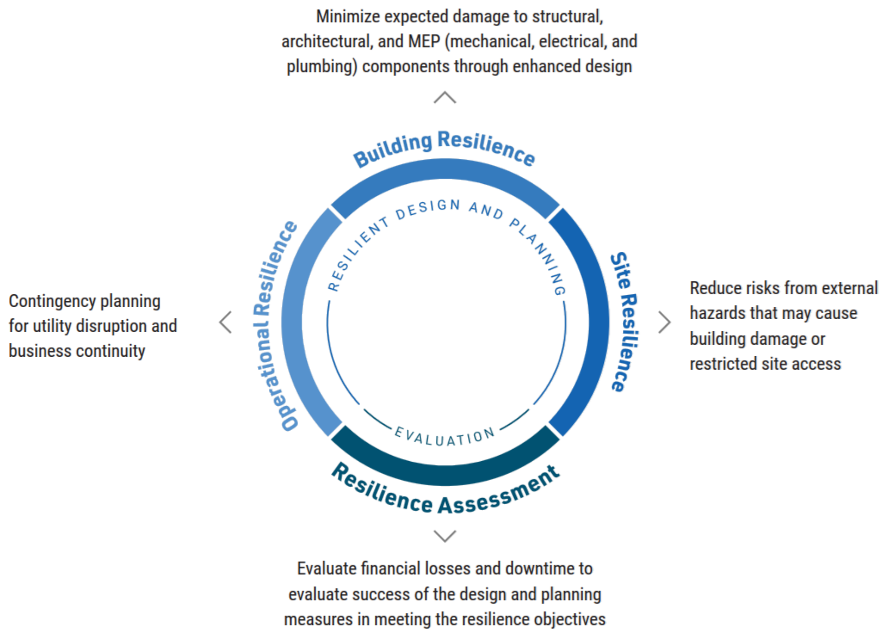


Figure 55: A diagram showing the general framework of the REDi assessment[258]

The uniqueness of the REDi system is that, unlike most rating systems, the system defines the main stakeholder that is responsible to lead the implementation of the adaptation measure as illustrated in the figure 56.

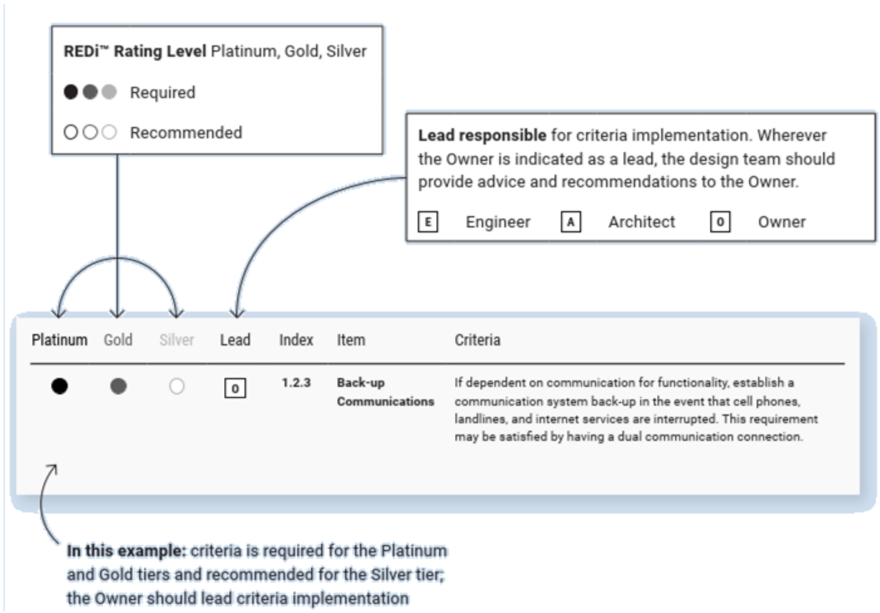


Figure 56: A diagram showing the criteria summary including the rating and lead responsible [258]

Moreover, REDi sets a clear objective to the achieved rating. For example, a platinum rated building is a building exposed to 3000-year Mean Recurrence Interval (MRI) wind event and is expected to have a probable loss < 1 % in terms of property damage, a continuous occupancy with no down time or less than 48h of functional recovery and that physical injures due to building component failure are unlikely. The REDi reflects the probable financial loss to a building in each wind event as a percentage of the total building replacement cost. The functional recovery term is used to represent the time required to establish re-occupancy and regain the facility's primary function such as HVAC, backup systems and lighting.

The REDi rating decreases from platinum and gold to silver depending on the used MRI, the resulted probable loss and the downtime of the building. The REDi recommends the platinum rating to be achieved in essential facilities or "mission critical buildings" that need to be operational in case of emergency such as hospitals, datacenters, etc. Residential buildings are generally recommended to aim for a silver rating.

The REDi system, like the RELi system, evaluates the relationship between a building and its surrounding urban environment in a unidirectional manner. It considers how the urban context affects the building's vulnerability but not vice versa. Therefore, the system is not suitable for a comprehensive, cross-scale assessment where both the building and urban planners can utilize the same framework to assess risks and develop adaptation measures in a coordinated and integrated manner. To enable such an assessment, a framework that accounts for the feedback loops between the building and the urban environment is necessary.

6.2.1.4 The Building Resilience Index (BRI)

The BRI system is developed by the International Finance Corporation (IFC) branch of World Bank in the late 2022. The BRI declares its aim as to create a straightforward self-reporting mechanism that enables property owners and developers to detect and tackle potential hazards in their buildings, while, at the same time, offering a channel for banks and insurance firms to determine the potential risks associated with the property [259]. This comprehensive system evaluates the risk and resilience of all types of buildings. It employs a uniform definition for all parties involved which promotes transparency and leads to increased resilience and decreased risks for all stakeholders across various regions. Furthermore, the system proposes resilient tactics that stakeholders may employ to enhance their resilient rating. The BRI defines a resilient building as the "building which can survive the natural and climate hazards its location is exposed to, and ideally continue its operations without disruption following an intense hazard event" [259]. The purpose of the Building Resilience Index is to compare the relative resilience of buildings, encouraging them to minimize structural risk, rather than evaluating them against an absolute performance standard. The BRI is intended to be used in conjunction with the EDGE green buildings certification developed by the IFC as well.

Similar to the REDi system, the BRI system rating measures the building resilience against probable maximum loss (PML), meaning the higher the achieved rating, the lower the PML. The rating results are plotted on 5-point scale system ranges from A+ to R as shown in the figure 57.

Level	Probable maximum loss	Definition
A+	~5%-15%	'A+' is equal to an 'A' with operational continuity measures The building meets all level 'A' requirements, plus three or more measures of operational continuity.
A	~5%-15%	The building incorporates global best practice mitigation measures for all applicable individual hazards, which are generally set above the local building code. It will likely survive all applicable hazards at high level.
B	~10%-30%	The building incorporates local building code requirements for all applicable hazards and many recommended good practices. It will likely survive some applicable hazards at a moderate-high level.
C	~30%-50%	The building incorporates local building code requirements, some of which may be outdated, and some recommended practices. It may survive some applicable hazards at a moderate level.
R	>50%	The building fails to meet the requirements of any of the above levels. It will likely not survive most applicable hazards, even at moderate level

Note: Any project at level R, C and B will have structural and residual risks. For A and A+ level a building may have residual risks.

Figure 57: A diagram showing the BRI rating system and meaning of the results[259]

The logic of the rating system follows the "Weakest Link Principle". The "Weakest Link Principle" states that the overall hazard category rating of a building is determined by the lowest score achieved in any of the four hazard categories. For instance, if a building scores three ratings of B but achieves a rating of C in one category, then the overall hazard rating for the building will be C. To attain an A+ rating, a building must achieve an A rating in all four hazard categories and implement at least three operational continuity measures.

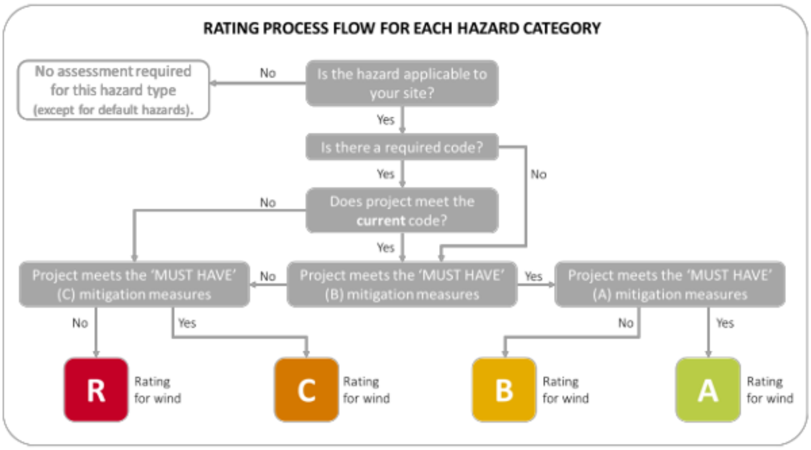


Figure 58: A flowchart showing the rating process used to rate the resilience for each hazard categorify[259]

The BRI system covers a wide range of natural hazards that are categorized in two families: (1) risks for operational continuity and (2) risks for physical integrity. The risks in the physical integrity family are organized around four main categories: wind (air motion), water (liquid motion), fire (rapid oxidation) and geo-seismic (ground motion). Each category contains a several subcategories of natural hazards. For example, the wind category will include Storms (Cyclone, Typhoon, Hurricane), Tornados, Downbursts.

The operational continuity family contains hazards that according to the BRI system do not pose a direct risk to the building structure but can impact its operation such as heatwaves, cold waves, and droughts. However, as the BRI address the hazards from the building not from the human perspective, the BRI system doesn't assess the impact of these risks on humans' health. Nevertheless, it offers a set of guidelines to adapt to them.

The uniqueness of the BRI assessment system is that it is generic and can be used to assess both existing and newly built buildings regardless of their use. Moreover, for each of identified hazards in the physical integrity family, the system provides a rather comprehensive list of adaptation measures (the BRI system names them mitigation measures) and categorizes them in accordance with each rating category from A+ to C. Although the BRI system acknowledges the importance of linking building resilience to the greater urban context, it specifically states that the spatial scale is out its scope[259].

6.2.2 Urban scale

Unlike buildings, which are easy to define, greater urban scales such as neighbourhoods, districts, and quarters are more elusive terms that can have different meanings for different people. For the purpose of this research, it is important to clarify both the 'district' and 'neighbourhood' terms.

A district is usually politically defined as a territorial division or administrative region within a larger politically defined urban area, such as a city. Districts are often used for local government, administration, and service delivery purposes, and they can serve various functions, including administrative, legislative, or judicial. For example, the city of Munich is divided into 25 districts (Stadtbezirke)[260] while Berlin, a much larger city, is composed of only 12 districts[261]. In this research, the political definition of district regardless of the area of the district is adopted. The term 'neighborhood' is more loose, as it describes a vague social and spatial concept that is "hard to define precisely, yet everyone knows it when they see it"[262].

In social sciences the term "neighborhood" is used to describe a limited urban area with boundaries that are determined based on personal and social perceptions [263, 264]. In urban planning a neighborhood can be defined as a limited urban area with a balanced use of land users in which its center is within five minute walk or about 500 meters from its edge and its residents interact socially[265-267].In this research the urban planners' definition of the term 'neighborhood' is ' used with the addition of the note that a neighborhood can stretch across the boundaries of single district.

In the context of resilience rating systems for urban areas, numerous systems address the city or the building scale, but far fewer tackle this elusive in-between urban scale. Furthermore, from the few systems that do address this in-between urban scale[268], one can observe a persistent hard separation between the scales building and the greater urban context. This leads to a general lack of holistic integration between both spatial scales[268].

In this review, the research will examine three examples that represent a mix of climate change adaptation projects, climate adaptation guidelines, and assessment systems for the neighborhood scales.

6.2.2.1 The Urban Community Resilience Assessment

The Urban Community Resilience Assessment tool (UCRA)was developed by The World Resources Institute to integrate local insights with overarching planning objectives through a bottom-up approach to resilience planning[269]. The UCRA approach to neighbourhood resilience focuses on community's social resilience. This includes infrastructural upgrades, early warning and evacuation communication, and trainings. The Community resilience is defined by the UCRA as the "communities' potential to respond to climate-induced natural disasters and learn from, adapt, and transform their essential functions and environments based on experience" [269].

The UCRA framework encompasses three components, and each component is divided into 10 categories with 60 indicators in total. These three components encompass the vulnerability context of cities, the resilience capacity of neighbourhoods, and the individual capacity. The individual capacity measures the ability of households to react to climate-related disasters such as personal habits and access to resources. The indicators within each component are adaptable and can be tailored to fit the local context. The UCRA rates each indicator's results on five-point scoring system as follows:

- 1 point (least resilient)
- 2 points (not very resilient)
- 3 points (moderately resilient)
- 4 points (resilient)
- 5 points (most resilient)

The UCRA framework consists of four stages, which are: preparation, data collection, data analysis and project planning. As per the system developers, the application of the framework took six to eight months to conclude in the three pilot cities [269]. This process enables cities to tailor the indicators, assemble a team of experts and community leaders to serve as advisors to the implementation team, conduct data collection and analysis, and collaborate with community members in creating resilience actions.

The novelty of the UCRA bottom-up approach is that it is human- and not system-centred. Moreover, it offers a chance to merge city-wide vulnerability evaluations and resilience plans with local neighbourhood concerns, connecting top-down and bottom-up information systems and resilience efforts. Its objective is to use disaster preparedness as a steppingstone to foster social networks and cultivate stronger, more prepared, and more resilient communities. However, although the built environment and the buildings conditions are assessed using the UCEA method, their coverage is rather simple and not suited for a European context as it focuses on the basic amenities such access to water and wastewater treatment, access to waste collection, access to education facilities and electricity coverage. These aspects are taken by the residents of most European cities for granted. Moreover, The UCRA system fails to rate the level of resilience of these essential services to climate impacts. such as the redundancy of the electrical and communication system, the urban heat island effect or the ability of the neighbourhood rainwater draining system to handle a downpour that exceed the 50 or 100 ARI (average recurrence interval) which is expected to intensify due to climate change.

6.2.2.2 *Hessen Checklist for climate adapted neighborhood (HLNUG):*

In the mid-2020 the Center for Climate Change and Adaptation at the Hessian Agency for Conservation, Environment and Geology published an interactive Pdf-file that the users can click through and be guided to a summary of the most important information as well as suggestions for guidelines, concepts, guidance documents, funding programs and case study examples[270].

The checklist is not a rating system but rather a guidance tool that urban planners can use to include climate change adaptation measures into their planning. The state of Hessen recognizes the importance of neighborhood adaptation and the multiple synergetic effects it has with climate protection, environmental protection, and nature conservation. However, it also highlights the fact that climate adaptation in neighborhoods is currently still a ‘niche’ area that is not well discovered. The checklist provides a list of seven criteria that are to be addressed in the creation of climate-adapted neighborhood. Within each criterion, the checklist asks if certain vulnerabilities or adaptation measures have been considered. These are:

1. City climate
2. Open and green spaces
3. Water and wastewater systems
4. Inhabitants
5. Surrounding environment
6. Infrastructure
7. Buildings in terms of their location and construction

The Pdf checklist system offers a quick, simple, and effective planning tool that helps to guide the planners in including climate adaptation measures. Nevertheless, it can be noted that in terms of climate adaptation at the building level the guide overwhelmingly focusses on literally ‘greening’ the buildings. This is evident in the fact that from the 12 checklist indicators, five indicators are asking if a façade or roof greening is integrated.

6.2.2.3 *The KlimaWohL Cooperative processes climate-adapted planning and constructing in the district.*

KlimaWohL stands for (Climate-Adapted Housing and Living) and is three-year cooperative research project that started in the year 2016 between the City of Hannover, Environmental Protection in the Department of Environment and Urban Greening, housing companies, and scientific support from the sustainify Institute. The project was selected as a municipal lighthouse project under the program "Measures to Adapt to the Consequences of Climate Change" funded by The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) [271]. KlimaWohl is a real case study project that used normal project development and construction process to illustrate how climate adaptation can be considered and implemented throughout the entire process, from planning and construction to the operation and use of a new residential neighborhood[271].

One of the main features of the KlimaWohL project is that it has integrated the climate adaptation consideration across the typical eight municipal planning phases and nine corresponding service phases of the Fee Structure for Architects and Engineers (HOAI), which a project should ideally pass through. In each phase the KlimaWohL process provides a checklist with important fields of action, actors, and communication formats. The checklist includes important points that should be checked regarding climate adaptation as well as repository of KlimaWohL adaptation options from which suitable measures can be selected.

The 'Hannover-Modell KlimaWohL' was tested during the project. The 'Hannover-Modell KlimaWohL', depicted in figure 59, offers a general orientation framework for the targeted implementation of climate adaptation measures for an urban new building project in the various phases from planning and construction to operation and use, addressing the relevant fields of action and actors in each case and developing suitable principles of cooperation. It also provides basic guidance for climate adaptation measures in existing buildings[272].

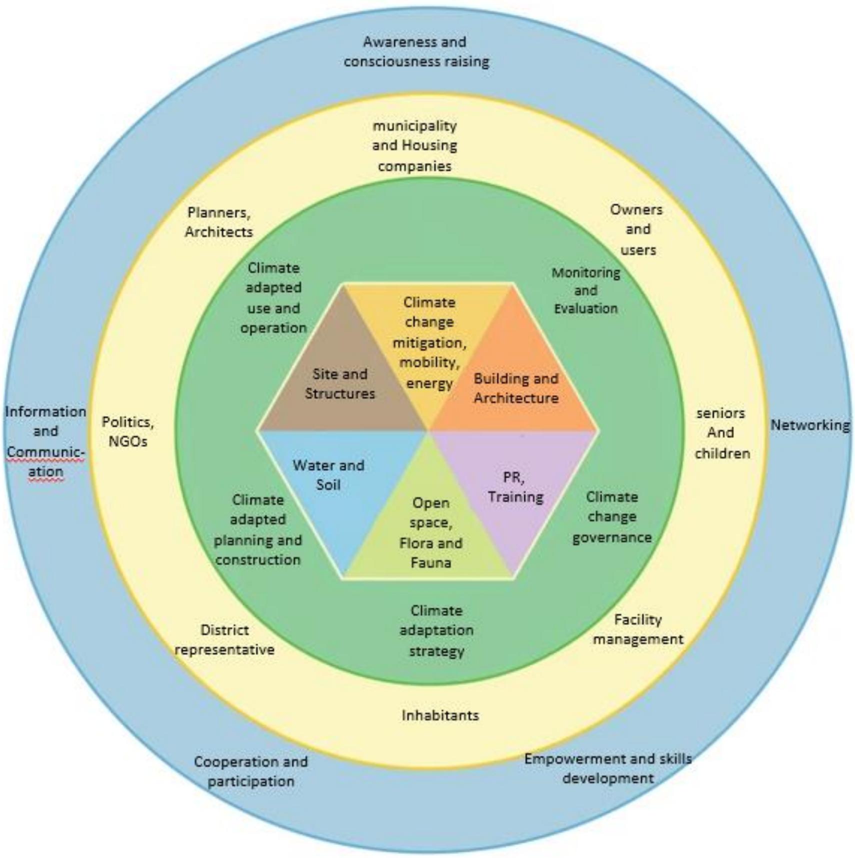


Figure 59: A diagram showing the Hannover-Modell KlimaWohL –used in the Herzkamp pilot project, adapted from[272]

The Hannover KlimaWohL model is designed as a recurring process and is based on three questions:

1. What is relevant to climate adaptation and what are the fields of action relevant to climate adaptation? (Hexagon in the core: thematic fields and green ring: process elements).
2. Who is to be involved? (Yellow ring: actors)
3. How is the cooperation between the actors structured? (Blue ring: guiding principles)

As per the Klimawohl developers[272], answering these three questions is fundamental for each project.

In terms of content, the relevant fields of action include the thematic fields listed in the hexagon (Fig.56) and correspond to the fields of action outlined in the climate adaptation strategy of the State Capital Hanover.

Further, they include the process-related elements shown in the surrounding green ring, such as: a municipal climate adaptation strategy, a climate-adapted planning and execution, and a climate-adapted operation/use.

The Klimawohl model considers that continuous monitoring and evaluation of own objectives are also important building blocks to permanently shape the ongoing adaptation process to the dynamically changing climate change[272].

A climate change governance stands for the entirety of the cooperative collaboration of all participants, i.e. the actors from the municipality, the housing industry, politics and the public, with the associated rules (e.g. legal provisions, contractual and other agreements, etc.), instruments (e.g. climate adaptation strategy, climate adaptation map, etc.) and communication formats (e.g. participation processes, coordination rounds, etc.).

The yellow ring lists the relevant stakeholder groups identified for the pilot project.

The five guiding principles for the cooperation of the stakeholders involved, as mentioned in the outer blue ring (Fig. 56), are included to achieve the following effects:

1. Awareness raising for climate adaptation measures,
2. Competence development and empowerment for own action,
3. Networking of relevant actors,
4. Information (one-sided) and communication (dialogical) and/or for the,
5. Participation (informal, formal) and cooperation (informal, open-ended).

In general, Klimawohl model offers an integrated and holistic method for implementing climate adaptation measures at neighborhood scale, however, the Klimawohl model doesn’t offer a way to quantify and rank the climate risks, their impacts, and the effectiveness of the applied adaptation measures in quantitative terms. In short, the framework remains very qualitative and lacks the necessary quantitative results that can help the planners and users to gauge and prioritize the risks and adaptation solutions.

6.3 Insights and Key Findings: The Landscape of Climate Change Resilience Rating Systems

The review made in this chapter showed that the IPCC AR5 generic climate risk and its German translation interpretation in the DIN EN ISO 14091 - 2021-07 (Anpassung an den Klimawandel - Vulnerabilität, Auswirkungen und Risikobewertung) is widely used by many federal Germany agencies to assess the climate related risk and vulnerability. The method developed by German Federal Ministry for Economic Cooperation and German development agency (GIZ) serves as a useful practical complement to the generic IPCC approach by providing a clear method for implementing the AR5 risk assessment concept in the real-life context. However, regarding assessing the climate risk and resilience of the built environment, it was noticed that the IPCC AR5 and DIN EN

ISO 14091 - 2021-07 risk assessment method is not universally followed (see Table 9). Moreover, not all systems provide a comprehensive or quantitative assessment tools. Moreover, some assessment systems are limited to a small number of hazards or exposure values.

Furthermore, none of the existing operational rating systems permit a cross-scale risk and resiliency assessment, meaning that neither the risk assessment nor the rating system can be used at other urban scales. Hence, the results obtained at one spatial scale cannot be translated or used on another scale, requiring the use of a new assessment system to generate and interpret the results. This limits the practical application of such rating systems, as decision-makers would only have a partial view of the state of the resiliency of their urban environment, making it challenging to develop comprehensive, integrated, and measurable climate adaptation solutions. This hinders the effort in making the entire urban fabric work together to effectively mitigate climate change risks.

Additionally, except for the BRI and REDi systems, all other rating systems fail to provide a clear quantitative understanding of the result of applying an adaptation measure on reducing climate change hazards risks. Meaning they assess the status-quo only but do not provide an answer to the reduced risk by implementing a certain or combination of adaptation measures.

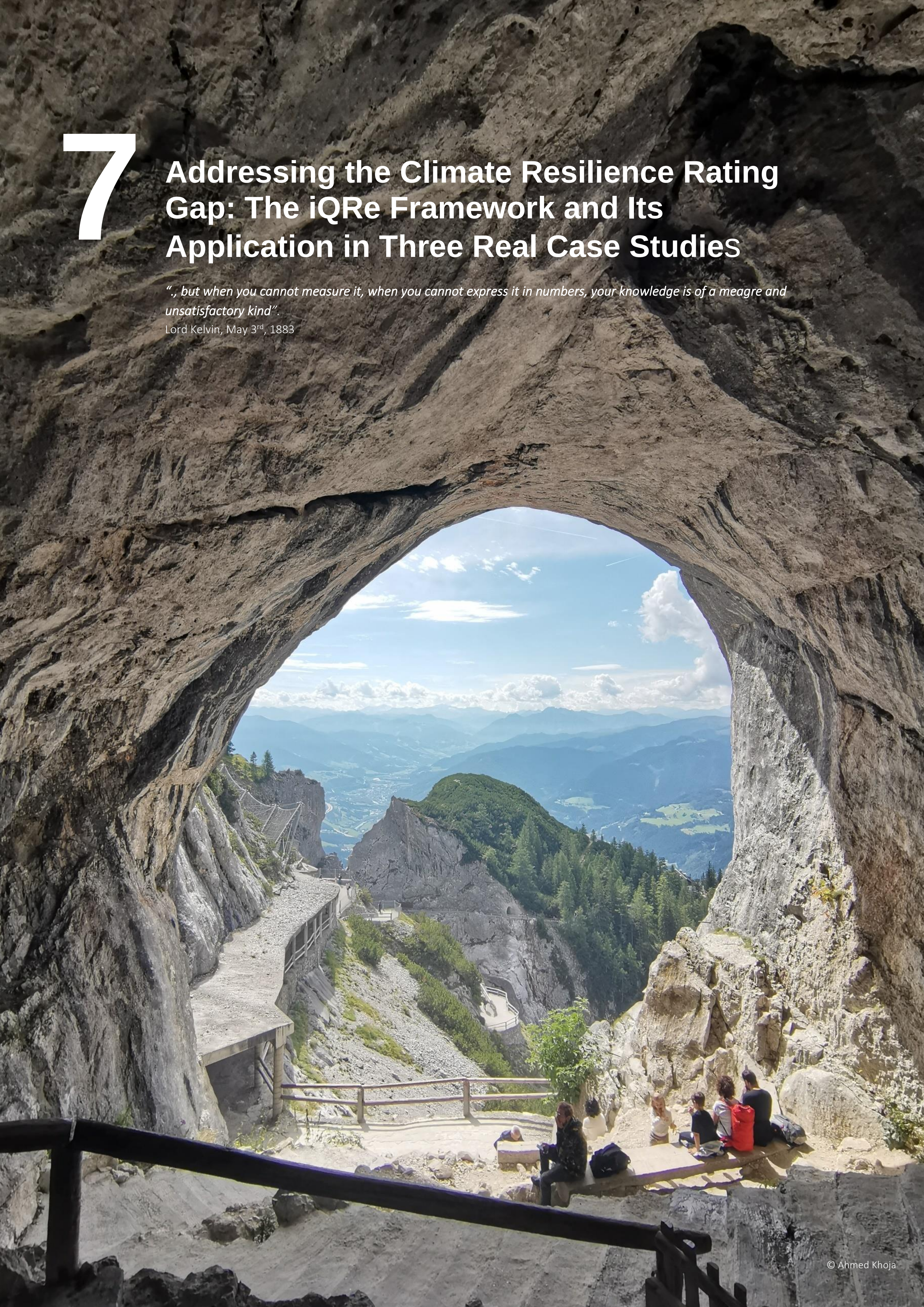
Table 11: A comparison between the analysed climate change resiliency framework in terms of application scale and inclusion of climate risk, vulnerability, and exposure into their system

Rating system	Cross scale?	Numerical or Descriptive results	IPCC AR5 Risk assessment method		
			Hazard assessment	Vulnerability assessment	Exposure assessment
REIl	No, Building only	Numerical	Generic	No	No
REDI	Partial unidirectional to building only	Numerical	Storm	Yes	Limited to storm hazard
Immo-risk	No, Building only	Numerical	heat, flood, hail, heavy precipitation, and storm	Yes	Limited- to only Monetary for hail and storm.
BRI	Partial unidirectional to building only	Numerical	Earthquake, heat, flood, hail, heavy precipitation, and winter storm	Yes	Limited- to building structure only
UCRA	Only Neighborhood	Numerical	Generic	Yes	Limited to social resilience
Klima-Wohl	Only Neighborhood	Descriptive	Generic	Qualitative	Qualitative
HLNUG	Only Neighborhood	Descriptive	Generic	Qualitative	Qualitative

7 Addressing the Climate Resilience Rating Gap: The iQRe Framework and Its Application in Three Real Case Studies

"., but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind".

Lord Kelvin, May 3rd, 1883



Urban built environments are an interconnected and interdependent systems. Improving their resiliency to climate change can best be achieved when vulnerability is addressed across multiple scales and sectors. Resiliency in the built environment requires bridging temporal and spatial scales and engaging a broad range of institutional actors[273]. For example, adapting to the universal climate change hazard of heatwaves is best tackled when buildings are properly insulated, ventilated, and situated in shaded environments that have a low urban heat island effect. Hence, both the building and the greater urban context are working in tandem towards the same goal.

The investigation done in chapter 6 showed that the existing rating systems for urban resilience, are not always fully aligned with the IPCC AR5 risk assessment approach. For the German context, this alignment is of vital importance given that IPCC guidelines, alongside the DIN EN ISO 14091 - 2021-07, are widely utilized across various urban and policy sectors in Germany. Ensuring a harmonized and cohesive approach to assessing climate change resilience across these diverse sectors is critical for creating coordinated and integrated strategies for climate adaptation. Moreover, as demonstrated in table 9, not all assessment systems provide quantitative results, and most lack the flexibility to allow the user to contextualize them according to the project's priorities and apply them across various phases of the project, from early assessment to decision making and monitoring or various RCP scenarios. Additionally, none of the existing operational rating systems allow a cross-scale risk and resiliency assessment. Thus, results obtained at one spatial scale cannot be translated or used at another, necessitating the use of a new assessment system for each scale. This restricts the practical application of such rating systems, as addressing climate hazards necessitates a balance of climate mitigation efforts with climate adaptation actions across multiple urban scales (building, neighbourhood, and district) in a continuous and integrated manner[47]

Similarly, as revealed in chapter 5, existing building rating systems such as energy performance labels and sustainability certification schemes do not provide holistic insights into the building's climate adaption performance , a topic they were not originally designed to address.

Based on these findings, this chapter outlines the development, testing of the Integrated Cross-Scale Urban Resilience Assessment framework and rating system, call the iQRe, in three case study sites in Bamberg, Germany.

Thus, this chapter is dedicated to answer the later part of this research hypothesis and its the second question:

What would be the key features and methodologies of a dedicated numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices?

7.1 An introduction to the iQRe Framework and Rating system.

The iQRe acronym stands for Integrated Cross-Scale Urban Resilience Assessment Framework and Rating system. The iQRe is developed in response to the shortcoming of the existing resilience rating systems for the German built environment, summarized in the introduction of this chapter, and detailed in chapters 5 and 6. The iQRe decision-making framework is based on the DIN EN ISO 14091 guidelines and is supported by a cross-sectoral and cross-scale rating system, that enables users to numerically assess the urban vulnerability to climate change risks and its resilience. In essence, resilience is the opposite of vulnerability [250] which is the The propensity or predisposition to be adversely affected[274] . In this sense, resilience to climate risks increases as vulnerability decreases[252].

A key part of iQRe framework concept is on enabling the users to trace the cross-sectoral relationships of climate adaptation actions to ensure that key urban sectors, actors, and scales work as a single interlocked system, providing decision-makers with holistic information about the urban environment's degree of adaptation to current and future climate hazards [273]. In the iQRe framework, the concept of 'cross-scale' is actualized through the integration and unification of key urban sectors across the spatial scales of the urban environment. The key urban sectors refer to those aspects or areas of urban environment that are critical for its functioning such as energy, water and wastewater, Human Wellbeing and Organization and are connected by default across the urban environment. The choice of the key urban sectors is made based on and in alignment with the seven key urban sectors identified by the IPCC AR5 “Urban Areas” as in need of adaptation the climate [85]. The full list of the iQRe urban sectors, later on “Sectors”, their definition in each urban scale and the assessment focus for each sector can be found in table 12.

In the iQRe framework these sectors, are harmonized and treated holistically across their value chain. For instance, the 'Water and Wastewater' sector can be assessed from its origin at the individual buildings, through its role in broader neighbourhood infrastructure, to its endpoint in treatment facilities in district. This cross-scale approach thereby captures the entire value chain of the water and wastewater within the three urban scales. Moreover, by fixing common sectors across the urban scales, the administrative responsibilities are clarified, and the allocation of adaptation can be better distributed. This provides an integrated picture of the sector’s climate resilience performance.

For instance, let us consider the “sector” of “structures “and the hazard of flooding. At the building scale, the vulnerability that the “structure” sector provides to hazard of flooding could be measured based on the relation of elevation of the lowest occupied floors in relation to a 100-year Average Recurrence Interval (ARI) flood threshold i.e. in building “X”, the occupied floor is “Y” cm over of below the 100 ARI flood threshold. At the neighbourhood scale, this approach can be expanded to calculate the number of “mission-critical” buildings whose lowest occupied floor is x cm above the 100 ARI flood threshold. Further, at the district scale, it can be determined by counting all the buildings in the district that are x cm above the 100 ARI flood threshold.

Now taking this same hazard of “flood “and assessing it from a different “sector” perspective such as the human health and wellbeing sector, we can find that this very same hazard will also be present, albeit differently. Here, the sector’s vulnerability to the risk of flood is more concerned with assessing the number of building users occupying a certain floor of the building rather than the physical elevation of the structure. At the building scale, the vulnerability of the health and wellbeing sector will be the “total number” of users whose lowest occupied floor is “X” cm above the flood threshold. This same line of thought can be further expanded to the neighbourhood scale by counting the “total number of users” that use mission-critical buildings whose lowest occupied floor is “X” cm above the flood threshold. At the district scale, the vulnerability of the health and wellbeing sector will be the “total number of users” in all buildings where the lowest occupied floor is “X” cm above the flood threshold.

In the case of heatwave hazard, the 'Energy' sector can assess the energy efficiency of air-conditioning systems at the building scale, while at the neighbourhood scale, the evaluation could be expanded to account for the total number of buildings equipped with energy-efficient air conditioning systems. Similarly, for the 'Structure' sector, resilience to heatwaves could be measured at the building scale by the thermal performance of individual buildings, such as their insulation and the materials used. At the neighbourhood scale, this could involve an aggregate assessment of buildings' thermal performance or the number of shaded buildings in relation to the free-standing ones. From the ‘Urban and spatial environment sector perspective, the impact of heatwaves at the building scale could be measured by looking at factors like the orientation of the building and the by assessing sunlight exposure using the DIN 5034-1 (Tageslicht in Innenräumen) and EN 17037 (Daylighting of Buildings) methodology. At the neighbourhood scale, the urban arrangement of the buildings hights and locations and the degree of shading provided by the overall urban morphology and natural elements, such as tree canopies, could be analysed to determine the area’s overall vulnerability to heatwaves from an urban standpoint.

This cross-scale integrated, and sector-specific approach provides a more coordinated strategy to build resilience against a specific hazard. However, as the same hazard can cause several types of loss (monetary, health, environmental, etc.) within the same sector, the iQRe framework classifies six distinct risk groups: Humans, assets, natural resources, infrastructure, critical services, and ecosystem. The choice of these risk groups is again made based on the IPCC AR6 definition of hazard , as it state that *“Climate change hazards may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision*[2]*, ecosystems, and environmental resources”*[275].

This segmentation of the built environment into sectors and re-connecting it via the risks and spatial scales, aim at allowing each sector to play its role across different scales in addressing the same hazard, thus making the

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[2] In the context of the IPCC, the risk of loss of service provision refers to the potential for climate change to disrupt or impair critical urban services that are necessary for maintaining public health, safety, and well-being The iQRe system refers to these elements as critical services.

administration and implementation of adaptation strategies more manageable and, allowing the urban resilience to be addressed more comprehensively than would be possible through a focus on individual scales or sectors alone. Moreover, as the iQRe provide numerical outputs to each risk group, the decision makers are in better position to prioritize and gauge the types of climate adaptation needed for each hazard, to reduce the risk to which risk group and in which sector.

Table 12: Definition of the unified cross scale Key urban sectors used in iQRe.

Sector	Definition	Buildings scale - DIN 276 cost groups	Urban scale	Assessment focus
Structures	refers to elements of the stationery structures in urban context	the sector is best reflected in the DIN 276 by the cost group 320 to 360	the sector is best represented by the buildings such as a house, hospital, and shop.	The assessment of the sector focuses on the structural and physical properties of the building footprint such as its walls, roof, and stairs
Urban and spatial environment		this sector is best reflected by the DIN 276 cost group 220 and 500	The sector refers to the interaction between the physical setting and spatial location of buildings and its connections to the surrounding infrastructure needed for the function of an urban area	the interaction between the physical setting and spatial location
Energy systems	The sector refers to any system installed at any scale that is primarily designed to supply energy-services to end-users	The sector is best reflected by the cost group 420 to 440 in the DIN 276.	higher urban scales, the sectors include local energy generators, energy transformers, pylons, and cables.	all the components of an energy system that are related to the production, conversion, delivery, and use of energy
Human wellbeing and organization	The sector refers to the state of a person or a group being comfortable, healthy, or happy. Climate change impacts can	not well presented in the DIN 276 at moment, nevertheless some aspects of the cost group 690 can	Governance, signs, emergency, and educational services	The assessment of the sector refers to two integrated aspects. The first aspect includes social and cultural factors such

	affect the health and wellbeing negatively [5].	contribute to addressing this sector		as comfort and perceived safety. The second aspect is concerned with the organizational processes. Organizational processes refer to the policies, procedures, and management practices of organizations, that affect the health and wellbeing of the user. Organizational processes is a key enabler for reducing climate risks [276].
Green and blue infrastructures	green infrastructure refers to trees, lawns, hedgerows, parks, fields, forests. Blue infrastructure refers to water elements, like rivers, canals, ponds, wetlands, etc.	this sector is best represented by the cost group 335, 353, 363, 570 and 580 depending on the location of the green and blue elements	The existence of one or more these elements in the neighbourhood or district boundary make it part of the assessment at that scale	The assessment of sector assesses the quality of these structures to provide a specific positive function or to prevent adverse impact.
Transport and mobility	The transportation sector refers to the all the system components that provide services to move people or goods	this aspect is covered in a several DIN 276 cost groups such as 371 to 375, 460, 531 to 534 and 546	the sector refers to bus, car and bike roads, pavements, light rail networks and other infrastructure elements that fall within the transport sector.	The assessment of the sector concerns the transport system ability to ensure that safe, swift, environmentally friendly, and affordable and equal, access to services, buildings and leisure using transport option.

Water and wastewater	the sector involves the collection, treatment, and distribution of water for domestic, commercial, and industrial use, as well as the collection, treatment, and disposal of rain and wastewater	this sector is covered in the DIN 276 mainly in the cost group 410	The existence of one or more these elements in the neighbourhood or district boundary make it part of the assessment at that scale	The assessment of sector assesses the quality of the water and wastewater systems to provide a specific positive function or to prevent and adverse impact.
Communication systems	The sector refers to a range of services related to telecommunications and information technology	the DIN 276 covers this sector in many cost groups such as 450, 480 and 630.	the sector includes aspects such internet, mobile phone services, networking, and data solutions. The sector also encompasses the infrastructure supporting these services. In addition, to technologies such as 5G wireless networks and the Internet of Things (IoT).	The assessment of the sector concerns the communication system ability to ensure that safe, swift, environmentally friendly, and affordable and equal, access to wired and wireless communication services

As started earlier, the iQRe Builds upon the general guidelines of the EN ISO 14091:2021 standard, "Adaptation to climate change—Guidelines on vulnerability, impacts, and risk assessment," and expand it accommodate the unique challenges of the built environment. This allows the iQRe to align with the international and national climate change risk assessment standard, promoting a more harmonized approach to assessing climate change resilience.

Nevertheless. To contextualize the generic EN ISO 14091:2021 standard to the challenges of the built environment, constituted adjusting the waterfall project management methodology of ISO 14091:2021 to hybrid Agile-Waterfall project management methodology. Moreover, as shown in table 13, the original three phase of ISO 14091:2021 are expanded in the iQRe framework to cover the action planning and implementation phases. Hence the iQRe framework is composed of five consequential phases that are supplemented with the three iterative reoccurring steps: data collection, descriptive analysis, validation.

Table 13: Comparison of the iQRe Framework and EN ISO 14091:2021 main steps and phases

IQRe		EN ISO 14091:2021	
Main Phase	Sub step	**Main phase**	Sub step
Pre-planning	Project charter and defining the project goal, scope and stakeholders and assessment method	**Preparation of Climate Change Risk Assessment**	Determination of the Context
			Identification of Objectives and Expected Outcomes
			Compilation and Commissioning of a Project Team
			Determination of Scope and Methodology
			Setting the Timeframe
	Identifying climate Hazard/ impact		Collection and Documentation of Relevant Information
	Identifying main climate parameters drivers and forcing		
	Iterative steps (data collection, descriptive analysis, validation)		Development of an Implementation Plan
			Transparency
			Participatory Approach
Preparation phase	Identifying the key urban sectors at risk	**Implementation of Climate Change Risk Assessment**	Screening of Impacts and Development of Impact Chains
	Data collection and stakeholder engagement.		Data Collection and Management
	Generating a risk assessment based on qualitative assessment of vulnerabilities and end user feedback.		
	Iterative steps (data collection, descriptive analysis, validation)		
Risk assessment phase	Development of the impact chains, calculating the risk via the iQRe rating system and supporting tool		Identification of Indicators
			Aggregation of Indicators and Risk Components
			Assessment of Adaptation Capacity

	Iterative steps (data collection, descriptive analysis, validation)		Interpretation and Evaluation of Finding
			Analysis of Intersectoral Interdependencies
			Independent Review
		Reporting and Communication of Climate Change Risk Assessment Results	
			Climate Change Risk Assessment Report
			Communication of Climate Change Risk Assessment Results
			Reporting of Findings as a Basis for Adequate Adaptation Planning
Action planning phase	Setting the targets	-	-
	Drafting the list of adaptation solutions		
	Selection and prioritization of adaptation actions		
	Development of details action plan		
	Iterative steps (data collection, descriptive analysis, validation)	-	-
Implementation and monitoring	Iterative steps (Risk assessment, data collection, descriptive analysis, validation)	-	-

With the context of the iQRe framework the iterative activity of "Data collection" encompass any activity that increases the magnitude and/or complexity of information included in the iQRe impact chain model at any urban scale. There are two distinct types of data collection, object-related data such as a U-Value, area, rated water flow, etc, and context related data which provides the decision maker with the necessary backdrop to interpret current performances such as user age group, use hours, etc. The iterative activity of is processing data from past events and presenting them to stakeholder to allow them to make an informed judgment on how to handle an event in the foreseeable future [277] It can be viewed as storytelling of the data to other stakeholders. Lastly, the Validation process which aims at ensuring each assumption made at one step is cross checked, and validated by the project team and allows for the transition to the next step in the project. Figure 60 provides an illustration of the five consequential phases and the three iterative steps that form the basis for the the iQRe decision-making process.

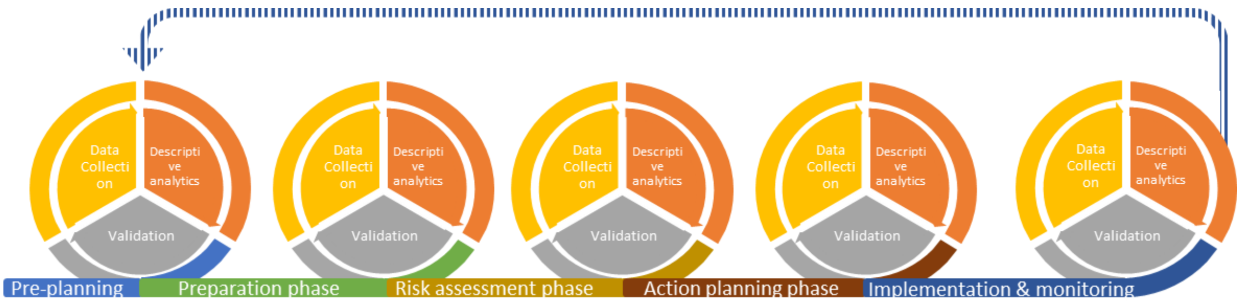


Figure 60: Illustration of the iQRe decision-making process consisting of 5 consequential phases with three iterative steps in each phase.

For the creation of the iQRe rating system, the iQRe merges GIZ concept of the practical application of the IPCC AR5 risk assessment approach with the generic multi-criteria analysis methodology of the “SB Method", developed by the International Initiative for a Sustainable Built Environment (iiSBE). The SB method enables the assignment of a normalized numerical value to each of the three components needed to assess climate risk: Hazard, Vulnerability, and Exposure. The SB Method was selected as basis for the rating because of its inherent flexibility, allowing it to be customized to different locations and rating circumstances[278]. The customizability of the SB Method is evident in its implementation in national rating systems of various countries, including Spain, Portugal, Italy, Japan, Czechia, and Canada [279-281].

Unlike other rating systems with predetermined benchmarks, the SB Method allows users to customize benchmark values and weights based on local conditions. This approach is more suitable for climate adaptation tasks as the responses and solutions applied are local to each case. Thus the SB method is able to incorporate sustainability and resilience in a single framework [29, 282].

The inclusion of the SB method with the IPCC approach to create a rating system the complements the iQRe decision-making framework provide the involved stakeholders with a numerical assessment system that enable to measure the impact of their adaptation interventions or allow them to evaluate the existing risks and adaptation needs.

7.2 An iQRe decision-making Methodology and Its Example Application to the three Case Studies.

This subchapter will illustrate the iQRe framework five phases and rating system in detail based on an example application of the iQRe system in three case study sites.

7.2.1 Pre-planning Phase

The Pre-planning phase consist of activities iterative processes, which serve achieving the following goals:

- Reaching a common agreement on the climate change risk assessment process on the overall objectives, methods, and scope of the assessment
- Defining the relevant stakeholders and the target audience
- An agreement the resources and time frame of the project
- Defining the project spatial and temporal boundaries
- Identifying the relevant climate parameters and key hazards and impacts

As in any other project, the pre-planning phase begins with creating a project charter, which formally authorizes the initiation of the project[283]. In this case, the city of Bamberg contracted the offices of Intep - Integrale Planung GmbH, and Essigplan GmbH in early 2022 to develop a preliminary plan for climate change adaptation measures for three of its youth centres: the youth centre on Margaretendamm (JUZ), Jugendtreff Ost (JO), and Jugendtreff GAUstark. The case studies presented an excellent opportunity to evaluate the application of the iQRe framework in real-life scenarios. On May 30th, 2022, a kick-off meeting was conducted via Voice over Internet Protocol (VoIP). During this meeting, the project goal, scope, duration, and key stakeholders were defined.

The project objective was set to assessing the resilience of the three case study sites to climate change impacts and propose climate adaptation measures to enhance their adaptation performance. The project team unanimously agreed to the use of the iQRe framework and rating for the conducting the assessment.

The scope of the project was limited to the building scale, and the project duration was set to three months, spanning the summer of 2022. The identified stakeholders include the owner (the city of Bamberg), the operator (Ja:Ba, a part of the youth welfare organization iSo-Innovative Sozialarbeit), the end user, and the consultancy team consisting of planners from Intep - Integrale Planung GmbH, Essigplan GmbH, and Hochschule München University of Applied Sciences (HM), represented by the author.

In the following, a brief overview of the three case studies is provided. Detailed photos and plans from these case studies can be found in Annex 10.13 of this research.

7.2.1.1 The youth center on Margaretendamm (JUZ)

The Youth Center on Margaretendamm (JUZ) is housed in a former leather factory that was constructed in the 1940s. In 1977, the building underwent conversion into a youth center, and an external multipurpose hall was added. This hall extension currently serves as an indoor skate hall, which includes a skateboard repair shop.

Situated on Margaretendamm 12a street in Bamberg, the youth center is approximately a 15-minute walk from the historical center of the city. It is located about 100 meters to the east of the Regnitz Riverbank. The primary target group for the center is teenagers and young adults between the ages of 16 and around 27. However, it is worth noting that the majority of youth visitors are in their late teens or early 20s. According to the operator of the youth center, the skate hall is particularly popular, especially during the winter and autumn seasons.

Figure 61: An aerial image from Google maps showing the location of the JUZ building (highlighted in Yellow), Notice the large multipurpose hall that was added to the west of the main building in 1970s.

The summer months witness a drop in the number of visitors which can be attributed to rooms overheating and the youth engagement in outdoors activities.

Figure 62: External photos of the JUZ, notice the slopped entrance and the large skating hall to the right of the main building.

The main building of the Youth Center on Margaretendamm (JUZ) comprises a basement, ground floor, first and second floors, as well as an attic. Additionally, there is an attached ski hall, which consists of a spacious, single-story room. Within the ski hall, there is also an attached repair shop, a storage room, and the only barrier-free toilet on the premises. The JUZ complex has a total heated area of approximately 990 m².

On the ground floor of the main building, you will find a café, a kitchen, storage rooms, and the main lounge. The main lounge is frequently used for larger events, and local concerts are held there around once a month. The first and second floors of the Youth Center on Margaretendamm (JUZ) are utilized for a range of activities, including a meeting room, exercise room, studio, and office space. On the ground floor, there is a terrace, and on the first floor, there is a roof terrace. The basement of the building houses a rehearsal room, recording studio, storage rooms, technical rooms, and toilets. In terms of heating, the building is connected to the district heat network, and its annual heating demand stands at approximately 150 kWh/m².


Figure 63: Images showing the interior of the Skate Hall and the main lounge, the ventilation ducts are out of operation.

7.2.1.2 The Jugendtreff Ost (JO)

The Youth Center East (JO) was constructed in 2017 and is situated near a school at Kloster-Langheim-Straße 11 in Bamberg. The JO center is centrally located on a flat plot of land surrounded by various sports fields and meadows.

The building itself consists of nine containers, with five measuring 3x6 meters and the remaining containers measuring 2.4x6 meters. The approximate total area of the containers is about 144 square meters. The one-level steel building is thermally insulated and rests on a gravel bed. Although the use of containers suggests potential for easy disassembly, the city of Bamberg currently has no plans to dismantle the structure, and it is intended for permanent use. The building is connected to the school's pellet-based heating system. The primary target audience for the youth center is children aged between 8 and 14 years old. The proximity of the building to a school complex, densely populated area, and surrounding sports fields makes it an attractive meeting spot for young children. Despite the great overheating experienced in the summer due to the black paint, lack of shading and overcrowded spaces, the operator reported that during the summer about 100 children a day visit the center. The numbers drop to about 15-20 visitors a day in winter.

Figure 64: An arial google maps image showing the location of the JO youth centre (highlighted in yellow).

Figure 65: A fontal and back images of the JO container building

The building is divided into four sections. Four containers to the south house an open-plan multipurpose hall with sections for video games, a kitchen, and a pool table. In the middle, there are the toilets and administrative office. To the north, two containers are used as a movie room, table-tennis area, or meeting room.

Figure 66: Images showing the interior of the JO centre.

7.2.1.3 The Jugendtreff GAUstark

The GAUstark youth centre is housed in a former administrative building of the municipality of Gaustadt. While the exact age of the building is unknown, it was converted into a youth centre in 1979 following the incorporation of Gaustadt into the city of Bamberg in 1972. Situated on a hill at Gaustadter Hauptstraße 44, the youth centre faces one of the main streets. The youth centre lacks a direct access to leisure facilities, with only a school located within walking distance. Currently, the youth centre is visited by about 15 children aged between 10 and 15 years. Notably, the building does not have its own heating boiler. Instead, it receives its heating energy from a nearby building.

Figure 67: An arial Google maps image showing the location of GAUstark youth centre (highlighted in yellow)

The GAUstark youth centre is comprised of a ground floor, first floor, second floor, and attic, with a partial basement. The total usable area of the building is approximately 210m². Currently, only the ground floor and 1st floor are used. Both the 2nd floor and the attic serve as a storage area, cannot be used du to fire protection regulation (missing escape routes). The basement area is empty, not developed, damp and not usable. Due to structural concerns, the large terrace of the first floor is not used and serve as fire escape route only.

Figure 68: Images of the unusable balcony on the first floor and a view southern facing faced of the GAUstark Building

Figure 69: A photo showing an interior room that is used to play table tennis and a photo showing the lack of outdoor space next to the building due the fire escape that was added recently (2021/22).

7.2.1.4 Identifying climate parameters, the main drivers and anthropogenic forcing.

The identification of the relevant climate parameter and drivers is a key element to understand the climate related hazard that the city, neighbourhood and building need to be prepared for. Climate parameters refer the variables that shape the climate of certain region, and they include for example, average rain fall, annual mean temperatures, and annual max temperatures. Moreover, the climate parameters include parameters such as number of summer days (days with a daily maximum temperature of at least 25°C) or number of ice days (days with a daily maximum temperature below 0 °C). These climate parameters are used as basis for the scientific monitoring climate change. A significant statistical change in these climatic phenomena can indicate the possible occurrence of a climate related impact such as an increase in the number of hot days or decrease in the amount of rain fall, which will increase the risk of climatic hazard such heatwaves or drought. These changes can be induced by combination of natural and anthropogenic forces. Having a clear understanding of the natural drivers and anthropogenic forces that contributing to the currently occurring as well as of the predicated change in the climate parameters is key to outline the expected type of climate change related hazard that the urban environment needs to adapt for. Moreover, it helps outline the type of adaptation actions suited to reduce the anticipated risks.

In most cases, cities and regions do have a clear view of the type of climate parameters that are closely monitored and are able to provide predication for the development of these climate parameters in the future.

In relation to the city of Bamberg, climate models for the coming 80 years are readily available at Germany Climate Service Centre (GERICS) and German weather service DWD [284]. Bamberg climate models found in GERICS provide a mid (2036-2065) and long term (2069-2098) prediction about the changes in key climate parameters based various emission development pathways (RCPs). For this research, the RCPs 8.5 and 4.5 scenarios are considered most relevant. This choice is made to align this study with a previous study made by Carsten, et al. 2020 which studied the climate risks and possible climate adaptation measures from macro perspective for the whole the Bamberg region [285].

Bamberg climate data from the years of 1951-2017 show that mean temperature has increased annually during the past 70 years at an average rate of 0.027°C per year. Resulting in observed increase in the mean temperature of the city of Bamberg by about 1.8 °C during the observed period[285]. This finding is inline with the observed mean temperature increase of 1.9 °C in the state Bavaria for the past 70 years as per the Bavarian climate report of 2021[34].

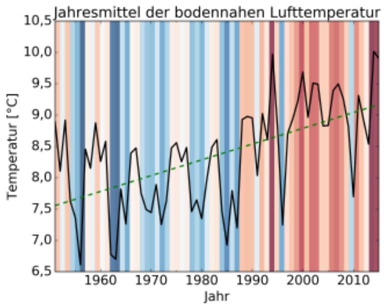


Figure 70: A Barcode representation of the average annual air temperature change in the district of Bamberg showing the increasing trend[284].

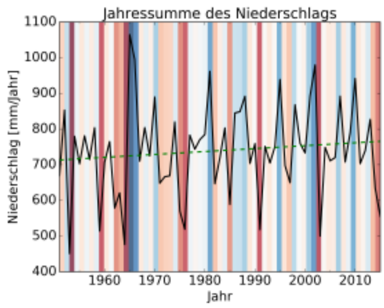


Figure 71: a barcode diagram showing the change annual amount of precipitation in mm/year during the past 70 years[284]

The following changes in some of the key climatic parameters are expected in the mid and long term future in relation to the reference period of climatic observation (1951-2017) [284, 285]

Table 14: A summary of expected change in key climatic parameters in mid and long term future in relation to the reference climatic observation[284, 285]

Climatic parameter	Timeframe	RCP 4.5	RCP 8.5
Annual mean average	2036-2065	+1,0 °C to +1,5 °C	+1,5 °C to +2,2 °C
temperature	2069-2098	+1,6 °C to +2,2 °C	+3,3 °C to +4,1 °C
number of summer days	2036-2065	+ 5 to +33.6 days	+ 5.2 to +43.7 days
	2069-2098	+ 4.7 to +40.6 days	+ 18 to +78.2 days
Number of tropical nights	2036-2065	+ 2 nights	+ 2 nights
	2069-2098	+ 3 nights	+22 nights
Number of Frost days	2036-2065	-40.2 to -16,9 days	-49 to -21.1 days
	2069-2098	-51.3 to 17.1 days	-88.2 to -33.3 days
Duration of heatwave	2036-2065	+ 5.7 days	+ 7.7 days
	2069-2098	+ 9.4 days	+ 23.2 days
Annual precipitation	2036-2065	-1% to +4%	+2 to +10%
	2069-2098	+3% to +5%	+1 to +11%
Heavy participation	2036-2065	+7% to +19%	+2% to +45%
events	2069-2098	+20% to +29%	+28% to +64%
Climatic water balance	2036-2065	-0,13 and 0,18 mm/day	-0,12 and 0,51 mm/day
(difference between precipitation totals and evaporation water losses)	2069-2098	-0,13 and 0,36 mm/day	-0,22 and 0,57 mm/day
Wind speed	2036-2065	-0,07 and 0,1 m/s	0,14 and 0,18 m/s
	2069-2098	-0,1 and 0,11 m/s	-0,14 and 0,21 m/s

For the climatic signal of hail, no accurate enough prediction models are possible[286]. Nevertheless, the Bavarian climate report of 2021 stated that extreme weather events such as heavy rain, hail, drought or storms are becoming more often in Bavaria and are expected to increase in the near and long term future[34]. Therefore, it can be assumed that hail events might increase in the midterm and long-term future.

7.2.1.5 Identifying climate Hazard/ impact

The climate hazard or impact are two key terms used to describe characteristics of climate change and its effects on geophysical systems, such as floods, droughts, sea level rise, increasing temperature, and frequency of heat waves. While hazards refer to specific events or conditions that pose a threat such as heavy rain, impacts refer to the effects of climate change on natural systems and human societies such as a flood.

A climate hazard consists of two parts climate signal and direct physical impact[250]. As the climate signal does not depend on exposure or vulnerability and can not be influenced by adaptation measures. The aim of increasing the resilience is to reduce the impacts of these hazards on the various risk groups. Through understanding the expected change in the climate parameters and the development of the natural and man-made drivers that is done in the previous step, the project team is provided with the required foundation to identify the key hazards and impacts that the community is facing and can face in the near and far future due to climate change. Based one the development trend of the climate signals and their expected development in the future (see table 12), the following climatic hazards has been identified for the case study:

- Heatwaves and warming trend,
- Floods and ground water level rising,
- Hail and heavy precipitation,
- Wind and storm, and,
- Drought.

Table 15: A summary of expected climatic hazards in the midterm and long-term future for the city of Bamberg based on the analysis made in pre-planning phase.

Expected Hazard	Hazard development trend [284, 285]	Justification based on [284, 285]
Heatwaves and warming trend	High increase	Higher annual mean temperature: by +2.2°C to 4.1 °C Increase in summer days (max. temp. >25°C): by 33 to 78 days. Increase in tropical nights: (min. temp. >20°C): by 2 to 22 days Longer heatwave: Up to +5.7 to 23 days

Floods and Ground water level rising	Moderate increase	Increase in heavy rainfall days (>20mm/d): up to +69% that follow long dry periods.
Hail and heavy precipitation	High increase	Increase in heavy rainfall days (>20mm/d): up to +69%
Drought	Medium increase	A decrease in climatic water balance by -13 to -22 mm/day
Wind and storms	Low increase	-0,1 to 0,22 m/s

7.2.1.6 Iterative process

- **Date Collection:**
  All gathered and collected data originate from official sources that can be trusted and enable a clear picture of the expected climate change in the case study city. Climate forces and human drivers that contribute to the climate change are depicted in the RPC models. This allows the user to understand the possible future developments of the natural drivers and anthropogenic forces as both can have a strong negative or positive impact on future climate hazards depending on the direction of their developments. In this study data originating exclusively from official sources were used [284, 285]
- **Descriptive analytics:**
  All relevant climatic data had been shared in clear, neutral, and understandable manner with the project stakeholders. This was done during the previous study made by[285]and during this study in 2022.
- **Validation:**
  The main stakeholders agree on the outcomes of the climate parameters analysis. This study is done in alignment with the city climatic expectation as demonstrated in [285].

7.2.2 Preparation phase

After organizing the project functional structure in the pre-planning phase, and identifying the climate change hazards and impacts, the preparation phase can start. The aim of the preparation phase is guiding the iQRe user into setting up the necessary framework for assessing, designing, implementing, and monitoring the climate change resiliency of the urban environment. The main objectives of this phase are:

- Identifying the key urban sectors at risk of climate impact
- Create the iQRe hazards and sectors matrix.
- Data collection
- Generating a qualitative risk assessment.

7.2.2.1 Identifying the key urban sectors at risk

The urban environment represents a complicated interconnected system that must be viewed holistically to get an accurate understanding of its performance, its weak and strong points. The urban environment performance is result of interaction of several natural and man-made domains which together represent a unified urban environment. As such, its important to identify the key urban sectors that are exposed to climate change hazards or the ones that can play a role in the climate change adaptation plans. The interaction between climate change and these urban sectors can reveal a wide range of synergies, challenges, and opportunities for adaptation with complex interlinkages that require high level of coordination between the urban services and sectors [287]. According to the IPCC, climate change will impact a wide range of interconnected city functions and systems, which are referred to as "Key Urban Sectors"[85]. In the German KWRA 2021 [33] and in study made by Carsten, et al. 2020 for the city and district of Bamberg these sectors are referred to as clusters[285].

Within the iQRe these key urban sectors or clusters are reorganized into eight “sectors”: Structures, Urban and spatial environment, Energy systems, human wellbeing and organization, Transport and mobility, green and blue infrastructures, Water and wastewater, and Communication systems (see table 12).

These chosen sectors are generally in alignment with the IPCC Key Urban Sectors, the German KWRA five cluster (Land, Water, Infrastructure, Economy and industry, and health) and Carsten, et al six cluster (Land, Water, Infrastructure, Economy and industry, health and culture, and spatial planning and emergency prevention).

The objective of this reorganization is twofold:

A. to address each sector holistically throughout its value chain at each urban scale and,

For instance, the 'Water and Wastewater' sector can be assessed from its origin at the individual buildings, through its role in broader neighbourhood infrastructure, to its endpoint in treatment facilities in district. This cross-scale approach thereby captures the entire value chain.

B. to identify the administrative responsibilities for each sector. By defining the common urban sectors, the allocation of adaptation tasks for each hazard and risk group can be better distributed.

For example, the urban sector of water and wastewater at the building level is typically handled by a mechanical engineer, known in Germany as Heizung, Lüftung und Sanitärtechnik (HLS). At the district level, the same topic is usually addressed by an independent Water & Sewer administration or department. This reorganization allows professionals at both scales to work together in an integrated manner to address the climate risk to this sector across multiple planning scales, with similar opportunities for other sectors.

Through this approach, the urban environment is treated as an interlocked system. This can help optimize the whole and not only the individual scales to become more resilient to climate change and better equipped to address the complex interlinkages between different urban services and sectors and ultimately reducing the risk of maladaptation.

To ensure a better understanding of the interaction between the identified hazards and the sectors, an iQRe relations matrix is created. In the matrix the key urban sectors are organized along the x axes and the climate hazards are organized in the Y axis as illustrated in the example in figure 72.

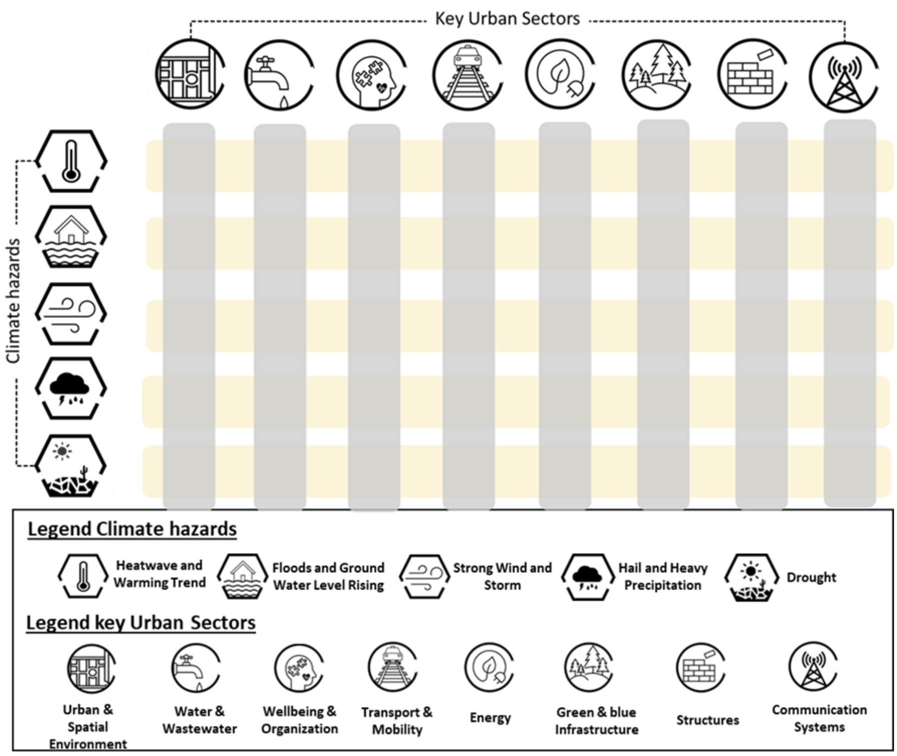


Figure 72: An example of the iQRe framework matrix showing the organization of the sectors in relation to climate impacts.

For the three-case study site (JUZ, JO and GAUstark), the project scope was to conduct a climate risk analysis at the building scale only. Therefore, the iQRe sectors were translated to their corresponding cost groups classification (as per the DIN 276) as follows in table 16:

Table 16: a table showing the representation of the key urban sector to cost groups classification as per the DIN 276.

Key sector	Cost group investigated
Structure	KG 320-380
Green and blue infrastructure	KG 570-580
Water and wastewater	KG 410
Energy	KG 420, 431, 433,434, 480
Communication	KG 450, 480
Urban and spatial planning	KG 510-540
Transport and mobility	-
Human wellbeing and organization	-(partially in KG 450, 690)

7.2.2.2 Data collection and stakeholder engagement.

As the climate hazards and key urban sectors to be investigated are defined, the aim of this step it to collect enough data about the study objects to formulate a qualitative understanding about the vulnerabilities of the different key sectors as well as to gain insights about the requirements, experience, and expectations of the stakeholders. In the Bamberg case study sites, this step was conducted in three stages:

I. Site visit with the representative of the youth centre operator and owner.

On June 14th, 2022, a site visit was conducted for all three youth centres. The research team, along with the managers of each youth centre and a representative from the city of Bamberg's property management, participated in the visit. During the site visit, pre-designed templates based on the iQRe matrix of key urban sectors were utilized to collect the necessary information. As illustrated in figure 73, these templates break down the buildings into specific sectors based on their DIN 276 classification. The purpose of these templates is to guide the data collection process during the site visit, ensuring a structured and efficient approach. They help focus on capturing the most relevant information required for conducting the iQRe risk assessment at a later stage. The documentation of the site visits is provided in annex's: 10.12, and 10.13.2, 10.13.4,and 10.13.6.

Throughout the visit, the research team, along with the youth centre managers and the property management representative, explored all rooms and outdoor areas of the buildings. The managers and property management personnel shared their experiences using or managing the buildings and highlighted any vulnerabilities related to climatic events.

Gebäude:		Kommentare, Beobachtungen			Kommentare, Beobachtungen
Allge-meine Infos	Alter Gebäude(technik)		Bauwerk Bau-konstruktion KG 300	Sonnenschutz (KG 338)	
	Altlasten (z.B. Radon, Offenliegende Mineralwolle, Asbest) --> Gebäudescreening, Schadstoffanalyse			Innenwände (KG 340)	
	Raumluftqualität (z.B. Feuchteproblem, Ecken, Anschlüsse)			Decken (KG 350)	
	Zustand Kellerräume (nutzbar? feucht?)			Dächer (KG 360)	
	Erfahrungen mit Wettereinflüssen (z.B. Hochwasser)			Grundkonstruktion (KG 380)	
Bauwerk Bau-konstruktion KG 300	Gründung (KG 320)		Bauwerk Techni-sche Anlagen KG 400	Wasser (Abwasser-, Wasseranlagen KG 410)	
	Außenwände (KG 330)			Wärmeversorgungs-anlagen (KG 420)	
	Außentüren und -fenster (KG 334) --> Verglasung			Lüftungsanlagen (KG 431)	

		Kommentare, Beobachtungen
Bauwerk Techni-sche Anlagen KG 400	Klima- und Kälteanlagen (KG 433/435)	
	Starkstromanlagen (KG 440)	
	Gebäudeautomation (KG 480)	
	Zerlegbarkeit/ Abmontierbarkeit der Gebäudetechnik Gebäudetechnik an verschiedenen Stellen: Dach, Keller, Räume, Revisionsschächte/ -klappen	
Außen-anlagen KG 500	Geländeflächen (KG 510)	
	Befestigte Flächen (KG 520)	
	Baukonstruktionen in Außenanlagen (KG 530)	
	Technische Anlagen in Außenanlagen (KG 540)	

		Kommentare, Beobachtungen
Gesund-heit und Wohl-befinden	Fernmelde- und Informationstechnische Anlagen (KG 450)	
	Betriebliche/ Organisatorische Abläufe	
Urbane Umge-bung		
Transport		
Notizen		

Figure 73: A copy of the templates used to gather information about the case study buildings showing the utilization of the iQRe method of breaking down the buildings into the key urban sectors as per the DIN 276 classification.

II. <u>Interactive workshops with the end users of the three youth centres.</u>

The aim of the interactive workshop is to gain insights about the requirements, experience, and expectations of the und users in relation to climate change hazards and rise the end user's awareness about the topic of climate change resiliency. Therefore, an interactive workshop was held at the JUZ and at the JO. No workshop was held at the GAUstark youth centre due to lack of participation. In total 16 person participated in the workshops.

Multiple channels were used to advertise workshops in advance. Including hanging posters in the youth centres (see figure 76), posting on social media channels and via personal invitations through the administrative staff. The content of the workshops was adjusted according to the age of the audience and was divided into three parts:

Firstly, the participants received an introduction to the topic of climate change and its affects on the city of Bamberg. The aim of the first part is to raise awareness about the future changes in the climate and gauge the participant awareness about the current climate conditions and the topic of climate change as whole. Therefore, a short presentation including simple interactive quiz questions were used (see figure 74).

Figure 74: Photos showing the poster used to advertise the project and part of the quiz used in the workshop.

The second part focused on understanding how participants use and experience their buildings and the impacts of various climate events on their use of different rooms and spaces. Building floor plans were presented, and participants marked areas where they had experienced or noticed impacts of climate events such as heatwaves or heavy precipitation, As depicted in figure 75.

Figure 75: images showing the interactive workshop and use of the floor plans to understand how the users interact with their building during climatic events.

Lastly, an open and interactive exchange took place to determine participants' requirements for building adaptation to climate change. The Participants generated ideas for interventions they desired to address the effects of climate change, such as green walls or solar shading. The results were recorded on the floor plans and are to be used in development of adaptation measures in the action plan phase.

III. <u>Use of Survey Questioners.</u>

The Survey questioners illustrated in figure 76 were used to gain insights about three main topics:

A. How the end users experience the impact of climatic events on their building (heatwaves and heavy precipitation). Three questions were designed to inquire about the rooms in the building that are perceived as cool or hot, as well as the end users' observations during heavy precipitation events.

B. To gauge the users' knowledge about behaviour rules during emergency events, two questions were included: The first question asked about how to behave in case of a fire, and the second question focused on how to behave during extreme weather events. The question about fire was included as it is less abstract for end users, and it can be assumed that even young users are familiar with it. Based on their responses, conclusions can be drawn about how they would behave in case of an extreme weather emergency.

C. Lastly, there was an opportunity for the users to express their opinions about any topics not addressed in the questionnaire. This provided space for them to share what is important to them and if they have any additional comments or suggestions.

The results of the end user engagement activities are summarized in annex 10.14.

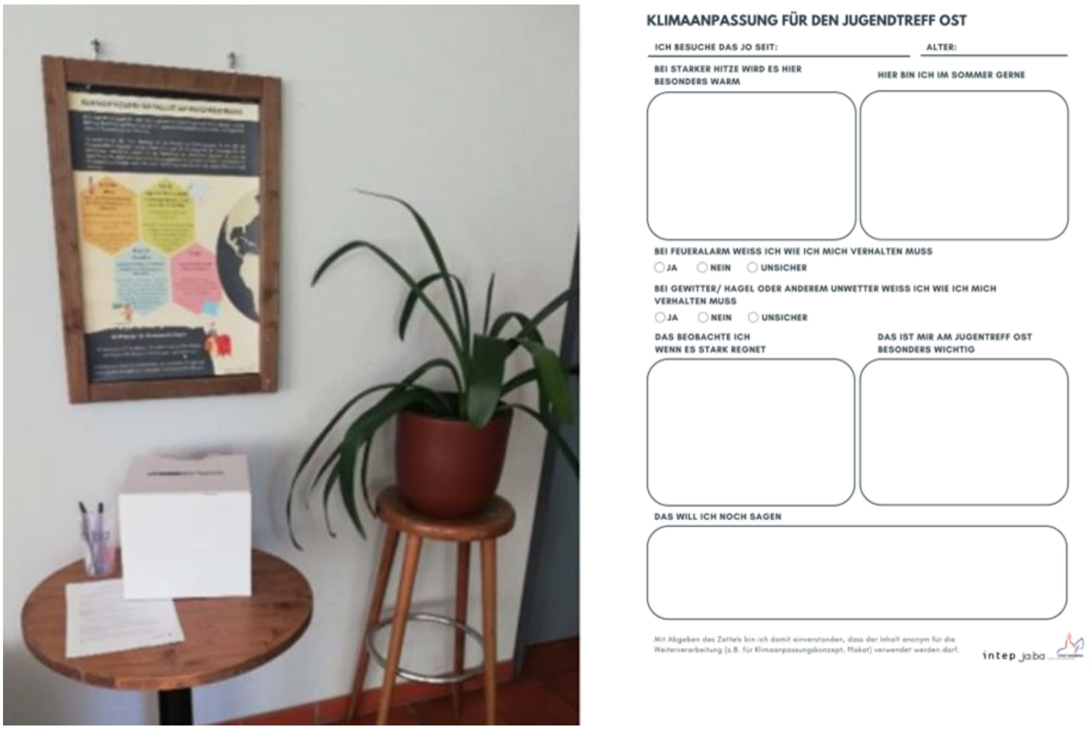


Figure 76: Images showing the distribution of survey questioners and the survey questioner template used in JO site.

7.2.2.3 Generating a risk assessment based on qualitative assessment of vulnerabilities and end user feedback.

The outcomes of the data collection process provided valuable information that helped identifying and pinpointing the vulnerabilities of the three case study buildings to the investigated climatic hazards. Based on the documented site observation, data gathering, and the feedback collected, the iQRe relation matrix is updated to accommodate for the actual vulnerabilities, climatic hazards and the risks groups exposed to the combination of vulnerabilities and hazards as displayed in figure 77.

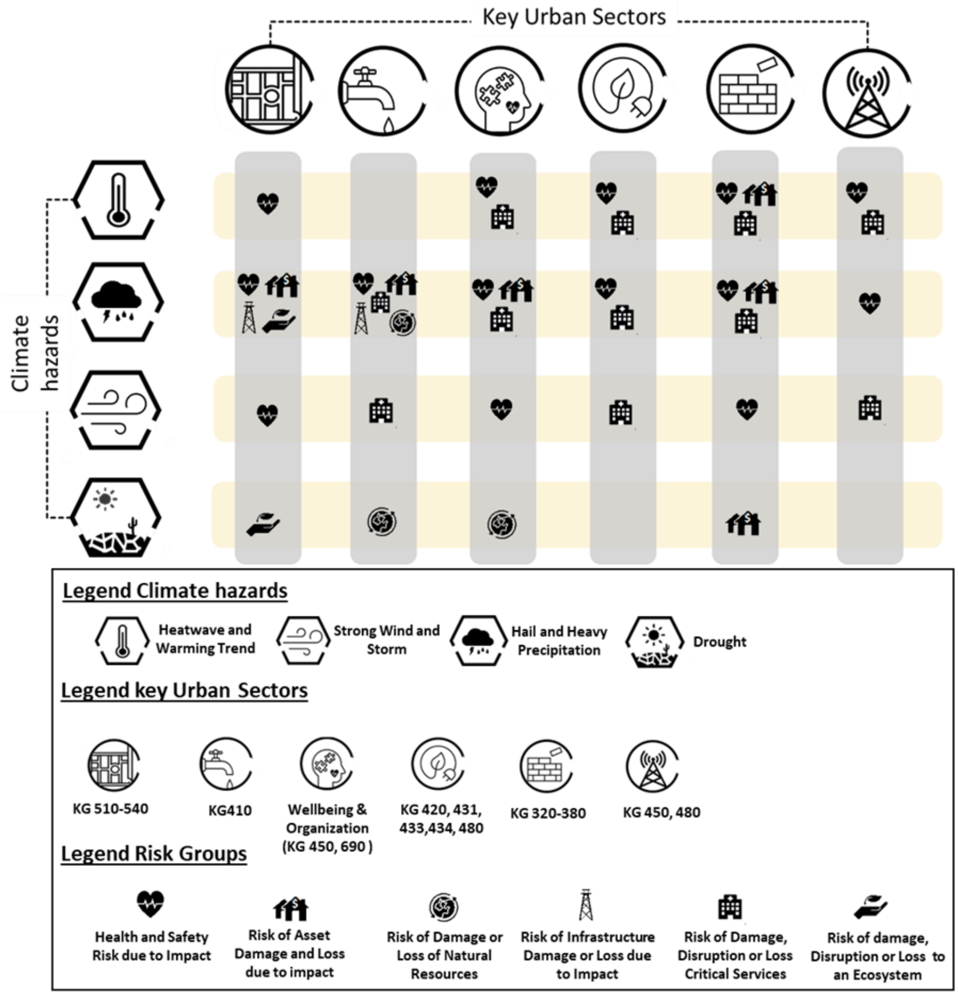


Figure 77: The updated iQRe matrix showing the hazards, sectors and risk groups that are to be investigated in the three-case study site based on the qualitative vulnerabilities and risk assessment.

The risks groups explain the expected impact of the hazard at each urban scale and sector. As per the IPCC definition, Climate change hazards may cause: loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision[3], ecosystems, and environmental resources[288].

Based on this definition, the following six categories of risk groups can be defined:

- Health and safety risk for inhabitants due to a hazard
- Risk of asset damage and loss due to a hazard
- Risk of damage and loss of natural resources due to hazard
- Risk of infrastructure damage or loss due to hazard
- Risk of damage, disruption, or loss critical services due to hazard
- Risk of damage and loss to an ecosystem due to hazard

[3] In the context of the IPCC, the risk of loss of service provision refers to the potential for climate change to disrupt or impair critical urban services that are necessary for maintaining public health, safety, and well-being such as hospitals, schools, energy supply, transportation, law enforcement and emergency services, and communication networks. The iQRe system refers to these elements as critical services.

This categorization of the risks groups helps gauge the type of climate adaptation needed, allow to prioritize the adaptation action, and maintain a balance between the complexity of the system and its clarity. The results of the qualitative risk assessment are provided in annex 10.12 and 10.13

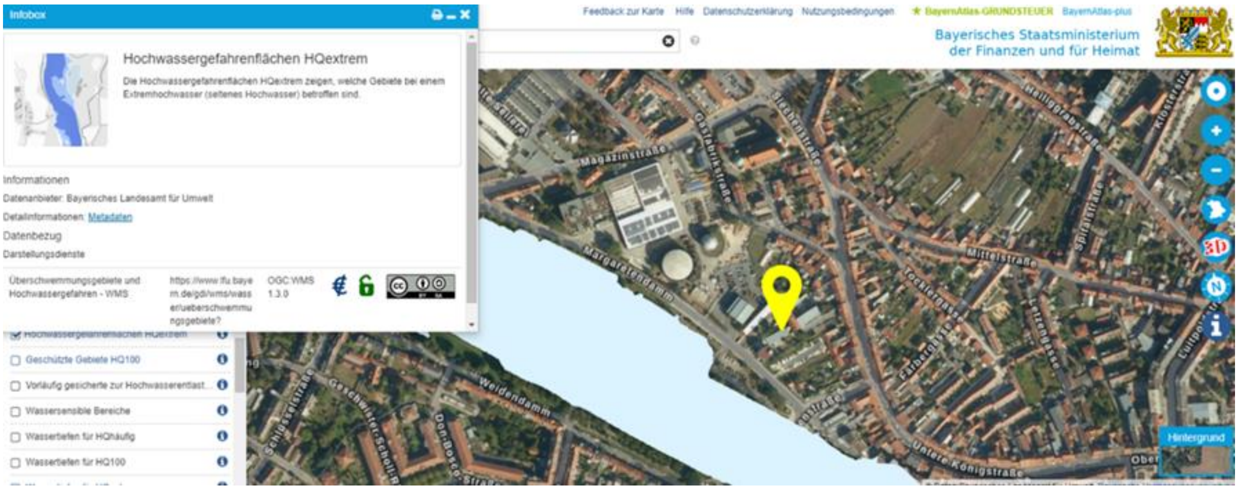


Figure 78: A screen shot from [1] with the yellow arrow showing the location of the JUZ centre being just outside the ARI 100 flood zone

It is to note that non of the sectors is considered at risk of floods due to the fact that all three site are located outside the flood risk zones according to the Bavarian ministry of finance and interior [1].

7.2.2.4 Iterative process

- <u>Data collection:</u>

  A list of information about the data sources for hazards, risk groups, vulnerability and exposure values should be provided.

- <u>Descriptive analytics:</u>

  The relevant information used to generate the iQRe matrix should be presented and shared in a transparent method. Moreover, the collected data about the climate parameters, hazards, Key risk sectors should be shared to all the stakeholders in clear, neutral, and understandable manner.

- <u>Validation:</u>

  Ensure that an agreement is reached between the stakeholders on the identified hazards, risk groups, vulnerability, and exposure and the iQRe relations matrix.

7.2.3 Risk assessment phase

Based on the iQRe risk matrix generated in 7.2.2.3, The goal of the phase is to enable the project team to translate the qualitative findings of the previous steps into quantifiable entities and to compute the climate change related risks and the resilience level. Therefore, the user is to assign a numerical value to each of the 3 components needed to assess the risk: hazard (H), exposure (E) and vulnerability (V). This is done with the help of the iQRe key performance indicator and assessment tools.

Moreover, during assessing climate change related risks and the resilience level, it is important to fulfil the following objectives:

- Develop the impact chain using the GIZ method and the SB rating system.
- Assign a numerical evaluation of the hazard likelihood in each sector as per the IPCC likelihood scale and RCP pathway scenario.
- Calculating the vulnerability scores per key sector via the iQRe KPIs and excel tool.
- Assign an appropriate exposure magnitude for each risk group in the iQRe risk calculation tool.
- Calculating the risk scores based on the aggregation of the vulnerability scores using the iQRe calculation tool.
- Aggregation of risk scores for the urban scale.

7.2.3.1 Development of the impact chains, calculating the risk via the iQRe rating system and supporting tool.

The first step in conducting the risk assessment is done via organizing climate hazards and risk groups into hierarchical and numerical impact chains. This simplifies the process of selecting the appropriate indicators, tracking cause-and-effect relationships and facilitate communication of the results.

The impact chains help prioritize areas of action in either the most vulnerable urban sector or in response to the most imminent climate impact.

To this end, the iQRe framework reorganizes the impact chains developed by GIZ[250] and merges them with the hierarchical levels (issue, category, criterion, and indicator) of the "SB method," as shown in Figure 79.

This converts the qualitative impact chain and risk matrix developed earlier into a rating system with numerical entities, where each element and in the matrix of climate risk (hazard, exposure, vulnerability) is assigned a value.

In the iQRe rating system the terms **hazards and impacts** are used to describe the effects of climate change and on geophysical systems, such as floods, droughts, increasing temperature, [289] and its is the tangible impacts of climate such as drought, and heat waves [145].

The element which contributes the generation of the climate related hazards, namely the **observed climate parameters** [250] (denoted with number 1in the figure 79) and the **natural or driving anthropogenic forces** [250] (denoted with number 2 in figure 79) are situated at the top of the chain. Although these elements are beyond the boundaries of the iQRe rating system, they provide, however, valuable insights about the likelihood of a climatic hazard occurrence (denoted with Nr.10 in figure 79).

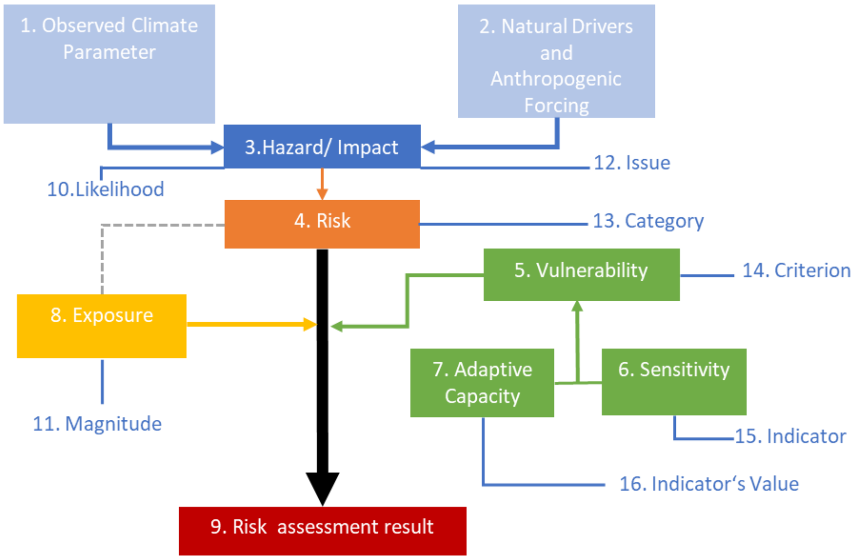


Figure 79: Illustration of the iQRe impact chain used in the rating system that merges the IPPC AR5 risk assessment concept with SB rating method flowing the GIZ impact chain approach.

The investigation done in the pre-planning phase will help pinpoint the predicted development of a climatic hazard (Nr.3). The defined hazard is translated into an "Issue". **Issues,** (Nr.12) are at top of the hierarchy of the rating system and contain within them several categories. At the "Issue" level the climate change hazards/impacts are classified based on alphabetical order. For example, A. Flood hazard, B. heavy precipitation, C, wind hazard, D. Drought, E. heatwave and warming trend, etc.

To account for the probability of a hazard occurrence at the time of the assessment or it is possible increase in the future (following for example the RCP 4.5 path), a hazard likelihood factor is assigned to each issue. The likelihood factor utilized in the iQRe system is based on the IPCC's 5-point likelihood scale [290] (detailed in the table 17). The findings of the research done in preparation phase contribute to gaging the correct probability of occurrence for each defined climate hazard.

Table 17: The IPCC based 5-point likelihood scale used in the iQRe rating system.

Likelihood of climate risk increase	Probability	Value
Unlikely	1–33%	1
About as likely as not	33–66%	2
Likely	66–90%	3
Very likely	90–99%	4
Virtually certain	99–100%	5

The value of the likelihood of climate risk probability is translated into a percentage weighting value to the corresponding "issue" in the iQRe risk calculation tool. The weighting will factor allow prioritizing the importance of each hazard (issue) as illustrated in figure 80.

likelihood of climate risk increase		Probability
Unlikely	1	0–33%
About as likely as not	2	33–66%
Likely	3	66–90%
Very likely	4	90–99%
Virtually certain	5	99–100%

STEP 1*	Assign the weight factor to Issues
STEP 2*	Assign the weight factors exposure magnitude and synergies
STEP 3**	For each criterion, set its weight in percentage (column I, yellow cell). You can take the values indicated in "Suggested weight" or modify it.

*weight factor for Issues ist be set based on the IPCC likelihhod scale above
** Exposur magnitued and postive synergies factors are described below
*** The tool uses the weights set of Column I for agregating the scores

ISSUES WEIGHT — STEP 1

Code	Issue	Weighting factor (1 to 5 points)	Suggested Weight	Weight (from STEP3)
A	Flood hazard	3	18,75%	18,8%
B	Extreme precipitation	5	31,25%	31,3%
C	Wildfire hazard	1	6,25%	6,3%
D	Drought and water scarcity	2	12,50%	12,5%
E	Storm and wind hazard	3	18,75%	18,8%
F	Warming trend	2	12,50%	12,5%
		TOT	100,0%	100,0%

Check: all sums must be 100%

Figure 80: A screen shot of iRQe tool showing how the issues (hazards) are assigned a weighting factor that reflect the likelihood of the climate hazard occurrence.

Based on the definition of the relevant climate hazard, the next step is to identify what or whom is at risk form that impact/hazard. This risk groups are denoted with the number (4) and each risk group is represented by category.

Categories are contained in "issues" and represent one of the six risk groups defined by the iQRe in 7.2.2.3, such as health and safety risk, risk to the ecosystem, risk to assets, etc., Each category is assigned a first-degree numerical order in addition to the alphabetical order of its issue. For example, for the issue/hazard "E. heatwave and warming trend" the following categories can be developed: E1 Inhabitants health and safety risk due to a heatwave, E2 Risk of asset damage and loss due to a heatwave, E3 Risk of asset damage and loss due to a heatwave etc.,

The vulnerabilities are allocated at the **criterion level** and are contained within categories. Criterion represents a specific assessment entity that evaluates the vulnerability of the risk group to a possible impact.

The system's vulnerability or lack there of i.e., resilience, depends on two factors: the sensitivity (Nr.6 in figure 79) and adaptive capacity of the system (Nr.7 in figure 79).

To measure vulnerability, each criterion is associated with one or more indicators, where the indicator represents sensitivity (the system attributes that directly affect the consequences of a hazard), and the indicator's value represents the degree of adaptation capacity (how well is the system prepared to respond to the these hazards[250]).

For example, in case the iQRe system is used at the building scale, to assess the vulnerability of “structure sector” to the hazard heatwave. The following impact chain can be created: the issue would be “E. heat wave”, category “E.1 Inhabitants health and safety risk due to a heatwave” the following criteria can be developed.

E1.1 Reflectivity of the building envelope

E1.2. Solar energy transmittance of glass

E1.3 Thermal energy performance of the building envelope

The indicator used to measure the criterion E1.1 is albedo of the building envelope. Therefore, the albedo values with a range between 0 and 1 is an indicator representing the sensitivity and the specific value of the albedo, say “0.3”, represent the adaptation capacity.

In this example the lower the albedo level the higher the vulnerability of the structure to the heatwave (more solar energy will be absorbed). To harmonize the system, the indicator values are normalized and rescaled on a scale from -1 to +5, relative to a defined benchmark. Benchmarks are the point of reference against which the results of the indicators are to be compared. Benchmarks can be derived from laws/regulations, technical standards, statistics data, typical performance values, or simulation and modelling, etc. The normalized numerical scores are translated descriptively as shown in table 18. The practical application of obtaining normalized incdicator score in the iQRe tool is shown in figure 81

Table 18: The descriptive meaning of the normalized scores in the iQRe system

Normalized score	Descriptive Meaning
-1	**under** the minimum acceptable performance (Inadequate)
0	A **minimum** acceptable performance (sufficit)
1	A **minimum increase** of performance (Satisfactory)
2	A **substantial increase** of performance (Good)
3	A **best practice** (Very Good)
4	An improvement towards the best (Excellent)
5	an **excellent and ideal** performance (out standing)

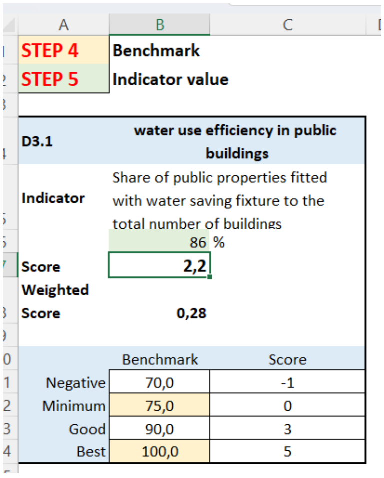


Figure 81: A screen shot from the iRQe tool showing how the indicator score is normalized in relation to a benchmark.

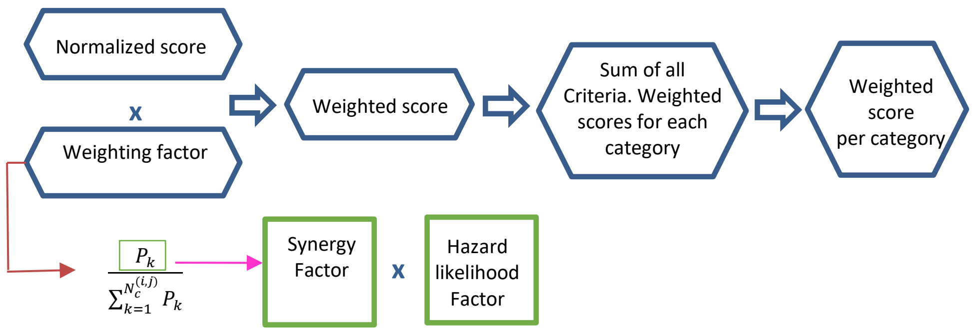
After normalization, a new set of data composed of the normalized scores for each criterion is available. The resulting normalized scores alone are not sufficient to accurately measure the impact of each criterion on the sector's vulnerability. This is because there are interconnections between climate adaptive measures, which can lead to conflicting trade-offs or positive synergies[19].

For instance, consider the example of green roofs in a building. Green roofs can have a positive impact on the building's resilience to heatwaves due to two reasons. Firstly, they improve the albedo (reflectivity) of the roof surfaces. Secondly, they, in most cases, enhance the thermal insulation of the building. As a result, a green roof has a greater synergistic effect on the structure's resilience to heatwaves compared to just considering the albedo value of the roof based on its colour or other paint material. To account for this positive synergistic effect, the iQRe supplement the normalized scores of the indicators with synergy multiplying factors that range from 1 = low to 3 = major as illustrated in table 19.

Table 19: Synergy multiplying factors used to assess the vulnerability of criterion in the iQRe framework.

Synergistic effect	Multiplying Factor
Low	1
Moderate	2
Major	3

The determination of synergy relation factors can be done based on expert judgment and literature research. The synergy factors are added the normalized score of the criterion as a relative weight as shown in (7).



(7)

- P_k : P is the weighting factor assigned to the criterion k , the k-th criterion in the j-th category of the i-th issue, k = 1,........ , $Nc(i,j)$
- $N_c^{(i,j)}$: is the number of criteria included in the category Ci,j category, j is the j-th category, and i is the i-th issue

The above-mentioned steps illustrated the logical and mathematical foundation used in the iQRe rating system to compute the climate hazard likelihood and the vulnerability (V) of an urban sector and scale. Nevertheless, to compute the risk as per as per the IPCC AR5 equation (1)

$$R = f\,(H, E, V) \quad (1)$$

a quantity reflecting the exposure (E) to the hazard (V) is required. The exposure (Nr.8 in figure 79), refers to the valuable elements of the system located in an area at risk of impact or hazard[145].

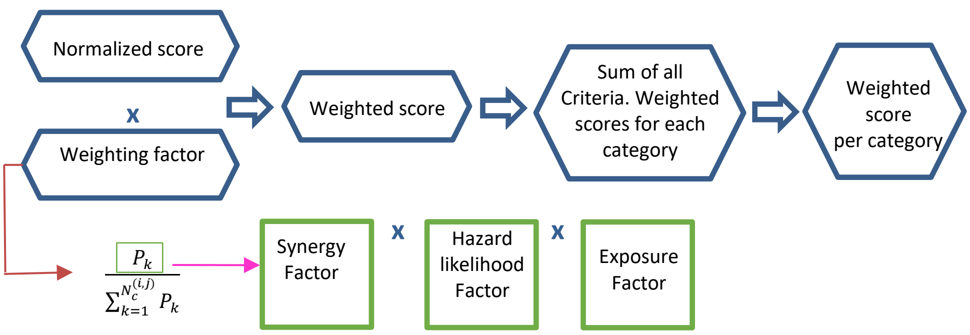
For example, for the key sector "structures" if the building is densely occupied by youth, elderly or other vulnerable groups, then there is major "human health risk" exposure to the "hazard" of heatwaves" even if the building structure elements show a general low vulnerability to heatwaves.

Due to the fluid and dynamic nature of the exposed elements, such as number of inhabitants of a certain building or number of subscribers to a certain energy provider, the iQRe uses exposure magnitude factors instead of hard exposure numbers. The extent of exposure factor is represented on 5 points scale that ranges from minor = 1, to reflect very low exposure to major = 5, for a very high exposure as illustrated in the table 53.

Table 20: Exposure factors used in the iQRe rating system.

Exposure magnitude	In %	Factor Value
Minor	< 10 %	1
low	10–20%	2
Moderate	20–30%	3
critical	30–50%	4
Major	> 50 %	5

The exposure magnitude is factored in the weight of the normalized score of the criterion in similar fashion to the synergy and climate hazard likelihood factors. Hence, the equation number (7) can now be adjusted as follows:



(8)

With having this last piece of puzzle in place it is possible now to get a risk assessment score at the criterion level. Figure 82 show how this exposure and synergy factor are inputted in the iQRe tool.

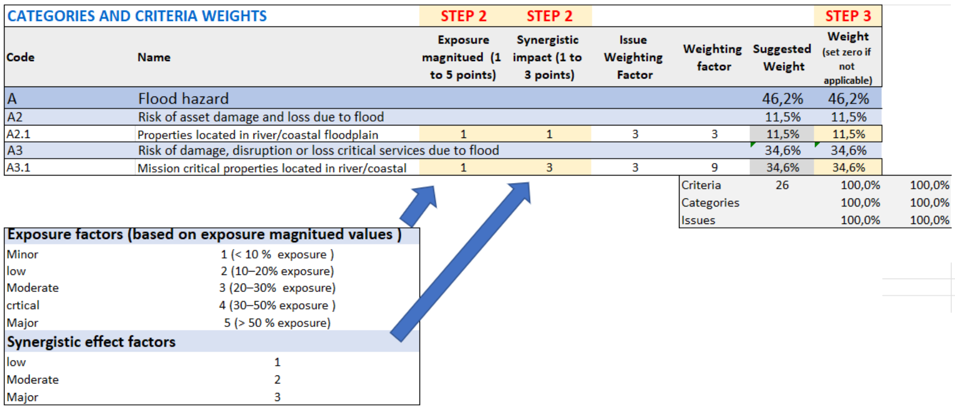


Figure 82: a screen shot of the iQRe tool showing how the synergy and exposure factors are assigned to each indicator and translate into changing the relative weighting of the indicator.

To facilitate the use of the iQRe rating system, a preliminary selection of Key Performance Indicators (KPIs) cards for each scale and key sector was assembled.

As shown in Table 21 Each KPI cards is organized based on it the issue, category, and criteria it addresses. Furthermore, the KPI description cards provide information about the source / developer of the KPI, the intent of the KPI, the cost group or sector it relates to , the indicator, the benchmark of the best performance and reference used to estimate the exposure value. Annex 10.15 provide an example list of KPIs assembled by the author for the building, neighbourhood and district scales. The intent of the list is just to provide an example of the possible KPI at each scale and don't claim to be completed or holistic as this is a task that stretch far beyond the scope of this research.

Table 21: An example of an iQRe KPI for the ***building scale*** *and* ***structure sector****, note that KPI provide a suggested benchmark for achieving an ideal performance, the end user is expected to adjust the other benchmarks according to their situations.*

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Groundwater resilient fundament and basement
Intent		Protect the building fundament and basement against Groundwater penetration
Building Costs- DIN 276		KG320
Indicator		The application of the water-resistant concrete as per the DAfStb guidelines (DAfStb-Richtlinie Wasserundurchlässige Bauwerke aus Beton) or bitumen sealed layers (black tray) as per DIN 18533.
Benchmark		The holistic application of the groundwater protection above the groundwater water threshold ((Recommended to be at least 30 Cm above a 500-year ARI (average recurrence interval) ground water level)
Synergistic Factor		Low
Criteria/ indicator source		Hochwasserschutzfibel Objektschutz und bauliche Vorsorge
Weblink		https://www.fib-bund.de/Inhalt/Themen/Hochwasser/
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.1	Hail and extreme precipitation safe windows and shutters
Intent		To protect the buildings user from Hail and extreme precipitation risks as well as increasing the user's safety
Building Costs- DIN 276		KG 330
Indicator		The percentage area of envelope and roof openings and windows that are protected against hail damage (use of shutters or anti-hail grille)
Benchmark		For an ideal performance, 100% of the building openings are protected against hail damage
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser ". Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Number of building user

As shown in the example of iQRe tool provided in figure 83, the selected KPIs and the benchmarks are inputted manually. The same is true for the weighting factors for the exposure and synergistic impact for each KPI. The tool automatically adjusts the benchmarks and calculate the normalized scores as depicted in the example provided in figure 83.

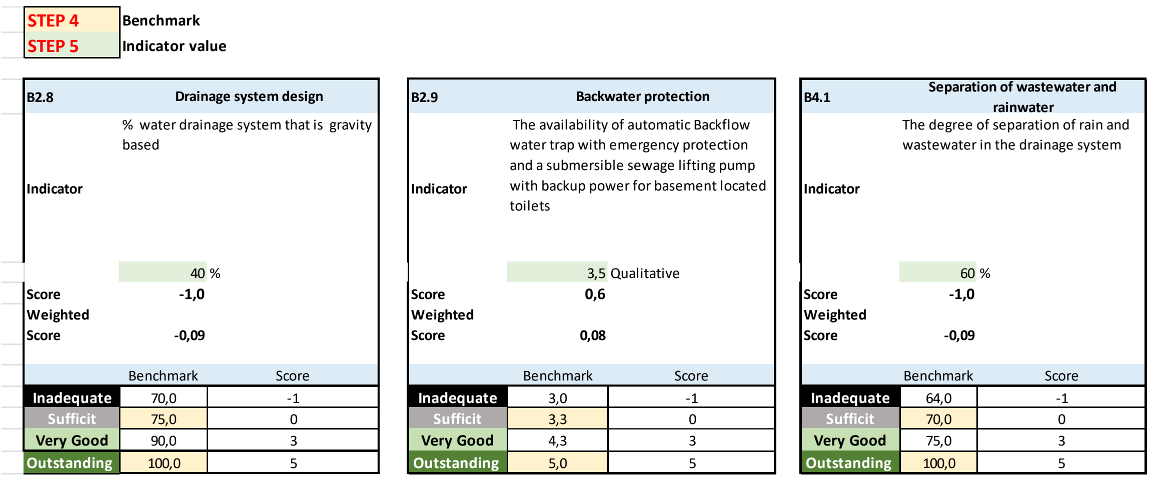


Figure 83: A screenshot from the iQRe excel based tool showing how the indicators values and benchmarks are inputted (green and yellow cells) and how the normalized and weighted scores are automatically calculated.

The resulting normalized and weighted criterion scores are aggregated at the categories level for each urban sector and scale as per the equation (9) and illustration in figure 84:

$$S_{i,j} = \sum_{k=1}^{N_c^{(i)}} \omega_{i,j,k}\, S_{i,j,k} \qquad (9)$$

- $\omega\ (i, j, k)$: the weighting factor associated with the criterion ci,j,k in the category Ci,j
- $S_{i,j}$: the normalized score resulting from aggregation of criteria included in the category Ci,j.

The values resulting from (9) are further aggregated to produce a single score for each issue:

$$S_{i,} = \sum_{J=1}^{N_c^{(i)}} \omega_{i,j}\, S_{i,j} \ (10)$$

- wi,j: the weighting factors for each category included in the issue Ai
- Sij: the performance score associated with the issue Ai

Code	Name	Score
A	Flood hazard	**2,9**
A2	Risk of asset damage and loss due to flood	2,5
A2.1	Properties located in river/coastal floodplain	2,5
A3	Risk of damage, disruption or loss critical services due to flood	3,0
A3.1	Mission critical properties located in river/coastal floodplain	3,0
B	Extreme precipitation	**2,0**
B2	Risk of asset damage and loss due to Hail, Snow	2,0
B2.1	properties located in Avalanche risk zone	1,5
B2.2	properties located in Landslide risk zone	2,5
C	Wildfire hazard	**2,5**
C2	Risk of asset damage and loss due to wildfire	2,5
C2.1	Properties located in wildfire risk zone	2,5
C3	Risk of damage, disruption or loss critical services due to wildfire	2,5
C3.1	Mission critical properties located in wildfire risk zone	2,5
D	Drought and water scarcity	**3,0**
D3	Risk of damage, disruption or loss critical services due to drought	3,0
D3.1	water use efficiency in public buildings	3,0
E	**Storm and wind hazard**	0,0
E1	Inhabitants health and safety risk due to wind	0,0
0	0	0,0
F	**Warming trend**	**2,5**
F1	Inhabitants health and safety risk due to heatwave	2,5
F1.1	Properties at risk of overheating	2,5

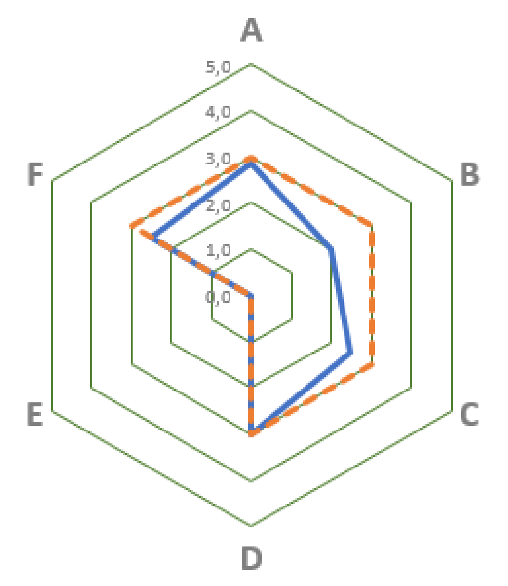
Figure 84: A screen shot from the iQRe district scale tool, showing the aggregation of the normalized resiliency scores at the indicator, category, and issue levels for each climate hazard.

Finally, the aggregated scores can be combined to produce an overall risk assessment score throughout the issues at the urban scale in question as per the following:

$$\sum_{v} = \sum_{J=5}^{N_c^{(i)}} \mathrm{W_i}\ \mathrm{S_i} \quad (10)$$

- $\sum_{v}$ is the weighted risk score for to all Hazards "issues"
- $\mathrm{W_i}$ represent the 'weighting factors for all issues' and express the relative influence of each issue on the final score, derived from the IPCC 5-point likelihood scale.

ISSUE		Score	Traget	Weight
A	Flood hazard	2,9	3,0	48%
B	Extreme precipitation	2,0	3,0	16%
C	Wildfire hazard	2,5	3,0	16%
D	Drought and water scarcity	3,0	3,0	8%
E	Storm and wind hazard	0,0	0,0	0%
F	Warming trend	2,5	3,0	12%
TOTAL Distrcit SCORE		2,6		



5	Out Standing
4	Excellent
3	Very Good
2	Good
1	Satisfactory
0	sufficit
-1	Inadequate

Figure 85: A screen shot of the iQRe tool showing the representation of the final risk assessment score for all issues in relation to the target score (doted line in orange)

7.2.3.2 The results of iQRe climate risk rating resilience of the JUZ building.

Based on the results of the qualitative risk assessment made in the preparation phase (refer to step 7.2.2.3, figure 78) specific iQRe Key Performance Indicators (KPIs) were chosen from the list provided in annex 10.15.1 . The selected KPIs were used to establish impact chains that can transform the qualitative risk assessment into a quantitative evaluation of the resilience of the JUZ building. The assessment of the four relevant hazards identified in the preparation phase (heavy rain, heatwave, drought, and wind) was made based on a hazard likelihood of occurrence according to 4.5 RCP scenario for the six selected sectors (Water and wastewater, Energy, Communication, Urban and spatial planning, and Human wellbeing and organization).

The assessment results showed that in the regard to the hazard of heatwaves and warming trend, the JUZ building scored an average of -0.3 points, i.e., inadequate, across its urban sectors. Sectors such as wellbeing and organization, energy, structure, and communication were identified as being particularly exposed and/or vulnerable to heatwaves. These results align with the feedback received during site visits and workshops.

Regarding the drought and storm/wind hazards, the JUZ building's sectors obtained an average score of 1.3 points (satisfactory) and 3.5 points (very good), respectively. This satisfactory performance was attributed to factors such as low exposure, low occurrence probability, and the implementation of adaptive measures like water-saving fixtures and sensor-operated water faucets. However, when it comes to extreme precipitation hazards, the building's performance is barely sufficient with an average risk score of 0.5. Sectors such as structure, energy, wellbeing and organization, and water and wastewater exhibited inadequate performance, with scores of -0.7, -0.1, -1.0, and -0.5, respectively. Figures 86 and 87 provide an example of the scoring card label of the JUZ building. For a comprehensive overview of the climate change risk assessment results for each sector within the JUZ building, including the selected Key Performance Indicators (KPIs), exposure values, and synergistic factors, please refer to annex 10.10.2 and annex 10.16.3.

Code	Name	Score
A	Flood hazard	**#DIV/0!**
A3	Risk of asset damage and loss due to flood	#DIV/0!
A3.2	Energy systems located above flood threshold	-1,0
B	Extreme precipitation	**-0,1**
B1	Risk of asset damage and loss due to hail and extreme precipitation	-0,3
B1.5	Waterproof sockets and switches	-1,0
B5	Risk of damage, disruption or loss critical services due to hail and extreme precip	-0,2
B5.9	Support of(micro)grid operation modes	-1,0
B5.10	Detecting faults of technical building systems	-1,0
C	Warming trend& Heatwaves	**-0,5**
C1	Health and safety risk for inhabitants due to heatwave	-1,0
C1.1	Cooling and ventilation system Capacity	-0,5
C5	Risk of damage, disruption or loss critical services due to heatwave	0,0
C5.2	Energy system that are protect from overheating	0
C5.3	Power backup systems	0
E	Storm and wind hazard	**5,0**
E5	Risk of damage, disruption or loss critical services due to Storm and wind hazard	5,0
E5.2	Energy supply lines protected from wind	0,04

Figure 86: Screen shot showing the energy sector scoring card of the of JUZ building, note the error sign next to the flood hazard. The flood hazard exists on the neighbourhood scale, but not on the building scale (exposure = 0).

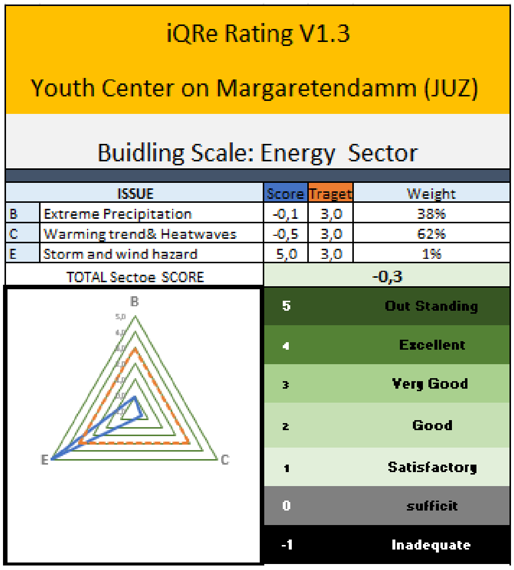


Figure 87: Results of the resilience rating of the energy sector of the JUZ building, the impact of Drought is not included as it does not create a hazard to the sector.

7.2.3.3 The results of iQRe climate risk and resilience rating of the GAUstark building.

The climate change risk assessment of the GAUstark building was done with the same KPIs and RPC scenario as for the JUZ building. In general, The GAUstark building demonstrated a slightly improved resilience performance over the JUZ building. This improvement can primarily be attributed to lower exposure levels in certain risk groups.

In terms of extreme precipitation hazards, the GAUstark building obtained an average score of 0.9 points (sufficient) across its sectors. However, the wellbeing and organization and structure sectors exhibited higher exposure and/or vulnerability to this hazard.

Regarding heatwaves and warming trends, the GAUstark building achieved an average score of 0.0 points (sufficient) across its sectors, indicating a relatively mediocre performance. Once again, the wellbeing and organization and structure sectors scored lower in this category.

The assessment of drought hazard resulted in a sufficient rating, with a total average score of 0.8 points. However, the water and wastewater sector, as well as the wellbeing and organization sector, scored below zero points when due to lack of training, awareness and water saving fixtures.

In terms of wind hazards, the GAUstark building demonstrated an overall low risk exposure, as evidenced by an average score of 2.5 points across its sectors.

Figures 88 and 89 provide an example of the scoring card label of structure sector of the GAUstrak building. For detailed overview of the climate change risk assessment results for each sector within the GAUstark building, including the selected Key Performance Indicators (KPIs), exposure values, and synergistic factors, please refer to annex 10.10.4 and 10.16.1

Code	Name	Score
A	Flood hazard	#DIV/0!
A1	Health and safety risk for inhabitants due to flood	#DIV/0!
A1.1	Occupancy above flood threshold	5,0
B	Extreme precipitation	-0,6
B1	Health and safety risk for inhabitants due to hail and extreme precipitation	-1,0
B1.1	Hail and extreme precipitation safe windows and shutters	-1,0
B1.2	Barrier free building	-1,0
B2	Risk of asset damage and loss due to hail and extreme precipitation	0,3
B2.1	Envelope moisture and rain protection	-0,1
B2.2	Hail resilience of the building envelope (KG 330-360)	0,1
B2.6	Water Resistant Materials and finshes	0,0
B5	Risk of damage, disruption or loss critical services due to hail and extreme precip	-0,7
B5.2	Leakage and rain proof technical rooms	0
B5.3	Protected and diverse technical pathways	0
B5.4	Ease of access, maintenance of technical systems and rooms	0
C	Warming trend& Heatwaves	0,4
C1	Health and safety risk for inhabitants due to heatwave	0,4
C1.1	Total solar energy transmittance of glazed windows and sunshades	-0,2
C1.2	Specific transmission heat loss of the building envelope	-0,1
C1.3	Reflectivity of the building envelope	0,2
C1.4	Efficiency of natural ventilation	0,3
C5	Risk of damage, disruption or loss critical services due to wildfire	-1,0
C5.1	Natural ventlation in telecommunications / control rooms	0,0
D	Drought and water scarcity	5,0
D2	Risk of asset damage and loss due to drought	5,0
D2.1	lateral loads restraint foundation and moisture intrusion protection	0,1
E	Storm and wind hazard	5,0
E1	Inhabitants health and safety risk due to Storm and wind hazard	5,0
E1.1	Strom anchored external fixtures	0,1

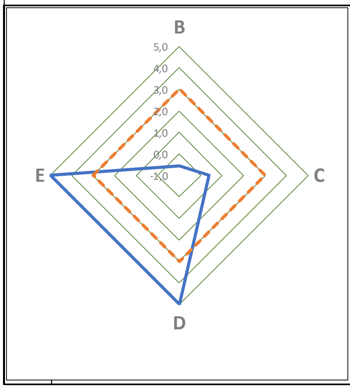
Figure 88: Screen shot showing the structure sector scoring card of the of GAUstark building, note the error sign next to the flood hazard. The flood hazard exists on the neighbourhood scale, but not on the building scale exposure (0).

iQRe Rating V1.3

GAUstark youth centre

Buidling Scale: Structure Sector

	ISSUE	Score	Traget	Weight
B	Extreme Precipitation	-0,6	3,0	46%
C	Warming trend&Heatwaves	0,4	3,0	52%
D	Drought and water scarcity	5,0	3,0	2%
E	Storm and wind hazard	5,0	3,0	1%
	TOTAL Sector SCORE	0,1		



5	Out Standing
4	Excellent
3	Very Good
2	Good
1	Satisfactory
0	sufficit
-1	Inadequate

Figure 89: Results of the iQRe resilience rating of the structure sector of the GAUstark building.

7.2.3.4 The results of iQRe climate risk and resilience rating of the Jo building.

The JO building stands out among the three studied buildings as the smallest and the only purpose- "built" modern youth centre. Furthermore, it complies with the 2016 requirements for energy-efficient buildings (3.0 generation of performance and rating systems). These two factors contribute to the relatively good climate change risk performance of the JO building compared to the GAUstark and JUZ buildings.

The JO building achieved a good score in terms of both the drought and wind hazards, with an average cross-sector score of 2.3 and 2.8 points, respectively. This performance is due to factors such as good thermal insulation, external sun protection measures, and effective natural cross ventilation.

However, when it comes to heatwaves and warming trends, the JO building only managed to achieve a score of 0.0 points, Despite the good thermal insulation, the external sun protection, and the good natural cross ventilation. This is attributed to the black colour of the envelope, the lack of external shading around the building perimeter and the high internal loads. The building experiences a high number of active young visitors (70 to 100) a day which engage in playing and cooking in limited 100 m^2 space during the summer months. Contributing to the challenges of heatwaves. These findings align with the feedback received from end users during the workshops.

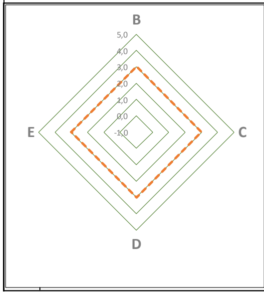
In terms of extreme precipitation hazards, the JO building obtained an average score of 1.5 points, representing a performance that falls between good and satisfactory. The wellbeing and organization sector shown in figure 90 and 91, as well as the urban and spatial planning sector, demonstrated inadequate performance with scores of -1.0 and -0.2, respectively.

For a comprehensive overview of the climate change risk assessment results for each sector within the JO building, including the selected Key Performance Indicators (KPIs), exposure values, and synergistic factors, please refer to annex 11.16.2 and 10.13.6

Code	Name	Score
A	Flood hazard	**#DIV/0!**
A1	Health and safety risk for inhabitants due to flood	#DIV/0!
A1.1	Availability of emergency response plan and evacuation routes for flood events	-1,0
B	Extreme precipitation	**-1,0**
B1	Health and safety risk for inhabitants due to hail and extreme precipitation	-1,0
B1.1	Availability of emergency response plan and evacuation routes for Hail, Snow and extreme precipitation events	-0,1
B1.2	Availability of emergency response training for users and behaviour during Hail,	-0,1
B1.3	Availability of alarm system during Hail, Snow and extreme precipitation events	-0,05
B2	Risk of asset damage and loss due to hail and extreme precipitation	-1,0
B2.1	maintenance of building structure against extreme precipitation threat	-0,1
B2.2	maintenance of building Technical systems against extreme precipitation threat	0,0
B5	Risk of damage, disruption or loss critical services due to hail and extreme precip	#DIV/0!
B5.5	Predictive maintenance for extreme precipitation threatened technical systems	0
C	Warming trend& Heatwaves	**-1,0**
C1	Health and safety risk for inhabitants due to heatwave	-1,0
C1.8	Wellbeing reporting	-0,1
C1.12	Maintenance of building technical systems against heatwave	-0,1
C1.10	Internal loads and internal heat gain	-0,2
C1.14	response training for users and behaviour rules during heatwaves events	-0,1
C5	Risk of damage, disruption or loss critical services due to heatwave	#DIV/0!
C5.1	Predictive maintenance for cooling and ventilation systems	0,0
D	Drought and water scarcity	**-1,0**
D3.1	Risk of damage and loss of natural resources due to drought	-1,0
D3.1	Water reporting	-0,02
D3.2	Water use awareness	-0,1
E	Storm and wind hazard	**-1,0**
E1	Inhabitants health and safety risk due to Storm and wind hazard	-1,0
E1.4	Availability of emergency response training for users and behaviour during storm eve	0,0

Figure 90: The scoring card of the wellbeing and organization sector of JO building, note the error signs (#DIV/0!) show that the result is not included in the risk assessment since the non existing exposure (exposure = 0).

iQRe Rating V1.3				
Youth Center East (JO)				
Buidling Scale: Wellbeing and Organization				
	ISSUE	Score	Traget	Weight
B	Extreme Precipitation	-1,0	3,0	39%
C	Warming trend&Heatwaves	-1,0	3,0	45%
D	Drought and water scarcity	-1,0	3,0	12%
E	Storm and wind hazard	-1,0	3,0	3%
	TOTAL Sector SCORE	-1,0		



5	Out Standing
4	Excellent
3	Very Good
2	Good
1	Satisfactory
0	sufficit
-1	Inadequate

Figure 91: The iQRe climate change risk rating for the wellbeing and organization sector of the JO building

7.2.3.5 Iterative process

- <u>Data collection:</u>

The work done in the previous 2 phases, empowered the project team with a sufficient level of information to set the most appropriate hazard factor for each of the expected hazards. The calculation of the indicators (vulnerability) requires the team to collect many information which if not properly structured can be time intensive and require large investments. The KPI description cards found in the annex 10.15 contain a brief list of required information for the calculation of each indicator and help guide the data collection action. Nevertheless, these are provided for guidance. As the quality of the assessment results are very much depended on the quality of the data collected. Therefore, a quality assurance plan must be considered.

- <u>Descriptive analytics:</u>

The iQRe supporting excel based rating tool allow to present the results in a clear, transparent, and trackable manner. The project team is encouraged to use the assessment results diagrams for the communication of the results with the wider public.

- <u>Validation:</u>

The iQRe multi sectoral nature of the rating system and the inherently connected sectors, hazards and scales serve as several layers of a validation systems. Moreover, the qualitative risk assessment and the findings of the end user workshops allow for further validating the results. If needed the team can devise a verification template that list the required evidence for each KPI. Here the images provided in following annex's 10.13.2 , 10.13.4 and 10.13.6 server that goal and help explain the results of each KPI

7.2.4 Action planning phase

The main objective of this phase is to develop an action plan that address the vulnerabilities and climate risks of the project and enhance its resilience. The climate change risk assessment results obtained from iQRe tool in the risk assessment phase, can guide the project team in this process. The rating assessment results provides a numerical, and objective overview of about the building's vulnerability and the risk groups exposer to the investigated climate change hazards. It also pinpoints the sectors that need attention, identifies the responsible actors across the value chain and the degree of exposure.

Therefore, this phase ideally starts with setting a desired resiliency score target for all investigated sectors. The planning team is then tasked with devising adaption interventions as part of an action plans that meet a set resiliency and the other financial, environmental, temporal, mitigation, etc targets. This process constitutes engaging in a multi-level iterative process of constructing and eliminating alternative scenarios. This process continues until a stable set of solutions is generated that meet all or most of the action plan's targets.

The resulting adaptation scenarios are then evaluated in a manner like a cost-benefit analysis. The cost side includes the costs and timeframes for implementation, while the benefit side is evaluated via the performance of Key Performance Indicators (KPIs) and the results of the risk assessment. In the following, the steps needed to generate a solid adaptation action plan are briefly discussed.

7.2.4.1 Setting the targets

The first step in the creation of the action plan is to set a number of S.M.A.R.T targets [291]. The iQRe risk assessment results and local goals would assist the project team in establishing strategic targets for their project. Moreover, it is of great importance to engage stakeholders in identifying and setting the targets. They might offer unique perspectives on priorities, feasibility, and potential impacts. For the case study sites it was agreed to investigate adaptation action that are **simple**, **cost effective,** and contribute **positively to the overarching mitigation targets**. The average cross-sectoral score was set for achieving ‘good' or 2.0 point on the iQRe scale.

7.2.4.2 Drafting the list of adaptation solutions

The aim of this step is to explore and select adaptation solutions that will allow to achieve the established targets of the action plan. With the help adaptation repositories as the ones provided in one of the platform listed annex 11 the team can start brainstorming possible adaptation solutions. Moreover, the team should maintain a close engagement with the stakeholders during the exploration and selection of the adaptation solutions as they could provide insight into local conditions, solutions, and preference. This will help ensure that the chosen solutions are inline with local knowledge, preference and building heritage . For example, as seen in the images in figure 92, the use of climbing vines as a solar shading tool is a very common site in the historical as well as modern streets of Bamberg. Indicating a local preference to this solution that is imbedded in the local building heritage. Annex 10.14 provide a brief description of the adaptation interventions highlighted by the JO and JUZ buildings users.

Figure 92: the user of climbing trees over the façade as adaptation solution is common site in Bamberg.

For the three case study sites, the project team assembled an initial list of adaptation solution. For each adaptation solution, the sector and risk addressed are named and is based on the finding summarized in figure 77. Moreover, a simple descriptive assessment for each solution in terms of its positive synergy effect, mitigation contribution, time, and cost needed for implementation. Table 22 provide an example of this list. The full list of suggested adaptation solutions collected by the team for the three projects is presented Annex 11.17.

Table 22: Example of adaptation solutions to extreme precipitation in the structure sector

Extreme Precipitation						
Nr.	Adaptation Solutions	Addressed Risk	Implementation			
			Synergy effect[4]	Mitigation effect[5]	Time[6]	Estimated Cost[7]
Structure sector						
1	Retrofitting the windows		Moderate	+	Long	€€€
2	Installing exterior shutters		High	+	Mid	€€€
3	Green roof		High	+	Long	€€€
4	Waterproof and moisture resistant interior finishes		Low	0	Mid	€€
5	Waterproof and moisture resistant exterior finishes		Low	0	Mid	€€
6	Water and moisture sealing of technical rooms		Low	0	Short	€
7	Air and moisture sealing of Building envelope		Moderate	+	Mid	€€

[4] The positive synergy effect indication is based on rough estimation that would vary from one location to the other.
[5] The assessment is made based on rough estimation and is used to provide a simple generalized assumption of the impact of solution on the GHG mitigation effort.
[6] The classification of the time needed for implementation (long, mid (midterm) and short) is used to provide a general estimation that can vary greatly from one site to the other and can vary greatly in range between several days to many months.
[7] The cost indication is based on general estimation and used to show a general range that can vary greatly in sum and is very much dependent on the specifics of each site.

7.2.4.3 Selection and prioritization of adaptation actions

As it's often the case, there are multiple combinations of adaptation solutions that could achieve the action plan targets. Therefore, it's essential to prioritize these actions in meaningful manner. This can be done using the iRQe assessment tool and KPIs with the help of the ranking criteria summarized in table 23:

Table 23: A suggestion for a Ranking criteria for the adaptation measures, adopted and expanded from [292]

Ranking Criteria	Descriptor
Maturity of technology	• Conventional • Well established, often used locally. • Well established, used elsewhere, adapted locally. • New, demonstrated, proven. • New, experimental
Reliability in terms of uncertainty in design	• Codified design procedure • Well established, rational design • Approximate design • Intuitive, no formal design
Reliability in terms of uncertainty in implementation	• Conventional construction • Established local practices and materials. • Established process elsewhere, adapted locally. • New process, conventional materials, demonstrated and proven. • New process, new materials, experimental
Safety during construction	• Established construction process. • Which safety consideration is required.
Typical cost	• Low, Medium, and High
Time required	• Short, Midterm and Long
Sustainability	• How far dose the solution contribute to improve the ecological, economical, and social sustainability
Synergistic effect	• To which extended the application of the solution would positively or negatively impact other solutions or sectors this can range from Low, moderate to high impact
Contribution to mitigation effort	• Would the application of the solution impact the GHG mitigation efforts positively or negatively
End-user and stakeholder acceptance	• The degree to which the proposed adaptation solution reflects the end-user, stakeholders' preferences.
Smartness	• Is the solution compatible with the internet or other connectivity options? • Can the solution interact with the user and adjust to them
Ease of Use	• Can the solution be used by all user groups? • How long would the training last for using the solution.
Linkage with local heritage	• The degree to which the solution reflects or preserve local building heritage

Once the project team has devised the action plan, agreed on the issues to be addressed, and determined the solutions and interventions to be used, the next step is to rerun the risk assessment as scenarios. This step should be conducted in the same way as the risk assessment phase. However, the project team is now considering 'what-if' scenarios, whereas in the risk assessment phase, the team was assessing the status quo. The information gathered during the end-user engagement action is to be used to guide the creation and assembly of the adaptation solution in the 'what-if' scenarios.

For the each of three case study sites, a tailored selection of adaptation solution was developed based on the above-mentioned criteria ensuring that the most vulnerable sectors are addressed and that end user as well as the overall project targets are taken into consideration. 'What-if' scenarios where tested and final list of adaptation solution was developed. The list provided in table 24 show an example of the selected adaptation solutions to face the extreme Precipitation hazard in the JUZ building.

Table 24: example of the selected adaptation solutions in the JUZ building.

Extreme Precipitation								
			Implementation					
Nr.	Adaptation Solutions	Addressed Risk	Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Structure Sector								
3	Install Green roof		High	+	Major	Long	€€€	***
4	Waterproof and moisture resistant interior finishes		Low	0	Moderate	Mid	€€	**
7	Air and moisture sealing of Building envelope		Moderate	+	Moderate	Mid	€€	**
Energy Sector								
8	Installation of waterproof sockets and switches		Low	0	Major	Short	€	***
9	Support of Micro-grid energy exchange		Moderate	+	Low	Mid	€€€	*
11	Local energy storage system		Moderate	+	Low	Short	€€	*
Water and wastewater sector								
12	Backwater protection		Low	0	Major	Short	€€	***
17	Sump water pump with battery backup		Low	-	Low	Short	€	**
Wellbeing and Organization								
18	Emergency response plan and evacuation routes are actual and updated in timely interval		High	+	Major	Short	€	***
19	Install emergency alarm system		High	+	Major	Short	€	***
20	Providing regular emergency response training and behavioral rules for extreme precipitation events		High	+	Major	Short	€€	***
21	Carrying out maintenance of building structure in regular time interval		High	+	Major	Short	€	***

Extreme Precipitation								
22	Carrying out maintenance of building technical system in regular time interval		High	+	Major	Short	€	***
Communication systems								
26	Improve and expand coverage of Wi-Fi and mobile networks		Moderate	0	Moderate	Short	€	**
Urban and spatial environment								
27	Provide Hail, Snow and extreme precipitation protected outdoor areas		Moderate	0	Moderate	Mid	€€	***
31	Provide an outdoor emergency meeting point		High	+	Major	short	€	***

The list of the selected adaptation solution for the three buildings can be found in the annexes 11.17.1, 11.17.2, and 11.17.3.

The resulting updated resilience assessment that can be achieved based on the implementation of the selected adaptation solution at each building is presented in the annexes 11.18.1,11.18.2, and 11.18.3.

7.2.4.4 Developing detailed action plan

Once the scenario results have been analysed, the team should compare the outcomes of each adaptation option and combinations of options to choose the action plan that best fulfils the project targets set earlier in this phase. Given the complexity of this step, which extends beyond the scope of this research, it was not studied in detail at the three case study sites. Nevertheless, some general notes can still be mentioned. For instance, it is important to consider constant engagement with stakeholders throughout this step. All project stakeholders (administration, co-operators, owner, users) and those within its broader context (municipality, neighbours, NGOs, local government, etc.) should actively participate in the decision-making process. Establishing regular consultation and feedback mechanisms is crucial to ensure widespread acceptance and support for the action plan.

Further, it's crucial to ensure there is sufficient commitment from all stakeholders to move forward with the project into the Implementation phase. Stakeholders should agree on the final action plan and be committed to its realization and ensure that appropriate funds are arranged, adequate workforce is available and legal permits are secured.

To facilitate continuous stakeholder engagement, the project team should develop a comprehensive communication plan early on. This plan should detail what information should be communicated, how and when it should be delivered, and who the intended recipients are. The communication plan aims to ensure that all stakeholders are sufficiently informed and actively involved throughout the project's lifecycle.

Hence, it is recommended that the final action plan is collectively chosen in a democratic and transparent process. This would ensure that the chosen action plan is the one that has the most supported and therefore theoretically enjoys the greatest likelihood of successful implementation.

7.2.4.5 Iterative process

- Data collection:
  in action planning phase, data collection involves collecting and adjusting data from other project stakeholders or suggestion. However, based on the final selection of adaptation solutions, the data collection needs to be supplemented with solid evidence.
- Descriptive analytics
  During each iteration loop, the validation of scenarios by stakeholders and the approval process led by the planning team are essential prerequisites for the application of descriptive analytics. This enables the preparation of clear and legible materials for survey-based or workshop-based discussions.
- Validation:
  In action planning phase, the range of validation activities is programmed entirely by the agreements reached during preparation and setting the targets phase. Foreseen validation activities include the validation of scenarios, the collection of adaptation solution or project proposals, the evaluation of the adaptation solutions and proposals.

7.2.5 Implementation and monitoring

While the implementation of a project is largely autonomous and external to the iQRe methodology, iQRe aims to facilitate evidence-based decision-making during this phase. It provides a framework for setting up an information regime that offers regular feedback both during the current planning term (through implementation reports) and for future planning terms (through continuous performance monitoring). This feedback should also incorporate input from stakeholders and end-users, ensuring their experiences and perspectives are considered in the ongoing evaluation and refinement of the project. This stakeholder feedback mechanism forms a vital part of the data collection and assessment processes, contributing to the project's adaptability and continuous improvement.

The design of this information regime is to be tailored to each specific project and to be managed by clear project team. This team is tasked with structuring data collection processes from the implementation and in-use phases, aligning the collected data with the project targets, local developments, and regional policies.

Also, the team is expected, for each project, to develop a unique set of monitoring indicators. These indicators may be project-specific, solution-specific, or both, and they account for the information necessary to assess the project's contribution to mitigating the climate change and adapting to its risks as identified in the risk assessment phase.

These monitoring metrics should be linked to the Key Performance Indicators (KPIs), allowing the progress towards maintaining project targets to be evaluated using iQRe KPIs, albeit with an adjusted benchmark. Which is in alignment of the SB method.

Furthermore, the project team must ensure that the implementation plan adequately addresses the following aspects:

- Risk Consequences
- Sustainability and mitigation Consequences
- Stakeholders' requirements
- Roles and Responsibilities
- Time Frame

By integrating diverse feedback channels — including values derived from Key Performance Indicators, data from performance monitoring, and regular input from stakeholders — the project can stay responsive to evolving needs and conditions. This comprehensive feedback approach enhances the project's effectiveness, adaptability, and long-term sustainability.

7.2.5.1 Iterative process

- Data collection:

  In the implementation phase, data collection refers to listing and assessing potential solutions, and collecting data in a case-by-case scheme for monitoring and tracking the action plan performance goals.
- Descriptive analytics

  As the project unfolds, it is probable that more detailed decision-making will be delegated to project stakeholders. Descriptive analytics refers to preparing monitoring and other project-related data for discussions.
- Validation:

  The regular inspection and examination of the project performance over a certain period and comparing the performance against KPI and benchmarks will help the project team validate the over or under achievements of the project targets.

7.3 Insights and Key Findings: The iQRe Framework and Bridging the Climate Resilience Assessment Gap.

This chapter addresses the research hypothesis and its second question by detailing the key features and methodologies of the Integrated Cross-Scale Urban Resilience Assessment (iQRe) framework and rating system. The iQRe framework is an attempt to bridge the revealed gaps in the existing resilience rating systems in terms of their alignment with national building practice and international norms, quantitative results, ability to apply across different project phases and RCP scenarios and transferability of the results across spatial scales and administrative roles to reduce the need to using different systems for each urban scale. In this sense, the iQRe framework is designed to capture the interconnected nature of the built environment and align with both international standards and German building practices. The iQRe framework and rating tool attempted to bridge the above-mentioned shortcomings in existing rating system by attempting to mirror the interconnected nature of urban environments and enabling to view the urban climate resilience across different scales (building, neighborhood, district) and sectors (energy, water, human wellbeing, etc.). Moreover, aligning the iQRe framework with national standards such as the DIN 276 and the DIN EN ISO 14091 guidelines enable the framework to be compatible with the building practices and the national climate risk assessment approach, for example the KWRA 2021. Moreover, the iQRe proposed an adapting the generic EN ISO 14091:2021 standard to the specific challenges of the built environment, by adjusting the standard's waterfall project management methodology to a hybrid Agile-Waterfall approach and by expanding the standard's three phases of ISO 14091:2021 two additional phases and three iterative steps.

The unique merger of the IPCC key urban sectors such as energy, water, wastewater, human wellbeing, and organization within the iQRe framework enable its users to trace the cross-sectoral relationships of climate adaptation actions and allow for the key urban sectors, actors, and scales to work as part of global interlocked cohesive system. The iQRe acknowledges that within the same sectors, a climate hazard can result in several monetary or non-monetary consequences. To address this fact, the iQRe builds upon the IPCC hazard definition and portions the risk into six risk groups. The segmentation of hazards, risk groups and urban sectors resulted in creating novel relation matrix that integrates the type of hazard to the sector to the risk groups exposed to that risk within the sector and spatial scale. To translate the qualitative risk matrix into quantitative values, the iQRe rating system integrates the IPCC AR5 risk assessment approach with the GIZ impacts chain method and merges them with the hierarchical levels (issue, category, criterion, and indicator) of the "SB method," from the International Initiative for a Sustainable Built Environment (iiSBE) and allow for the assignment of normalized numerical values to the three components required to assess climate risk: Hazard, Vulnerability, and Exposure. The built-in flexibility of the SB method in defining the benchmarks and weighing factors is a crucial feature for allowing it to be contextualized for used for various locations and project circumstances. Moreover, the SB Method hierarchical levels are aligned with national sustainability rating systems which again facilitate its use adaptation by existing certification system. The developed excel based rating tools facilitate the application and communication of the iQRe risk assessment and resiliency results.

In the second part of this chapter, the iQRe risk assessment framework and rating tools were tested at three real life case studies at the city of Bamberg. Due to time and project scope constraint, the testing of the framework was limited to it first four phases and the project scope was limited to the building scale and to handful of hazards and sectors. Hence, the spatial cross scale application of the iQRe framework was not validated. Nevertheless, the rating tool and the system KPIs, the alignment of the iQRe sectors with the DIN 276 cost groups and the qualitative and quantitative risk assessment as well as qualitative and quantitative impact adaptation solutions on the resiliency of the building have all be tested and proved most useful in guiding the team in what is practically a new venture to all the participant as the climate adaptation topics are quite novel to many planners.

However, the testing also showed the limitation of such analytical tools in capturing the context related information about how the building administrators and users deal with and adapt to extreme weather events and their level of awareness and preparedness for such events in the future. Here, the site visits conducted with the building operators and the workshops held the end users helped to provide the team with invaluable insights about the perceived climate risks and adaptation requirements and anticipation that could not have been clear for the planning team from the reading the raw data or conducting the site visits alone. In essence, these site visits and end user engagement highlighted the existing gaps in climate adaptation knowledge and preparedness among building users, a topic that falls within the broader concept of “Climate Adaptation Literacy”. Actually, it can be argued that both the level of maintenance of the active and passive adaptation system coupled with the level of “Climate Adaptation Literacy[8]” among the end users might hold the key to the success and failure of any adaptation intervention, as without them the risk and reliance assessment rating would remain a theoretical exercise with limited practical impact. Both lessons can be relearned via a “Vernomimicry” approach to vernacular climate change adaptation methods.

In conclusion, the research made in this chapter has provided an adequate answer to the second research question “What would be the key features and methodologies of a dedicated numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices?” and proved that original research hypothesis that debated that value of “A dedicated numerical climate resilience assessment framework and rating system that capture the interconnected nature of the built environment and align with both international standards and German building practice” in overcoming the shortcomings of the existing rating systems frameworks.

[8] We understand the climate adaptation literacy as the sum of awareness, knowledge, and skills that enable building users and stakeholders to recognize, understand, and respond to the specific challenges and hazards posed by climate change in a manner that is aligned with the climate adaptation and mitigation objectives and to transfer on lessons learned to the other stakeholder, thereby ensuring the safety, resiliency, sustainability , and functionality of the material and non material values of the building

8 Closing the Gaps, Concluding the Journey: Views on Germany's Building Performance Requirements for the Post 2° Era

“., but my words, like silent raindrops fell and echoed in the wells of silence”.

Sound of silence: Simon and Garfunkel, 1964

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Cities are the lifeblood of the global economy, and the habitat of the majority of humans. The crucial role of the urbanized world we live in comes with a significant environmental cost and is very susceptible to the impacts of climate change. Acknowledging that the city is not the sum of its buildings, nevertheless, the key insight that emerges from this research showed the centrality of the built environment to the climate change equation, in both the mitigation and in the adaptation domains. Nearly all key urban sectors identified by the IPCC as susceptible to climate change impacts are either located within or intricately linked to the building and or part of the greater built environment. Buildings, in fact, often serve as either origins or destinations for various sectors including water, energy, and transportation networks. This highlights the significant role the built environment plays in climate change - a role that can no longer be overlooked or treated in isolation at various spatial scales. The same conclusion is voiced in the German 2021 risk analysis as underscores the urgency to address the risks of climate change to the built environment[36].

Indeed, Throughout history, the rise and fall of cities have been deeply connected to how effectively they implement and adapt the laws and norms that manage the relationship between man-made structures and the natural world [13]. However, with the anticipated significant changes in climate in the upcoming years, our buildings and broader built environments are facing increased risks. They must now contend with climatic and weather conditions that they weren't initially designed to withstand. The work done in this research showed that impacts of climate change are already being observed at the German building sector. This underscores the importance of reevaluating and updating the current building performance standards to meet these new challenges and to supplement the existing mitigation biased building laws with holistic adaptation provisions. Moreover, it is important to keep in perspective that more than two-thirds of Germany's building stock is made up of energy hungry and inefficient structure that will continue to be used even beyond the 2045 carbon neutrality target date. This highlights that the existing buildings represent the largest potential for greenhouse gas (GHG) reduction, but they are also the most vulnerable to risk. Although the investigation made in this research showed that the existing German building norms are very outdated and only a handful is updated to incorporate adaptation to climate change, we still believe that tackling this challenge with existing building mindset that guide the development of norms and laws might be not the appropriate path to follow. To start with building norms and standards still relay on historic data and past experiences to draft lows about build buildings that are to operate in the future! Furthermore, building codes are set the minimum acceptable level of construction and not the optimum[293].

Actually this shortcoming of existing norms, has moved the real estate market to develop other quality seals and building rating system such sustainability smartness labels as they provide the investor with a competitive marking and performance edge that goes beyond the minimum requirements[236]. Nevertheless, the fact that there is a handful of systems and standards on the market that that address this issue show that both the regulator and the market are still in the early stage of incorporating the adaptation requirements in their rating systems.

Moreover, as the buildings do not stand physical and culturally in isolation but are rather and integral part of the greater urban and social fabric, it would be inadequate to address the climate crisis only at the level of individual buildings. To effectively combat climate change within this environment, it is essential to combine efforts across various time frames, social contexts, and spatial dimensions. This approach also involves engaging a broad spectrum of institutional actors, whose influence and responsibilities go far beyond the confines of single buildings.

The perceived climate adaptation shortcomings of the existing norms and rating systems coupled with spatial and temporal complexity of climate adaptation requirements in the built environment has been the driving thought behind this research hypothesis which argue that “Current building performance and rating systems in Germany inadequately incorporate climate change adaptation and fall short in numerically evaluating building resilience to climate change. A dedicated numerical climate resilience assessment framework and rating system that capture the interconnected nature of the built environment and align with both international standards and German building practice can over come this shortcomings and supplement existing frameworks”.

Challenging or proving this hypothesis constituted answering the two key and central questions that guided the development of this thesis:

A. How do buildings adapt to impacts of the climate, and to what extent contemporary (post 1970s) performance and rating systems in Germany integrate climate change adaptation measures?
B. What would be the key features and methodologies of a dedicated numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices?

The following subchapter guides the reader into how this research attempted to answer both these questions. Moreover, it will discuss the other questions that remained either not answered by this research or that arise because of it.

8.1 Answers to the Research Questions

A) How do buildings adapt to impacts of the climate, and to what extent contemporary (post 1970s) performance and rating systems in Germany integrate climate change adaptation measures?

Local climate has historically been, and will continue to be, a central driving force in shaping the built environment. It significantly influences the design of our buildings and cities, and largely dictates their performance requirements. The building performance requirements and rating systems have as evolved over thousands of years in response to technological, social, economic, and environmental factors. In this research we have segmented the evolution of the building performance requirements into six distinct generations, starting with the 0.0 generation of building “Shelter” and concluding with the most recent one in operation the 5.0

generation which describe the “Smart” building. Throughout this development, the interaction and adaptation to the local climate has been a common denominator. In this study a review of the strategies and methods used by each generation has been closely investigated. The vernacular architecture was selected in this study to present the adaptation solutions found in the 0.0 generation of buildings. The vernacular architecture adaptation strategy to climate events is characterized by simplicity and community collaboration and passive solution that worked in harmony with nature. In conclusion, it is found that there are five core design principles that are commonly applied in vernacular buildings and are transferable and applicable to our modern world which are:

Simplicity: The vernacular buildings are rather simple constructions that can be assembled and disassembled with simple tools and manpower only. The construction is usually a collaborative work that can be accomplished in a relatively short time and allows for a swift reconstruction and adaptation of the building [164, 294, 295] .

Transient Structures and Local Materials: Unlike modern constructions designed for permanence, vernacular buildings often have shorter lifespans and are designed with maintenance in mind [166]. This characteristic stems from the use of locally sourced natural materials and simple techniques, necessitating regular maintenance and allowing for agile adaptation to environmental changes [294, 296].

Resource and Location -efficient Design: In vernacular architecture, form is treated as inexpensive, while materials are considered expensive. This approach results in creating efficient and effective shapes, maximizing material utilization, and utilization of site specific advantages [164].

Community-Centric Building Practices: Building in the vernacular is a communal act, fostering the transfer of accumulated knowledge and traditions across generations. This communal approach ensures that constructions are harmonious, inline with the neighbouring structures and align with broader community interests [297].

Integration with Urban Fabric: The vernacular architecture is embedded in the greater urban fabric to the degree that the boundaries of the urban scale and building scales are blurred and both planning scales are interwoven. This meant that both scales acted together as a single unit complementing each other[167, 168]. The effectiveness of this principle in providing appropriate climate adaptation was documented in Al-Lyaly [169] and Taleb and Abu-Hijleh [170] studies.

Moving to the 1.0 generation of buildings (the safe building) show that a lot of the adaptation strategies used in the in 0.0 generation has moved along into the 1.0 generation. However, as fire safety, law enforcement, and transport requirements started to become more profound, and trade-offs between climate adaptation and other societal needs started to take place. for example, the fire safety requirements influenced material choices, leading to the dominance of brick-based buildings clay-based roof tiles in Europe over more traditional and climate adapted wooden structures and thatched roofs. This era also witnessed a decoupling between buildings and their urban context, as narrow wind and sun protected streets gave way to wider, straight streets to accommodate civil defence, fire safety, and mobility requirements.

The 2.0 generation of buildings, emerging from the fallout of the Industrial Revolution, was marked by s technological and scientific breakthroughs and unprecedent economic and population growth that drove the demand for fast construction using prefabricated elements and standardized designs. This era, spanning from the late 19th century to the mid-1970s, was characterized by a shift in focus from just providing safe structures to ensuring they were also sanitary, meeting basic sanitary needs like fresh air, running water, and sunlight access. This technological and scientific advancement of the 19th century, allowed to the use active and energy-intensive systems to adapt to the surrounding climate. These systems offered an unparalleled level of comfort and adaptation, causing to the gradual replacement of the traditional passive systems being gradually by prefabricated and engineered solutions. In essences, the world moved from gradually from building with nature to building despite it. As a result, the universal type of architecture we are accustomed to today was born a. As a result, these buildings became highly dependent on active systems for climate adaptation, neglecting traditional passive methods. However, the convenience offered by these systems resulted in a heavy reliance on fossil fuels and other finite resources, shaping the contributing greatly to the climate change challenge we are facing today.

By the early 1970s, the energy-efficient generation (3.0) was introduced to mitigate the negative economic and environmental consequences of the society over reliance on imported fossil fuels. The efforts to reduce the energy consumptions of buildings spearheaded this quest and are still the main tool used to reduce the greenhouse gas emissions and resource consumption.

By the mid 1980s, the limitations of the 3.0 generation in fostering comprehensive sustainable development became apparent. This realization sparked the emergence of sustainable building performance standards by 1990s onwards. Nowadays, with the introduction of the QNG quality seal, these sustainable building performance criteria are poised to become the new norm in Germany's building performance requirements and evaluation systems.

Simultaneously, advancements in technology, alongside the widespread availability of computing power and internet access, have laid the groundwork for the development of smart buildings and rating systems for them. These smart building rating systems enhance the efforts of previous generations by minimizing energy consumption and, consequently, greenhouse gas emissions. They achieve this by a real-time adaptation of the building operations to the singles received from the surrounding environment or other building and network providers, hence facilitating the exchange of information and resources between buildings. The explicit inclusion of the SRI rating system in the EPBD legislation signals that the 5.0 generation of building rating systems is also on the verge of becoming the next standard in the realm of building evaluations.

However, as climate adaptation is gaining more attention and legislations such as the EU Taxonomies are putting it at equal footing with the climate mitigation action. Also, we it widely known and proven that a lot of the performance requirements of the 3.0, 4.0 and 5.0 generation of building can play a dual positive effect in reducing the greenhouse gas and improving the building resiliency. Therefore, the second part of the first question dealt with investigating the degree to which climate adaptation is, intentionally or not, included in the existing German rating systems. The topic of measuring the effectiveness of each adaptation is considered out of scope. Qualitatively assessing the inclusion (directly or indirectly) of adaptation provisions was made using simple, yet detailed classification in which the level climate adaptation of inclusion was evaluated for 8 rating system, across 5 climatic hazard and 7 sectors via a descriptive 4-point assessment system that range between 'absent,' assigned 0 points; 'somewhat included,' assigned 1 point; 'Fairly included,' assigned 2 points; or 'well included,' assigned 3 points. For more information on the criteria used for each awarded point please refer to table 3

The results of this analysis and literature investigation showed clearly that the current building norms and regulations are lagging in including future climatic conditions. It was shown that from the large number of norm and standards that regulate the performance of a buildings, only a small percentage of building-related norms have been updated by late 2022 to reflect on the anticipated impact of climate change hazard the building performance. Truly , the required updates to the building norms and regulations must carefully weigh the trade-offs between enhancing building the resiliency and the potential increase in construction costs and design complexity, which might hinder or postpone projects [298]. Nevertheless, according to the American National Institute of Building Sciences', every $1 spent on climate resilience strategies and in designing buildings beyond the provisions outlined in the 2015 International Codes (I-Codes), $4 can be saved in return [245]

The qualitative research revealed gaps in inclusion of climate change adaptation provisions, with inadequate consideration of certain hazards such as drought and insufficient attention to key urban sectors like communication, green and blue infrastructure, human wellbeing and organization and transport and mobility.

Supplementing the 3.0 generation requirements with sustainable building or smart building rating systems improves inclusiveness of climate adaptation but remains overall limited in certain areas, including adaptation to storms, wind hazards, heavy precipitation, and drought.

In conclusion, the analysis made in the chapters 5 identified six climate adaptation inclusion gaps in the existing building performance requirements and rating system:

- **Firstly,** the performance requirements of the energy efficient building (3.0 generation) rarely consider climate adaptation. A very small fraction of the existing building laws and design norms are updated to include provisions for climate change adaptation.

- **Secondly,** although some sustainability rating systems acknowledge the importance the of climate adaptation such as the NaWoh V3.1 and DGNB NKW and propose indicators to measure them. However, they do not clearly describe the type of adaptation requirements needed or provide the tool to quantify the impact of applied measures on the building climate adaptation.

- **Thirdly,** all investigated rating systems are spatially constrained to the building boundary itself and generally do not allow for coupling and tracing the impact of climate adaptation measures applied to the building on the greater urban scale and vice versa or to expand the use of the same rating system at a greater urban scale. Adapting to climate impacts implies that the building as a unit and the greater urban fabric work in tandem, complementing one another and adequately accounting for the interdependencies within the various urban sectors and the cascading effects of climate impacts [15].

- **Fourthly,** the current generation of rating systems (3.0, 4.0 and 5.0) are mainly designed to assess newly built buildings. However, as two-thirds of the German building stock was built according to outdated standards that predominantly belong to the 2.0 generation of performance requirements (sanitary), addressing climate adaptation in this generation of buildings urgently needed as such buildings usually exhibit the high vulnerability to the climate hazards.

- **Fifthly,** the existing rating system provide a universally applicable guidelines and benchmarks, against which the performance is rated. The topics of climate change adaptation are local in nature and thus varies from one location to the other, the rating system need to be flexible or complemented with a flexible system that can link the universal mitigation goals with local adaptation requirements.

- **Lastly,** the analysis showed that in many cases the requirements for climate mitigation efforts result – intentionally or not – into an increased integration of the climate resiliency and adaptation topics. Nevertheless, these considerations remain fragmented, mitigation biased and, the degree improved resiliency remain not yet clear. This conclusion is also reflected in the DAS 2021 assessment of the response indicator BAU-R-4.

On this basis it became apparent that the existing German building performance requirements and rating systems exhibit significant gaps in embracing climate adaptation within their requirements, necessitating a more comprehensive, flexible, and locally tailored approach to building design in the face of climate change. Consequently, this conclusion confirms the first part of this research hypothesis. The validation of this hypothesis paves the way for exploring the second part, which is guided by the following research question: *What would be the key features and methodologies of a dedicated numerical climate resilience assessment framework and rating system that can capture the interconnected nature of the built environment and align with both international standards and German building practices*?

Answering this questing started by conducting a thorough review of the existing climate risk and urban resilience rating systems. The findings this review made can be summarize d as follows:

- In Germany, many policy sectors and federal agencies follow the DIN EN ISO 14091 - 2021-07 (adaptation to climate change) is creating their climate risk and adaptation requirements.
- The reviewed urban resilient systems partly follow the assessment methodology of the DIN EN ISO 14091 - 2021-07 (adaptation to climate change) or the lack the alignment with the IPCC AR5 risk assessment approach (see chapter 6)
- Many of the reviewed urban resilience rating systems do not offer quantitative results, furthermore they lack the necessary flexibility to be adapted to the specific priorities of a certain projects or are limited to certain hazard.
- Many reviewed urban resilience systems lack the capability to adjust adaptation requirements based on future climate projection or RCP scenarios.

- Existing operational rating systems fall short in facilitating a cross-scale risk and resilience assessment. Consequently, results at one spatial scale are not easily transferable to another, leading to the need for different assessment approach systems for each scale.

In response to these challenges and, the Integrated Cross-Scale Urban Resilience Assessment (iQRe) framework was developed. To bridge these identified gaps, the iQRe framework incorporates the following main concepts:

- **Alignment DIN EN ISO 14091 guideline and German building practices:**
  The iQRe framework adapts the generic EN ISO 14091:2021 standard to the unique challenges of the built environment. It modifies the standard's waterfall project management approach into a hybrid Agile-Waterfall method, expanding the standard's three phases into five phases and adding three iterative steps to be suite the unique challenges of the built environment. The iQRe five consequential phases can be integrated with the widely used fee structure for architects and engineers (HOAI) as per the suggestion provided in the:

Table 25: Mapping of the iQRe framework phases with the corresponding HOAI Phases

iQRe main phases	iQRe Sub step	Corresponding HOAI Phase
Pre-planning	Project charter, defining project goal, scope, stakeholders, assessment method	**LP 1**: Basic Evaluation (Grundlagenermittlung)
	Identifying climate Hazard/impact and climate parameters drivers and forcing	
Preparation phase	Identifying the key urban sectors at risk	**LP 2:** Preliminary Planning (Vorplanung)
	Data collection and stakeholder engagement	
	Generating a risk assessment based on qualitative assessment of vulnerabilities and end user feedback	
Risk assessment phase	Development of the impact chains, calculating the risk via the iQRe rating system and supporting tool	**LP 3:** Design Planning (Entwurfsplanung)
Action planning phase	Setting the targets, Drafting the list of adaptation solutions, Selection, and prioritization of adaptation actions	**LP 3:** Design Planning (Entwurfsplanung)
	Development of detailed action plan	**LP 4:** Approval Planning (Genehmigungsplanung) **LP 5:** Execution Planning (Ausführungsplanung)

Implementation & monitoring	Iterative steps (Risk assessment, data collection, descriptive analysis, validation)	**LP 6:** Preparation of the Contract Award (Vorbereitung der Vergabe), **LP 7:** Participation in the Contract Award (Mitwirkung bei der Vergabe), **LP 8:** Construction Supervision (Objektüberwachung), **LP 9:** Project Completion (Objektbetreuung und Dokumentation)

- **Embracing the Interconnected Nature of the Built Environment and alignment with the German building practices:**
  The iQRe framework adopts a cross-sectoral and cross-scale approach, enabling the assessment of climate resilience across different urban sectors (energy, water, human wellbeing, etc.) and scales (building, neighbourhood, district). Thus, the iQRe allow for its system to be used across various scales and sectors. In the iQRe framework, the concept of 'cross-scale' is actualized through the integration and unification of key urban sectors across the spatial scales of the urban environment. The key urban sectors are based on seven key urban sectors identified by the IPCC AR5 "Urban Areas" as in need of adaptation the climate [85]. Moreover, to facilitate the practical implementation within the German building practices, the iQRe sectors at the building scale are largely aligned with the DIN 276 Cost Groups for buildings. The definition of the iQRe urban sectors at each urban scale can be found in table 12.
- **Streamlining the urban climate resilience and clarifying administrative tasks:**
  Through the iQRe unification of common sectors across the urban scales, the administrative responsibilities are clarified, and the allocation of tasks can be better distributed. When these sectors are integrated, a comprehensive picture of the project's climate resilience performance emerges. This cross-scale, sector-specific approach encourages a coordinated strategy to build resilience against specific hazards. However, the iQRe framework acknowledges that a single hazard can lead to multiple types of losses within the same sector - be it monetary, health-related, or environmental. To address this complexity, iQRe classifies risks into six distinct categories based on the IPCC AR6 definition of hazard [275].
  By segmenting the built environment into defined sectors and reconnecting these through shared risks and spatial scales, the iQRe framework facilitates each sector in playing its role across different scales in addressing the same hazard. This approach not only makes the administration and implementation of adaptation strategies more manageable but also help streamline the urban resilience process.

- **Numerical Assessment of the Climate Resilience**

  The iQRe rating system enables the assignment of a normalized numerical value to each of the three components needed to assess climate risk: Hazard, Vulnerability, and Exposure. For tracing the causal relationships between the three components, the iQRe and merges GIZ concept of the practical application of the IPCC AR5 risk assessment approach with the generic multi-criteria analysis methodology of the “SB Method", developed by the International Initiative for a Sustainable Built Environment (iiSBE).

- **Alignment with the European and German sustainability rating practicess**

  By merging the iQRe rating system with the SB method, the iQRe rating method achieves compatibility with most German sustainability rating systems. Since both the SB method and most of the German systems like BNK, BNB, DGNB align with the hierarchical logic and guidelines of the European CEN/TC 350 norm (Cen/Tc 350 - Sustainability of Construction Works). This alignment allows the iQRe to complement existing rating system and to be easily integrated into a broader, well-established ecosystem of building rating systems used in Germany.

- **Flexibility and Customizability**

  In the realm of climate resilience, adaptation solutions need to be tailored to the specific context of each location in terms of local vulnerabilities, hazard probability and exposure magnitude. As the iQRe follows the same principles of the SB Method, this local contextualization is possible through the choice of project indicators and by the customization of the benchmark values and weights to suit local conditions and project targets. This enables devising site, sector, and risk specific adaptation solutions. This used response can be normalized and evaluated within a greater numerical system. Thus, offering a numerical basis of the decision-making process.

Testing the iQRe on three case study buildings has clearly demonstrated the benefits of having a flexible and integrated framework that that can numerically measure the resiliency of the existing structures and identify, rate, and rank the needed climate adaptation actions for each site. Moreover, the framework proved very helpful in guiding both the planning team, the building operator, and the owner through the process from the early stages of setting the climate change hazards senses, data collection, interaction with end-users, up to the data validation, risk assessment and finally to choosing the adaptation targets and actions. The piloting of the framework failed short of testing the cross-scale application of the iQRe system and impact of the selected adaptation solution on the resiliency of the tested buildings. In conclusion, it can be said the iQRe framework, with its detailed phases and iterative steps, is well-equipped to validate the second part of this research’s hypothesis. The iQRe framework and rating system offers a dedicated, numerical, and interconnected approach to climate resilience assessment, tailored to the German context yet aligned with international standards, thereby narrowing the resiliency gap in current German building performance and rating systems. Nevertheless, the pilot site testing of the tool and framework has brought to light two crucial aspects necessary to further bridge this resiliency gap. Firstly, there is an urgent need to enhance the level of knowledge and preparedness related to climate adaptation among building users, operators, and investors. This area is a part of the broader concept of "Climate Adaptation Literacy". Secondly, the focus must also be on the level and quality of maintenance and upkeep of the building's passive and active systems. These two factors are of upmost importance in determining the success or failure of any adaptation strategy, tool, or framework. Consequently, this research underscores the importance of treating adaptation to climate hazards with the same level of priority as fire safety instructions in buildings and in school curricula. These two lessons echo some of the key principles found in the vernacular approach to climate adaptation, which can be revisited through a "Vernomimicry" method.

8.2 Recommendations for Future Work.

As is the case with any research journey, the deeper we investigate a question the more other undiscovered questions arise. This is also true for this work. This research attempted to explore the climate change interaction with the building sector, assess the degree to which adaptation to climate change is integrated in the existing building performance requirements and rating system as well as to gauge the gaps in the existing building and urban resilience rating system and to propose an urban resilience assessment framework and rating system to bridge these gaps for the German building sector and environment. Nevertheless, it became evident as we progress with this research that the topic of climate adaptation and resilience in the urban sector remains largely an uncharted territory. In this sense, this final sub chapter aims to shed light on some of the areas which are worthy of further investigation and were beyond the limits and scope of this research. The following list of recommendations stems not only from the findings and limitations encountered during this study but also from acknowledging the urgent need to address climate change adaptation at several urban and social levels, in order to giving our buildings, communities, and future generations a better chance to withstand, absorb and co-exist the unpredictable nature of our changing climate.

- Climate Adaptation Literacy: Research and attention should be given for exploring strategies to improve climate adaptation "literacy" among key stakeholders like building users, operators, and investors. The goal is to go beyond raising awareness about climate change but do equip the building users with the needed knowledge about how to act and react in case of climate hazard event. It was noticed that there are no clear guidelines that can help the user correctly act in case of hail or flood warning or even heatwaves. This could include the development of a scale to measure the level of adaptation literacy and to include it in educational programs, workshops, and training sessions tailored to different groups.

- **Moving from Vernacular to Vernomimicry:** As we embrace a new climatic era, designers and planners are forced to produce architectural design that can address the dual challenge of mitigation and adaptation. This requires incorporating a design paradigm that is “with” nature and not “despite” it. Vernacular design, being the indigenous science of building, can serve as a valuable source of inspirations for climate adaptation solutions. Research should be done to investigate the degree to which the lessons learned from the vernacular can be adapted to the existing modern world requirements.
- **Adaptation Strategies for Existing Building Stock:** Retrofitting the existing building stock will remain the largest source and challenge to achieve a carbon neutral future. It would be appropriate to investigate how the existing building can be renovated to achieve the dual purpose of mitigating the causes of climate change and adapting to it.
- **Long-Term Impact Studies of Climate Adaptation Measures:** The literature is filed with passive, active and nature-based adaptation solutions. Nevertheless, to avoid the performance gap, it would be important to conduct interdisciplinary long term monitoring studies to assess the real life and long-term effectiveness of climate adaptation measures in buildings and urban areas.
- **Coupling the urban climate Adaptation with social justice and socio-economic impacts:** Effort must be taken to ensure that climate adaptations are inclusive and equitable. Therefore, there is a need to understand the socio-economic impacts of these measures and ensure that they do not disproportionately affect underprivileged communities. Furthermore, there is a need to understand the long- and short-term economic benefits of such adaptation measures.
- **Development of a Dynamic Rating System:** the developed rating systems are designed to capture a moment in the past or predict an ideal performance for the future. However, as climate is dynamic by nature, the rating system needs to be able to adjust accordingly. With the help of digital building logbooks, smart buildings system and artificial intelligence computing power, it might be possible to evolve the existing system into dynamic and flexible rating system that can adapt and adjust to changing climate conditions and local needs.
- **Expanding the refining of the building standards and regulations**: this work proposed a unique amendment to the EN ISO 14091:2021 norm to suit the requirements of the building sector. Nevertheless, there is a need to expand this effort to incorporate of the proposed iQRe framework into a new dedicated standard assessing the climate resilience of the built environment. Moreover, it is important to further investigate the applicability of current policy and regulatory frameworks in supporting climate adaptation in the building sector and to suggest the needed improvements.

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9 References

10 Annexes

10.1 Annex 1 : Overview of Potential Co-benefits (Green arrow) and Adverse Side-effects (Orange arrow) Associated with Mitigation Actions in Buildings[299]

Co-benefits/Adverse side-effects	Residential buildings	Commercial buildings	Buildings in developed countries	Buildings in developing countries	Retrofits of existing buildings	Exemplary new buildings	Efficient equipment	Fuel switching/RES incorporation/green roofs	Behavioral changes	References
Economic										
Employment impact	X	X	X	X	X	X	X	X		Scott et al. (2008); Pollin et al. (2009); Ürge-Vorsatz et al. (2010); Gold et al. (2011)
Energy security	X	X	X	X	X	X	X	X	X	IEA (2007); Dixon et al. (2010); Borg and Kelly (2011); Steinfeld et al. (2011)
Productivity										Risk (2002); Kats et al. (2003); Loftness et al. (2003); Singh et al. (2010b)
Enhanced asset values of buildings	X	X	X	X	X	X		X		Miller et al. (2008); Brounen and Kok (2011); Deng et al. (2012b)
Lower need for energy subsidies	X	X	X	X	X	X	X	X	X	Urge-Vorsatz et al. (2009); GEA (2012)
Disaster resilience	X	X	X	X	X	X				Berdahl (1995); Mills (2003); Coaffee (200B)
Social										
Fuel poverty alleviation (reduceddemand for energy)	X		X	X	X		X	X		firado Herrero et al. (2012b); Healy (2004); Liddell and Morris (2010); Hills (2011); Ürge-Vorsatz and firado Herrero (2012)
Fuel poverty alleviation (in cases ofincreases in the cost of energy)				X				X		GEA (2012); Rao (2013)
energy access (high investment costs needed, etc.)	X		X	X	X		X	X		GEA (2012); for a more in-depth discussion please see Section 7.9.1
Noise impact, thermal comfort	X	X	X	X	X	X				jakob (2006); Stoecklein and Skumatz (2007)
Increased productive time for women and children (for replaced traditional cookstoves)	X			X			X	X		Reddy et al. (2000); Lambrou and Piana (2006); Hutton et al. (2007); Anenberg et al. (2013); Wodon and Blackden (2006)
Rebound effect								X		Greening et al. (2000); Sorrell (2007); Hens et al. (2009); Sorrell et al. (2009); Druckman et al. (2011); †rge-Vorsatz et al. (2012a)
Health/Environmental										
Health impact due to:										
Reduced outdoor pollution	X	X	X	X	X	X	X			Levy et al. (2003); Aunan et al. (2004); Mirasgedis et al. (2004); Chen et al. (2007); Crawford-Brown et al. (2012); Milner et al. (2012); see Section
Reduced indoor pollution	X			X			X	X		Bruce et al. (2006); Zhang and Smith (2007); Duflo et al. (2008);WHO (2009); Wilkinson et al. (2009); Howden-Chapman and Chapman (20 2); Milner et al. (20 2);
Improved indoor environmental conditions	X	X	X	X	X	X				Risk (2002); Singh et al. (2010b); Howden-Chapmanand Chapman (2012); Milner et al. (2012)
fuel poverty alleviation	X		X	X	X		X			Tirado Herrero et al. (2012b); Healy (2004); Liddell and Morris(2010); Hills (2011); Ürge-Vorsatz and firado Herrero (2012)
Insufficient ventilation (sick buildingsyndrome), sub-standard energy efficiency technologies,etc.	X	X	X	X	X		X			Risk (2002); GEA (2012); Milner et al. (2012)
Ecosystem Impact	X	X	X	X	X	X	X	X	X	Aunan et al. (2004); Mirasgedis et al. (2004); †rge-Vorsatz et al. (2009); Cam (2012)
Reduced water consumptionand sewage production	X	X	X	X	X	X	X			Kats et al. (2005); Bansal et al. (2011)
Urban heat island effect	X		X	X	X	X		X		Cam (2012); Xu et al. (2012b); see Sections 9.5 and 12.8

10.2 Annex 2: Overview of DIN Norms and VDI Guidelines Identified by [43] that Address the Urban Built Environment, Organized by the Area and Scale of application (as of early 2023)

Climate impact / Hazard (from [36, 85, 135])	Norm, guideline, or recommendation	Key Urban sector addressed as per IPCC [85]	Climate change consideration
	Latest update	climate change strategy	Application scale
floods, flash floods and increase in ground water levels	DIN 1986-Entwässerungsanlagen für Gebäude und Grundstücke Teil 100: Bestimmungen in Verbindung mit DIN EN 752 und DIN EN 12056	Water, wastewater, and sanitation systems	The standard details the methodology to produce a certification for protection against flooding
	2016	Adaptation	Building
	DIN EN 752 Entwässerungssysteme außerhalb von Gebäuden – Kanalmanagement; deutsche Fassung	Water, wastewater, and sanitation systems	The impacts of climate change should be taken into consideration to ensures that the sewer system will continue to meet performance criteria over the design life of the system
	2017	Adaptation	Neighbourhood, District
Extreme precipitation	DIN 1986-Entwässerungsanlagen für Gebäude und Grundstücke Teil 100: Bestimmungen in Verbindung mit DIN EN 752 und DIN EN 12056	Water, wastewater, and sanitation systems	The values used for determining the precipitation levels and amounts has been updated with the KOSTRA-DWD-2010 (Coordinated heavy

			precipitation regionalization and evaluation published by the German Meteorological Service), Nevertheless this data is now obsolete as KOSTRA-DWD-2023 has been updated
	2016	Adaptation	Building
	DIN EN 752 Entwässerungssysteme außerhalb von Gebäuden – Kanalmanagement; deutsche Fassung	Water, wastewater, and sanitation systems	The norm asks to consider possible changes in rainfall levels due to climate change.
	2017	Adaptation	Neighbourhood, District
Warming Trend (Indoor climate)	DIN V 18599-10 Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung - Teil 10: Nutzungsrandbedingungen, Klimadaten	Energy	The climate data used in the test reference year has been updated in 2010 to take the climate change into account
	2018	Mitigation	Building

	VDI 4710 Meteorological data for the building services t,x correlations from 1991 to 2005 for 15 climatic zones in Germany	Energy	The correlation tables for the outdoor-air temperature (t) and water vapour content (x) have been updated to take the impacts of climate change into account
	2011	Adaptation and Mitigation	Building
	VDI 6018 Cooling in building services Planning, construction, and operation	Energy	The VDI list four indicators to measure the environmental impact of the cooling system
	2018	Mitigation	Building
Warming Trend (Urban climate) Vegetations in settlements	VDI 3787: Environmental meteorology Human biometeorological requirements in the framework of recreation, prevention, therapy, and rehabilitation	Human wellbeing and organization	The guideline takes into account the expected increase in heat stress due to climate change in its uniform quality standards for bioclimate, air quality and noise
	2010	Adaptation	Neighbourhood, District
Cross cutting issues	VDI 3785 Environmental meteorology Methods and presentation of investigations relevant for planning urban climate	Cross cutting	The standard purpose a systematic and standardized presentation for urban climate change analysis maps
	2008	Adaptation	Neighbourhood, District

10.3 Annex 3: Assessing the Inclusion of Climate Change Adaptation Measures in the 3.0 Generation of Buildings Performance Requirements.

Table 26: Rating of the 3.0 generation performance requirements adaptation to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems	DIN 1986-Entwässerungsanlagen für Gebäude und Grundstücke Teil 100: Bestimmungen in Verbindung mit DIN EN 752 und DIN EN 12056	3	The DIN 1986 standard details a methodology to produce a certification for protection against flooding
Green and blue infrastructure	-	0	
Energy systems	-	0	
Transportation and mobility	-	0	
Communication systems	-	0	
Human wellbeing and organization	-	0	

Table 27: Rating of the 3.0 generation performance requirements adaptation to the climate change hazard of heavy precipitation.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of heavy precipitation		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	§ 13 of the GEG require achieving a minimum of envelope air tightness, Moreover, § 11 the GEG requires the use of DIN 4108-3 which offer protection against rain	1	An air tight envelope can reduce the risk of water vapour condensation inside the construction [137]
Water, wastewater, and sanitation systems	DIN EN 752 Entwässerungssysteme außerhalb von Gebäuden – Kanalmanagement; deutsche Fassung	2	The values used for determining the precipitation levels and amounts has been updated with the KOSTRA-DWD-2010 (Coordinated heavy precipitation regionalization and evaluation published by the German Meteorological Service), Nevertheless this data is now obsolete as KOSTRA-DWD-2020 is used from 2023 onwards
Green and blue infrastructure	-	0	
Energy systems	-	0	
Transportation and mobility	-	0	
Communication systems	-	0	
Human wellbeing and organization	-	0	

Table 28: Rating of the 3.0 generation performance requirements adaptation to the climate change hazard of storm and wind.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind hazard		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	§ 13 of the GEG require achieving a minimum of envelope air tightness	1	An air tight envelope can improve the durability of the construction elements and increase the resilience against wind and storm hazard[137]
Water, wastewater, and sanitation systems	-	0	Storms can cause a distribution to water supply and wastewater systems[300]
Green and blue infrastructure	-	0	
Energy systems	§ 13 of the GEG require achieving a minimum of envelope air tightness	1	An air tight envelope can improve the energy systems efficiency and increase the resilience against wind and storm [137]hazard
Transportation and mobility	-	0	
Communication systems	-	0	

Human wellbeing and organization	§ 13 of the GEG require achieving a minimum of envelope air tightness	1	An air tight envelope can reduce the occurrence of draft and improve indoor thermal comfort[137]

Table 29:Rrating of the 3.0 generation performance requirements adaptation to the climate change hazard of drought.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage [135]
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems	-	n/a	In most cases, there is no direct risk at the energy sector of the building from the drought.
Transportation and mobility	-	n/a	In most cases, there is no direct risk at the transport sector of the building from the drought.
Communication systems	-	n/a	In most cases, there is no direct risk at the

			communication sector of the building from the drought.
Human wellbeing and organization	-	0	

Table 30: Rating of the 3.0 generation performance requirements adaptation to the climate change hazard of warming trend and heatwave.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	Building law, Norm or VDI guidelines name	Rating	
Structures	§ 11 and § 18 of the GEG Mindestwärmeschutz	2	The thermal insulation values outlined GEG requirements can greatly improve the building's resilience to heatwave[25, 104]
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	VDI 4710 Meteorological data for the building services t,x correlations from 1991 to 2005 for 15 climatic zones in Germany	3	The correlation tables for the outdoor-air temperature (t) and water vapour content (x) have been updated to take the impacts of

			climate change into account
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	-	0	electronic components are susceptible to overheating and an increase in temperature can result in a reduced lifespan and cascading failure [301, 302].
Human wellbeing and organization	The §14 of the GEG require the buildings to adhere to the minimum summer heat protection values outlines in the DIN (4108-2:2013-02) Wärmeschutz und Energie-Einsparung in Gebäuden – Teil 2: Mindestanforderungen an den Wärmeschutz	1	The DIN 4108 uses a simple, static method to determine the building thermal performance in the summer that doesn't take the impact of climate change into account

10.4 Annex 4: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of the DGNB NKW (Neubau Kleine Wohngebäude), Version 2013 Label

Table 31: Rating of the DGNB NKW adaptation performance requirements to the climate change hazard of hazard flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	DGNB Indicator	Rating	
Structures	Site 1.2.3 flood	0	The Site 1.2.3 results do not influence greatly, if any the building total score and is informative in nature. Moreover, the indicator is calculated using historical data that do not take the effects of climate change into account
	TEC 1.6 – recycling and disposal concept		The ease of dismantling the building's technical and envelope components can improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take the maintenance and retrofitting into account
Water, wastewater, and sanitation systems	-	0	

Green and blue infrastructure	ENV 2.3 – land consumption	2	The indicator encourages brown filed development with compensation measures as well as the reduction of soil sealing.
	SOC 1.6 – 1.2 green roofs		Although the use of green roofs is encouraged, the indicators is qualitative, and not compulsory.
Energy systems	TEC 1.6 – recycling and disposal concept	0	The ease of dismantling the building's technical and envelope components can improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take the maintenance and retrofitting into account
Transportation and mobility	Site 1.2.3 Quality of the road connection,	0	The topic is relevant to many climate hazards, however, the indicator's results do not influence greatly, if any the building total score and is of informative nature
	Site 1.2.2 cycle paths		
	Site 1.2.1 Accessibility of the public transport stop		
Communication systems	TEC 1.6 – recycling and disposal concept	0	The ease of dismantling the building's technical

			and envelope components can improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take the maintenance and retrofitting into account
Human wellbeing and organization	SOC 2.1 barrier free design	1	A barrier free design can reduce the users vulnerability to adverse climate impacts[303]

Table 32: Rating of the DGNB NKW adaptation performance requirements to the climate change hazard of heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of heavy precipitation		Comments
	DGNB NKW Indicator	Rating	
Structures	TEC 1.6 – recycling and disposal concept	0	The ease of dismantling the building's technical and envelope components can improve the building's resilience to adverse climatic impacts. However, the indicator doesn't take the maintenance and retrofitting into account
	TEC 1.3 Air tightness		An air tight envelope can reduce the risk of water vapour condensation inside

			the construction [137]. However, this fullfed by default as it's a GEG requirement. So no points awarded to avoid double counting.
	SOC 1.6 – 2.4 characteristics of the exterior areas		indicator checks if some sort of wind, solar and rain protection are installed in the outside seating areas. Nevertheless, the consideration is rather ambiguous and of marginal effect
Water, wastewater, and sanitation systems	ENV 2.2.1 The water usage index	1	The indicator encourages the use of local rain catchments to reduce the load of heavy precipitation on the wastewater system
Green and blue infrastructure	ENV 2.3 – land consumption	2	The indicator encourages brown filed development with compensation measures as well as the reduction of soil sealing
	SOC 1.6 – 1.2 green roofs		Although the use of green roofs is encouraged, the indicators is qualitative, and not compulsory

Energy systems	TEC 1.6 – recycling and disposal concept	0	The ease of dismantling the building’s technical and envelope components can improve the building’s resilience to adverse climatic impacts. However, the indicator doesn’t take the maintenance and retrofitting into account
Transportation and mobility	Site 1.2.3 Quality of the road connection	0	The topic is relevant to many climate hazards, however, the results do not influence greatly, if any the building total score and are informative in nature
	Site 1.2.2 cycle paths		
	Site 1.2.1 Accessibility of the public transport stop		
Communication systems	TEC 1.6 – recycling and disposal concept	0	The ease of dismantling the building’s technical and envelope components can improve the building’s resilience to adverse climatic impacts. However, the indicator doesn’t take the maintenance and retrofitting into account
Human wellbeing and organization	SOC 2.1 barrier free design	1	A barrier free design can reduce the users vulnerability to adverse climate impacts [303]

	SOC 1.6 – 2.4 characteristics of the exterior areas		indicator checks if some sort of wind, solar and rain protection are installed in the outside seating areas. Nevertheless, the consideration is rather ambiguous and of marginal effect

Table 33: Rating of the DGNB NKW adaptation performance requirements to the climate change storm and wind hazard

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind hazard		Comments
	DGNB NKW Indicator	Rating	
Structures	TEC 1.3 Air tightness	0	An air tight envelope can improve the durability of the construction elements and increase the resilience against wind and storm hazard[137]. However, this fullfed by default as it's a GEG requirement
	Site 1.2.2 Winter Storm, Hazard		The Site 1.2.2 results do not influence greatly, if any the building total score and are informative in nature. Moreover, the indicator is calculated using

			historical data that do not take the effects of climate change into account
Water, wastewater and sanitation systems	-	0	Storms can cause a distribution to water supply and wastewater systems[300]
Green and blue infrastructure	-	0	
Energy systems	TEC 1.3 Air tightness	0	An air tight envelope can improve the energy systems efficiency and increase the resilience against wind and storm hazard[137]. However, this fullfed by default as it's a GEG requirement. no points awarded to avid double counting
Transportation and mobility	Site 1.2.3 Quality of the road connection Site 1.2.2 cycle paths Site 1.2.1 Accessibility of the public transport stop	0	The topic is relevant to many climate hazards, however, the results do not influence greatly, if any the building total score and are informative in nature

Communication systems	-	0	
Human wellbeing and organization	TEC 1.3 Air tightness	0	An air tight envelope can reduce the occurrence of draft and improve indoor thermal comfort[137]. However, this fullfed by default as it's a GEG requirement
	SOC 1.6 – 2.4 characteristics of the exterior areas		indicator checks if some sort of wind, solar and rain protection are installed in the outside seating areas. Nevertheless, the consideration is rather ambiguous and of marginal effect to the total score

Table 34: Rating of the DGNB NKW adaptation performance requirements to the climate change hazard drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	DGNB NKW Indicator	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage[135]
Water, wastewater, and sanitation systems	ENV 2.2.1 The water usage index	2	The indicator requires the use of water saving

			fixture and encourage the use of gray water systems
Green and blue infrastructure	-	0	No KPI found
Energy systems	-	n/a	In most cases, there is no clear relation between the building's energy systems of and drought
Transportation and mobility	-	n/a	In most cases, there is no clear relation between the building's transport sector and drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	-	0	

Table 35: Rating of the DGNB NKW adaptation performance requirements to the climate change hazard of warming trend and heatwaves

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	DGNB NKW Indicator	Rating	
Structures	TEC 1.3.1 specific transmission heat loss	0	By default, the GEGE thermal insulation values outlined GEG requirements must be adhered. The

			thermal insulation values outlined GEG requirements can greatly improve the building's resilience to heatwave[25, 104] . To avoid double counting, no points awarded.
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	-	0	
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	-	0	Electronic components are susceptible to overheating and an increase in temperature can result in a reduced lifespan and cascading failure [301, 302].
Human wellbeing and organization	SOC 1.1.4 operative temperature during the cooling session	2	The indicator asks to use the updated test reference years -

			TRY 2010, and to take into account extreme summer values as well as the urban heat island effect
	SOC 1.6 - 2.3 improve the microclimate		The indicator checks if effort is made to improve the outdoor microclimate such as the use of green façade or the use of highly reflective coatings. Nevertheless, the consideration is rather ambiguous and of marginal effect
	SOC 1.6 – 2.4 characteristics of the exterior areas		indicator checks if some sort of wind, solar and rain protection are installed in the outside seating areas. Nevertheless, the consideration is rather ambiguous and of marginal effect

10.5 Annex 5: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of The Bewertungssystem Nachhaltiger Kleinwohnhausbau (BNK_V1.0) Label.

Table 36: Rating of the BNK adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	BNK Indicator	Rating	
Structures	-	0	
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	3.5.1 – land consumption	1	The indicator encourages the reduction of soil sealing, however, even if 85% of land is sealed. Minimum points will still be awarded by the BNK system
Energy systems	3.2.2 Decentralised generation of regenerative energy	1	the indicator encourages the use of self generated energy, or providing it to third parties nevertheless points can be achieved even if the same requirement of the GEG are meet or slightly exceeded
Transportation and mobility		0	

Communication systems		0	
Human wellbeing and organization	1.7.1 barrier free design	1	A barrier free design can reduce the users vulnerability to adverse climate impacts[303]
	4.2.1 Building documentation including user manual		The indicator asks that the users are provided with instruction on how to use the technical building systems (TBS), water saving and energy saving practices as well as emergency contact numbers

Table 37: Rating of the BNK adaptation requirements to the climate change hazard of heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of heavy precipitation		Comments
	BNK Indicator	Rating	
Structures		0	
Water, wastewater, and sanitation systems	3.4.1 Use of water saving fittings	1	The indicator encourages the use of local rainwater catchments or gray water to reduce the load of heavy precipitation on the wastewater system

Green and blue infrastructure	3.5.1 – land consumption	1	The indicator encourages the reduction of soil sealing, however, even if 85% of land is sealed minimum points will be awarded by the BNK system
Energy systems	3.2.2 Decentralised generation of regenerative energy	1	the indicator encourages the use of self generated energy, or providing it to third parties nevertheless points can be achieved even if the same requirement of the GEG is meet or slightly exceeded
Transportation and mobility	-	0	
Communication systems	-	0	
Human wellbeing and organization	1.7.1 barrier free design	1	A barrier free design can reduce the users vulnerability to adverse climate impacts [303]
	4.2.1 Building documentation including user manual		The indicator asks that the users are provided with instruction on how to use the technical building systems (TBS), water saving and energy saving

			practices as well as emergency contact numbers

Table 38: Rating of the BNK adaptation requirements to the climate change hazard of storm and wind

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind hazard		Comments
	BNK Indicator	Rating	
Structures	-	0	
Water, wastewater, and sanitation systems	-	0	Storms can cause a distribution to water supply and wastewater systems[300]
Green and blue infrastructure	-	0	
Energy systems	3.2.2 Decentralised generation of regenerative energy	1	The indicator encourages the use of self generated energy, or providing it to third parties nevertheless points can be achieved even if the same requirement of the GEG is meet or slightly exceeded
Transportation and mobility			

Communication systems	-	0	
Human wellbeing and organization	4.2.1 Building documentation including user manual	1	The indicator asks that the users are provided with instruction on how to use the technical building systems (TBS), as well as emergency contact numbers
	SOC 2.1 barrier free design		A barrier free design can reduce the users vulnerability to adverse climate impacts [303]

Table 39: Rating of the BNK adaptation requirements to the climate change hazard of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	BNK Indicator	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage[135]
Water, wastewater, and sanitation systems	3.4.1 Use of water saving fittings	2	The indicator requires the use of water saving fixture and encourage the use of gray water systems
Green and blue infrastructure	-	0	
Energy systems	-	n/a	In most cases, there is no clear

			relation between the building's energy systems of and drought
Transportation and mobility	-	n/a	There is no clear relation between the building's transport sector and drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	1.1.2 Drinking water quality.	1	Drought can deteriorate the water quality and cause pipe damage, which may pose health risk to the building users [304]. The indicator addresses this issue partially and indirectly.
	4.2.1 Building documentation including user manual		The indicator asks that the users are provided with instruction on how to use the technical building systems (TBS), water saving and energy saving practices as well as emergency contact numbers

Table 40: Rating of the BNK adaptation requirements to the climate change hazard of warming trend and heatwaves

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	BNK Indicator	Rating	
Structures	-	0	By default, the GEGE thermal insulation values outlined GEG requirements must be achieved. the GEG thermal insulation can greatly improve the building's resilience to heatwave[25, 104]
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	-	0	
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	-	0	Electronic components are susceptible to overheating and an increase in temperature can result in a reduced lifespan and

			cascading failure [301, 302].
Human wellbeing and organization	1.2.1 Summer heat protection	0	The BNK uses DIN (4108-2:2013-02) to evaluate the building performance regarding summer heat protection as the one used in the German EPC. The DIN 4108 doesn’t take the impact of climate change into account. In all this indicator is this fullfed by default as it’s a GEG requirement. No points awarded as to avoid double counting

10.6 Annex 6: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of The Qualitätssiegel Nachhaltiger Wohnungsbau (NaWoh V3.1) label.

Table 41: Rating of the NaWoh adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	NaWoh Indicator	Rating	
Structures	2.2.4-2 Response to increased flood risk	2	The indicator requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	2.2.5 Durability		The indicator includes taking precautions against extreme weather events such as flood, nevertheless, the requirements are descriptive and doesn't allow to evaluate the impact of the applied measures
	2.2.7 Ease of disassembly and recycling		The ease of dismantling the building's envelope components can improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take

			the maintenance and retrofitting into account
Water, wastewater, and sanitation systems	2.2.4-2 Response to increased flood risk	2	Although the indicator requests taking the impact of flood on the water and wastewater systems into account, the requirements are descriptive and doesn't allow to evaluate the impact of the applied measures
	2.2.6 Ease of maintenance/ retrofitting of building technical systems		The indicator includes the ease of maintenance and retrofitting the building's water and wastewater system, which can improve the building's resilience to adverse climatic impacts
Green and blue infrastructure	3.1.3-1– land consumption	2	The indicator encourages brown filed development with compensation measures (green roofs) as well as the reduction of soil sealing
	3.1.3-2 Soil sealing		The indicator encourages reducing soli sealing and using green roofs and rainwater catchments

Energy systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling and retrofitting the building's technical components can improve the building's resilience to adverse climatic impacts [30], nevertheless, the indicator requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	3.2.2 Energy generation for tenants and third parties		The rating system asks to account for locally generated renewable energy that can be exported to the local energy network or used by 3rd parties. This can improve the resilience of the energy systems in case of network supply disruptions due to flood event
Transportation and mobility		0	
Communication systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling the building's technical and envelope

			components can improve the building's resilience to adverse climatic impacts[30]
Human wellbeing and organization	1.3.1 barrier free - access to the buildings and dwellings apartments	2	A barrier free design can reduce the users vulnerability to adverse climate impacts[303]
	2.2.4-2 Response to increased flood risk		The indicator checks if Rules of behaviour are established in case of flood event.
	5.2.3-2 Provision of information to users		The indicator asks that a multilingual information pack is handed for each tenant on their first or re-letting of the dwelling. The information pack shall include aspects about emergency information and security

Table 42: Rating of the NaWoh adaptation requirements to the climate change hazard of heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard heavy precipitation		Comments
	NaWoh Indicator	Rating	
Structures	2.2.2 Structural moisture protection	2	The indicator request to adhering to the requirements of the norm 4108-3(Climate-related moisture

			protection)as well as testing the rain tightness of windows and doors according to the European norm of EN 1027 Moreover, it is required t show proof of adhering to the suggestion of the norm series DIN 18195 Waterproofing of buildings, nevertheless, all these norms are not updated to take the climate change impact of heavy precipitation into account
	2.2.5 Durability		The indicator encourages taking precautions against hail and snow impacts, nevertheless, requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	2.2.3 Air tightness		An air tight envelope can reduce the risk of water vapour condensation inside the construction [137]. However, this fullfed by default as

			it's a GEG requirement. To avoid double counting, no points awarded
	2.2.7 Ease of disassembly and recycling		The ease of dismantling the building's envelope components can improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take the maintenance and retrofitting into account
Water, wastewater, and sanitation systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	1	The indicator includes the ease of maintenance and retrofitting the building's water and wastewater system, which can improve the building's resilience to adverse climatic impacts
Green and blue infrastructure	3.1.3-1– land consumption	2	The indicator encourages brown filed development with compensation measures (green roofs) as well as the reduction of soil sealing
	3.1.3-2 Soil sealing		The indicator encourages reducing soli sealing and using

			green roofs and rainwater catchments
Energy systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling and retrofitting the building's technical components can improve the building's resilience to adverse climatic impacts [30], nevertheless, the indicator requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	3.2.2 Energy generation for tenants and third parties		The rating system asks to account for locally generated renewable energy that can be exported to the local energy network or used by 3rd parties. This can improve the resilience of the energy systems in case of network supply disruptions due to heavy precipitation event
Transportation and mobility	1.1.4-3 Parking facilities for cars	1	The system asks in highest requirement to provide a temporary parking lot

			for deliveries, maintenance and emergency services
	1.1.4-1 Parking facilities for bikes		The system asks for the parking facilities to be protected from the weather
Communication systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling the building's technical and envelope components can improve the building's resilience to adverse climatic impacts[30]
Human wellbeing and organization	1.3.1 barrier free - access to the buildings and dwellings apartments	1	A barrier free design can reduce the users vulnerability to adverse climate impacts[303]
	5.2.3-2 Provision of information to users		The indicator asks that a multilingual information pack is handed for each tenant on their first or re-letting of the dwelling. The information pack shall include aspects about emergency, information, and security

Table 43: Rating of the NaWoh adaptation requirements to the climate change hazard of storm and wind

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard wind and storm		Comments
	NaWoh Indicator	Rating	
Structures	2.2.3 Air tightness	2	An airtight envelope can improve the durability of the construction elements and increase the resilience against wind and storm hazard [207]. However, this fullfed by default as it's a GEG requirement
	2.2.4 -3 Response to increased storm risk		The indicator requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	2.2.5 Durability		The indicator includes taking precautions against storm and wind impacts, nevertheless, requirements are descriptive and doesn't allow to evaluate the effectiveness of the applied measures
	2.2.7 Ease of disassembly and recycling		The ease of dismantling the building's envelope components can

			improve the building's resilience to adverse climatic impacts[30]. However, the indicator doesn't take the maintenance and retrofitting into account
Water, wastewater, and sanitation systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	1	Storms can cause a distribution to water supply and wastewater systems[300]. The indicator includes the ease of maintenance and retrofitting the building's water and wastewater system, which can improve the building's resilience to adverse climatic
Green and blue infrastructure	-	0	
Energy systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling and retrofitting the building's technical components can improve the building's resilience to adverse climatic impacts [30], nevertheless, the indicator requirements are descriptive and doesn't allow to

			evaluate the effect of the applied measures
	3.2.2 Energy generation for tenants and third parties		The rating system asks to account for locally generated renewable energy that can be exported to the local energy network or used by 3rd parties. This can improve the resilience of the energy systems in case of network supply disruptions due to storm event
Transportation and mobility	1.1.4-3 Parking facilities for cars	1	The system asks in highest requirement to provide a temporary parking lot for deliveries, maintenance, and emergency services
	1.1.4-1 Parking facilities for bikes		The system asks for the parking facilities to be protected from the weather
Communication systems	2.2.6 Ease of maintenance/ retrofitting of building technical systems	2	The ease of dismantling the building's technical and envelope components can improve the building's resilience to adverse climatic impacts[30]

Human wellbeing and organization	1.3.1 barrier free - access to the buildings and dwellings apartments	1	A barrier free design can reduce the users vulnerability to adverse climate impacts[303]
	5.2.3-2 Provision of information to users		The indicator asks that a multilingual information pack is handed for each tenant on their first or re-letting of the dwelling. The information pack shall include aspects about emergency, information, and security

Table 44: Rating of the NaWoh adaptation requirements to the climate change hazard of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	NaWoh Indicator	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage[135]
Water, wastewater, and sanitation systems	ENV 2.2.1 The water usage index	2	The indicator requires the use of water saving fixture and encourage the use of gray water systems
Green and blue infrastructure	3.1.3-2 Soil sealing	0	The indicator encourages reducing soli

			sealing and using green roofs. Which can increase the resilience to drought, nevertheless, a positive influence on drought depends on the type of the planted greenery[305].
Energy systems	-	n/a	In most cases, there is no clear relation between the buildings. energy systems of and drought
Transportation and mobility	-	n/a	There is no clear relation between the building's transport sector and drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	5.2.3-2 Provision of information to users	1	The indicator asks that a multilingual information pack is handed for each tenant on their first or re-letting of the dwelling. The information pack shall include

			aspects water saving

Table 45: Rating of the NaWoh adaptation requirements to the climate hazard of warming trend and heatwaves

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	NaWoh Indicator	Rating	
Structures	-	0	By default, the GEGE thermal insulation values outlined GEG requirements must be meet. the GEG thermal insulation can greatly improve the building’s resilience to heatwave[25, 104]
Water, wastewater, and sanitation systems	-	n/a	-
Green and blue infrastructure	-	0	
Energy systems	-	0	
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	-	0	Electronic components are susceptible to overheating and an increase in temperature can result in a reduced lifespan and

			cascading failure [211, 212].
Human wellbeing and organization	1.2.1 Summer heat protection	0	The NaWoh uses DIN (4108-2:2013-02) to evaluate the building performance regarding summer heat protection as the one used in the German EPC. The DIN 4108 doesn’t take the impact of climate change into account. In all this indicator is this fullfed by default as it’s a GEG requirement. No points awarded as to avoid double counting.

10.7 Annex 7: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of in the Smart Readiness Indicator (SRI) Label.

Table 46: Rating of the SRI adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	SRI Indicator	Rating	
Structures	DE-4 Reporting information regarding performance of dynamic building envelope systems	1	Position of each product, fault detection, predictive maintenance, real-time & historical sensor data can improve the reliability of the system and resilience against adverse climate impacts

Water, wastewater, and sanitation systems	DHW-3 Report information regarding domestic hot water performance	0	The SRI include the requirement of Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault, nevertheless its limited to hot water supply and not wastewater and freshwater
	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults		central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the water and sanitation systems in face network disturbance due climate impact [306]. but it's limited to the active parts of the system.

Green and blue infrastructure	-	0	
Energy systems	H-1c Storage and shifting of thermal energy	2	The SRI include the requirement of HW storage vessels controlled based on external signals (from BACS or grid), which can server domestic need in case of network disturbances
	H-1f Thermal Energy Storage (TES) for building heating (excluding TABS)		The SRI include the requirement of Heat storage capable of flexible control through grid signals (e.g. DSM), which can server domestic need in case of network disturbances
	H-4 Flexibility and grid interaction		The SRI include the requirement of optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control), which can prepare the system in advance to adverse climate impact
	H-3 Report information regarding heating system performance		The SRI include the requirement of Central or remote reporting of performance evaluation including forecasting and

			predictive management and fault detection. This can improve the resilience of the heating system in fact of climate change adverse impact [306]
	C-1g control of Thermal Energy Storage (TES) operation		Cold storage capable of flexible control through grid signals (e.g. DSM). This can improve the resilience of the cooling system in face network disturbance
	C-3 Report information regarding cooling system performance		Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the cooling system in fact of climate change adverse impact
	C-4 Flexibility and grid interaction		Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control). This can improve the resilience of the

			energy system in face network disturbance
	E-3 Storage of (locally generated) electricity		On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-2 Reporting information regarding local electricity generation		Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-8 Support of(micro)grid operation modes		Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode). This can improve the

			resilience of the energy system in face network disturbance due climate impact
Transportation and mobility	-	0	
Communication systems	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	The SRI demand a central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the TBS system in face network disturbance due climate impact[306]
Human wellbeing and organization	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	This can improve the resilience of the TBS system in face network disturbance due climate impact

Table 47: Rating of the SRI adaptation requirements to the climate change hazard of heavy precipitation.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard heavy precipitation		Comments
	SRI Indicator	Rating	
Structures	DE-1 Window solar shading control	1	Predictive blind control (e.g. based on weather forecast). This can spare the blinds from getting damaged
	DE-4 Reporting information regarding performance of dynamic building envelope systems		Position of each product, fault detection, predictive maintenance, real-

			time & historical sensor data (wind, lux, temperature…). This can improve the reliability of the system and resilience against adverse climate impacts
Water, wastewater, and sanitation systems	DHW-3 Report information regarding domestic hot water performance	1	The SRI include the requirement of Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection, nevertheless its limited to hot water supply and not wastewater and freshwater
	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults		central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the water and sanitation systems in face network disturbance due climate impact[306]
Green and blue infrastructure	-	0	
Energy systems	H-1c Storage and shifting of thermal energy	2	The SRI include the requirement of HW storage vessels

			controlled based on external signals (from BACS or grid), which can server domestic need in case of network disturbances
	H-1f Thermal Energy Storage (TES) for building heating (excluding TABS)		The SRI include the requirement of Heat storage capable of flexible control through grid signals (e.g. DSM),), which can server domestic need in case of network disturbances
	H-4 Flexibility and grid interaction		The SRI include the requirement of optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control), which can prepare the system in advance warning of adverse climate impact
	H-3 Report information regarding heating system performance		The SRI include the requirement of Central or remote reporting of performance evaluation including forecasting and predictive management and fault detection. This can improve the

			resilience of the heating system in fact of climate change adverse impact
	C-1g control of Thermal Energy Storage (TES) operation		Cold storage capable of flexible control through grid signals (e.g. DSM). This can improve the resilience of the cooling system in face network disturbance
	C-3 Report information regarding cooling system performance		Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the cooling system in fact of climate change adverse impact
	C-4 Flexibility and grid interaction		Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control). This can improve the resilience of the energy system in face network disturbance
	E-3 Storage of (locally generated) electricity		On site storage of energy (e.g. electric

			battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-2 Reporting information regarding local electricity generation		Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-8 Support of(micro)grid operation modes		Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode). This can improve the resilience of the energy system in face network disturbance due climate impact

	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults		central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the energy system in face network disturbance due climate impact
Transportation and mobility	-	0	
Communication systems	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the energy system in face network disturbance due climate impact
Human wellbeing and organization	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	an advanced central automatic control system with fault detection and diagnosing capabilities can help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building

Table 48: Rating of the SRI adaptation requirements to the climate change hazard of wind and storm

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard wind and storm		Comments
	SRI Indicator	Rating	
Structures	DE-1 Window solar shading control	1	Predictive blind control (e.g. based on weather forecast). This can spare the blinds from getting damaged
	DE-4 Reporting information regarding performance of dynamic building envelope systems		Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature…). This can improve the reliability of the system and resilience against adverse climate impacts
Water, wastewater, and sanitation systems	DHW-3 Report information regarding domestic hot water performance	1	The SRI include the requirement of Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection nevertheless its limited to hot water supply and not wastewater and freshwater
	MC-4 Detecting faults of technical building systems and		central indication of detected faults and alarms for all relevant

	providing support to the diagnosis of these faults		TBS, including diagnosing functions. This can improve the resilience of the sanitation system in face network disturbance due climate impact
Green and blue infrastructure	-	0	
Energy systems	H-1c Storage and shifting of thermal energy	3	The SRI include the requirement of HW storage vessels controlled based on external signals (from BACS or grid), which can server domestic need in case of network disturbances
	H-1f Thermal Energy Storage (TES) for building heating (excluding TABS)		The SRI include the requirement of Heat storage capable of flexible control through grid signals (e.g. DSM),), which can server domestic need in case of network disturbances
	H-4 Flexibility and grid interaction		The SRI include the requirement of optimized control of heating system based on local predictions and grid signals (e.g. through model predictive control), which can prepare the system in advance warning of

			adverse climate impact
	H-3 Report information regarding heating system performance		The SRI include the requirement of Central or remote reporting of performance evaluation including forecasting and predictive management and fault detection. This can improve the resilience of the heating system in fact of climate change adverse impact
	C-1g control of Thermal Energy Storage (TES) operation		Cold storage capable of flexible control through grid signals (e.g. DSM). This can improve the resilience of the cooling system in face network disturbance
	C-3 Report information regarding cooling system performance		Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the cooling system in fact

			of climate change adverse impact
	C-4 Flexibility and grid interaction		Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control). This can improve the resilience of the energy system in face network disturbance
	E-3 Storage of (locally generated) electricity		On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-2 Reporting information regarding local electricity generation		Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the energy system in face network disturbance due climate impact

	E-8 Support of(micro)grid operation modes		Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode). This can improve the resilience of the energy system in face network disturbance due climate impact
	H-1c Storage and shifting of thermal energy		The SRI include the requirement of HW storage vessels controlled based on external signals (from BACS or grid), which can server domestic need in case of network disturbances
	H-1f Thermal Energy Storage (TES) for building heating (excluding TABS)		The SRI include the requirement of Heat storage capable of flexible control through grid signals (e.g. DSM),), which can server domestic need in case of network disturbances
	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the

			energy system in face network disturbance due climate impact
Transportation and mobility	-	0	
Communication systems	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the technical system in face network disturbance due climate impact
Human wellbeing and organization	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	an advanced central automatic control system with fault detection and diagnosing capabilities can help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building

Table 49: Rating of the SRI adaptation requirements to the climate change hazard of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	SRI Indicator	Rating	
Structures	-	0	Drought can increase the risk of

			soil settling damage [135]
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems	-	n/a	There is no direct risk at the energy sector of the building from the drought
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	-	0	

Table 50: Rating of the SRI adaptation requirements to the climate change hazard of warming trend and heatwaves

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	SRI Indicator	Rating	
Structures	DE-1 Window solar shading control	1	Predictive blind control (e.g. based on weather forecast). This can improve the building climatic performance

	DE-4 Reporting information regarding performance of dynamic building envelope systems		Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature…). This can improve the reliability of the system and resilience against adverse climate impacts
	DE-2 Window open/closed control, combined with HVAC system		The SRI require an automated mechanical window opening based on room sensor data In addition to Centralized coordination of operable windows, e.g., to control free natural night cooling. This can reduce the risk of overheating.
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	V-3 Free cooling with mechanical ventilation system		This can reduce the load on the grid and energy consumption, hence

			improving the reliability
	C-2a Generator control for cooling		This can reduce the load on the grid and energy consumption, hence improving the reliability
	C-1g Control of Thermal Energy Storage (TES) operation		This can reduce the load on the grid and energy consumption, hence improving the reliability
	C-4 Flexibility and grid interaction		Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control). This can improve the resilience of the energy system in face network disturbance
	E-4 Optimizing self-consumption of locally generated electricity		Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability.
	E-3 Storage of (locally generated) electricity		On site storage of energy (e.g. electric battery or thermal storage) with

			controller optimising the use of locally generated electricity and possibility to feed back into the grid. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-2 Reporting information regarding local electricity generation		Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the energy system in face network disturbance due climate impact
	E-8 Support of(micro)grid operation modes		Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode). This can improve the resilience of the energy system in face network

			disturbance due climate impact
	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults		central indication of detected faults and alarms for all relevant TBS, including diagnosing functions. This can improve the resilience of the energy system in face network disturbance due climate impact
	C-3 Report information regarding cooling system performance		Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection. This can improve the resilience of the cooling system in fact of climate change adverse impact
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults	1	electronic components are susceptible to overheating and an increase in

			temperature can result in a reduced lifespan and cascading failure [301, 302].
Human wellbeing and organization	V-2c Heat recovery control: prevention of overheating"	1	
	C-1b Emission control for TABS (cooling mode)		This type of advanced control system can help to improve the energy efficiency and comfort of a building, while also reducing the cost of cooling. Using an intermittent operation and room temperature feedback control system can also help to improve the overall sustainability of the building.
	MC-4 Detecting faults of technical building systems and providing support to the diagnosis of these faults		an advanced central automatic control system with fault detection and diagnosing capabilities can help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building

10.8 Annex 8: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of in The SmartScore Label

Table 51: Rating of the SmartScore adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	A BIM model of the building can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time in an event of exposures to climate hazard[307]
Water, wastewater, and sanitation systems	UF5:6 Predictive maintenance	0	When the building's systems are able to predict when a piece of equipment might fail this helps maintenance work to be performed before faults occur which increase the resilience of the building systems [306]. However, this remain limited to the active part of the system and not its passive elements
	UF5:3 System alarms		The indicator demand the users to be alerted in real

			time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building. However, this remain limited to the active part of the system and not its passive elements
Green and blue infrastructure	-	0	
Energy systems	UF5:3 System alarms	1	The indicator demand the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF5:6 Predictive maintenance		When the building's systems are able to predict when a piece of equipment might fail this helps maintenance work to be performed before faults occur[306]

Transportation and mobility	-	0	
Communication systems	UF5:3 System alarms	2	The indicator demand the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	TF1:1 Physical diversity of tenant connectivity routes		The indicator demand that smart workplace solutions can be enabled via a resilient and reliable internet connection protected from single points of failure. The physical separation can protect against a variety of external factors, such as fire, flooding. Moreover, it can also help to reduce the risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in another component
	TF3:1 Network infrastructure		the indicator aims to ensure that the critical components

			for the distribution of smart building capabilities are located in the best possible environment for their stable and ongoing operation. a reliable, resilient, and secure network that allows the efficient monitoring and control of all edge devices and connected systems.
	TF3:4 Wireless networks		The indicator aim to ensure that reliable, resilient and secure networks is in place. This allows the efficient monitoring and control of all relevant IoT and edge devices
Human wellbeing and organization	UF5:3 System alarms	2	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF6:4 Emergency alerts		building users can react to a potential security and health

			risks in the building and surrounding area. This can help the users taking protective measures[140]

Table 52: Rating of the SmartScore adaptation requirements to the climate change hazard of heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of heavy precipitation		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	A BIM model of the building can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time in an event of exposures to climate hazard [239]
Water, wastewater, and sanitation systems	UF5:6 Predictive maintenance	0	When the building's systems can predict when a piece of equipment might fail this helps maintenance work to be performed before faults occur which increase the resilience of the building systems [238]. However, this remains limited to the active part of the system and not its passive elements.

	UF5:3 System alarms		The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building. However, this remains limited to the active part of the system and not its passive elements
Green and blue infrastructure	-	0	
Energy systems	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF5:6 Predictive maintenance		When the building's systems can predict when a piece of equipment might fail this helps maintenance work to

			be performed before faults occur
Transportation and mobility	-	0	
Communication systems	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	TF1:1 Physical diversity of tenant connectivity routes		The indicator demand that smart workplace solutions can be enabled via a resilient and reliable internet connection protected from single points of failure. The physical separation can protect against a variety of external factor and can also help to reduce the risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in other components
	TF3:1 Network infrastructure		the indicator aim to ensure that the

			critical components for the distribution of smart building capabilities are located in the best possible environment for their stable and ongoing operation. a reliable, resilient, and secure network that allows the efficient monitoring and control of all edge devices and connected systems.
	TF3:4 Wireless networks		The indicator aims to ensure that reliable, resilient and secure networks is in place. This allows the efficient monitoring and control of all relevant IoT and edge devices
Human wellbeing and organization	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF6:4 Emergency alerts		building users can react to a potential

			security and health risks in the building and surrounding area. This can help the users taking protective measures[140]

Table 53: Rating of the SmartScore adaptation requirements to the climate change hazard of storm and wind hazard

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind hazard		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	A BIM model of the building can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time in an event of exposures to climate hazard[307].
Water, wastewater, and sanitation systems	UF5:6 Predictive maintenance	1	When the building's systems can predict when a piece of equipment might fail this helps maintenance work to be performed before faults occur which increase the resilience of the building systems [238]. However, this remains limited to the active part of the system and not its passive elements

	UF5:3 System alarms		The indicator demand the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building. However, this remains limited to the active part of the system and not its passive elements
Green and blue infrastructure	-	0	
Energy systems	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF5:6 Predictive maintenance		When the building's systems are able to predict when a piece of equipment might fail this helps maintenance work to

			be performed before faults occur
Transportation and mobility	-	0	
Communication systems	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	TF1:1 Physical diversity of tenant connectivity routes		The indicator demands a resilient and reliable internet connection protected from single points of failure. The physical separation can protect against a variety of external factor and can also help to reduce the risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in other components
	TF3:1 Network infrastructure		the indicator aim to ensure that the critical components for the distribution of

			smart building capabilities are located in the best possible environment for their stable and ongoing operation. a reliable, resilient, and secure network that allows the efficient monitoring and control of all edge devices and connected systems.
	TF3:4 Wireless networks		The indicator aims to ensure that reliable, resilient and secure networks is in place. This allows the efficient monitoring and control of all relevant IoT and edge devices
Human wellbeing and organization	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
	UF6:4 Emergency alerts		building users can react to a potential security and health

			risks in the building and surrounding area

Table 54: Rating of the SmartScore adaptation requirements to the climate change hazard of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	Drought can increase the risk of soil settling damage [135], A BIM model of the building can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time in an event of exposures to climate hazard[239]
Water, wastewater, and sanitation systems	UF3:3 Water reporting	1	Having a solution to track the building's water consumption in real time can help reduce consumption
Green and blue infrastructure	-	0	
Energy systems	-	n/a	There is no direct risk at the energy sector of the building from the drought

Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	UF3:3 Water reporting	1	users can receive early warnings of problems with the water supply
	UF6:4 Emergency alerts		building users can react to a potential drought alert[140]

Table 55: Rating of the SmartScore adaptation requirements to the climate change hazard of warming trend and heatwaves

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwaves		Comments
	SmartScore Indicator	Rating	
Structures	TF2:5 Asset information model	1	A BIM model of the building can reduce the building vulnerability in the pre disaster and post disaster phases and reduce the down time in an event of exposures to climate hazard [239].
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater

			sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	UF5:3 System alarms	1	The indicator demands the users to be alerted in real time when a building system fails. This help building operators to quickly identify and resolve issues with TBS, minimize downtime, and ensure the safe and efficient operation of the building
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	UF5:3 System alarms	1	electronic components are susceptible to overheating and an increase in temperature can result in a reduced lifespan and cascading failure [301, 302].
Human wellbeing and organization	UF2:3 Wellbeing reporting	1	The indicator asks to provide the user and operator with a solution to track

			and report on the building's wellbeing key performance indicators in real-time
	UF2:5 Comfort optimization		The indicator asks to provide the user and with a solution to optimize comfort conditions in common spaces

10.9 Annex 9: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of The WiredScore Label

Table 56: Rating of the WiredScore adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	WiredScore Indicator	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems	E2 Tenant backup power	1	Provision of designated space to tenants and service providers, for the placement of private generator / backup power can increase the resilience of the power system and reduce downtime
Transportation and mobility	-	0	
Communication systems	A1 In-building mobile performance	3	A reliable reception of mobile can help ensure that emergency alert text messages are received
	A3 Backbone cabling		Provision of building-owned backbone cabling for the distribution of systems and services throughout the building can increase the resilience

			of the communication system and reduce down time
	A5 Riser in-building technology equipment space		The extra space can increase the resilience of the communication system and reduce down time
	B1 Building Infrastructure - Points of Entry		WiredScore requires the use of underground pathways. This can reduce the risk of network disruption in case of climate change related event.
	B2 Points of entry diversity		single point of entry are vulnerable to failure. The physical separation can protect against a variety of external factor and can also help to reduce the risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in other components
	C4 Leak / flood protection for telecommunications room		The indicator demand that telecommunications room is set above the floodplain level local to the room, and protection measures are in place against internal leaks / flooding
	D3 Riser diversity		connectivity services are susceptible to disruption in the vertical service routes by factors such as in-building construction work, maintenance, fire,

			and flooding. Riser diversity provides a physical separation of incoming services at the riser level, which improves the resiliency of business-critical service.
	E1 Telecommunications equipment backup power		Provision of a building backup power source with capabilities to supply emergency power can protect telecommunications feeds / equipment from power failures due to either mains network outages or damage caused by extreme weather events
Human wellbeing and organization	A1 In-building mobile performance	1	A reliable reception of mobile signals can help ensure that emergency alert text messages are received. This can help the users taking protective measures[140]

Table 57: Rating of the WiredScore adaptation requirements to the climate change hazard of hazard heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard heavy precipitation		Comments
	WiredScore Indicator	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems			
Green and blue infrastructure	-	0	
Energy systems	E2 Tenant backup power	1	Provision of designated space to tenants and

			service providers, for the placement of private generator / backup power can increase the resilience of the power system and reduce downtime
Transportation and mobility	-	0	
Communication systems	A1 In-building mobile performance	3	A reliable reception of mobile can help ensure that emergency alert text messages are received
	A3 Backbone cabling		Provision of building-owned backbone cabling for the distribution of systems and services throughout the building can increase the resilience of the communication system and reduce down time
	A5 Riser in-building technology equipment space		The extra space can increase the resilience of the communication system and reduce down time
	B1 Building Infrastructure - Points of Entry		WiredScore requires the use of underground pathways. This can reduce the risk of network disruption in case of climate change related event.
	B2 Points of entry diversity		single point of entry are vulnerable to failure. The physical separation can protect against a variety of external factor and can also help to reduce the

			risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in other components
	D3 Riser diversity		connectivity services are susceptible to disruption in the vertical service routes by factors such as in-building construction work, maintenance, fire, and flooding. Riser diversity provides a physical separation of incoming services at the riser level, which improves the resiliency of business-critical service.
	E1 Telecommunications equipment backup power		Provision of a building backup power source with capabilities to supply emergency power can protect telecommunications feeds / equipment from power failures due to either mains network outages or damage caused by extreme weather events
Human wellbeing and organization	A1 In-building mobile performance	1	A reliable reception of mobile signals can help ensure that emergency alert text messages are received . This can help the users taking protective measures[140]

Table 58: Rating of the WiredScore adaptation requirements to the climate change hazard of storm and wind hazard

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind hazard		Comments
	WiredScore Indicator	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems			
Green and blue infrastructure	-	0	
Energy systems	E2 Tenant backup power	1	Provision of designated space to tenants and service providers, for the placement of private generator / backup power can increase the resilience of the power system and reduce downtime
Transportation and mobility	-	0	
Communication systems	A1 In-building mobile performance	3	A reliable reception of mobile can help ensure that emergency alert text messages are received
	A3 Backbone cabling		Provision of building-owned backbone cabling for the distribution of systems and services throughout the building can increase the resilience of the communication system and reduce down time
	A5 Riser in-building technology equipment space		The extra space can increase the resilience of the communication system and reduce down time

	B Building Infrastructure - Points of Entry		WiredScore requires the use of underground pathways. This can reduce the risk of network disruption in case of climate change related event.
	B2 Points of entry diversity		single point of entry are vulnerable to failure. The physical separation can protect against a variety of external factor and can also help to reduce the risk of cascading failures, where the failure of one infrastructure component triggers a series of failures in other components
	D3 Riser diversity		connectivity services are susceptible to disruption in the vertical service routes by factors such as in-building construction work, maintenance, fire, and flooding. Riser diversity provides a physical separation of incoming services at the riser level, which improves the resiliency of business-critical service.
	E1 Telecommunications equipment backup power		Provision of a building backup power source with capabilities to supply emergency power can protect telecommunications feeds / equipment from power failures due to either

			mains network outages or damage caused by extreme weather events
Human wellbeing and organization	A1 In-building mobile performance	1	A reliable reception of mobile signals can help ensure that emergency alert text messages are received. This can help the users taking protective measures[140]

Table 59: Rating of the WiredScore adaptation requirements to the climate change hazard of drought.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	WiredScore Indicator	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage [135]
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems	-	n/a	There is no direct risk at the energy sector of the building from the drought
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the

			building from the drought
Human wellbeing and organization	A1 In-building mobile performance	1	A reliable reception of mobile signals can help ensure that emergency alert text messages are received

Table 60: Rating of the WiredScore adaptation requirements to the climate change hazard of warming trend and heatwave.

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwave		Comments
	WiredScore Indicator	Rating	
Structures	-	0	
Water, wastewater, and sanitation systems	-	n/a	There is no direct risk at the water and wastewater sector of the building from the heatwaves
Green and blue infrastructure	-	0	
Energy systems	E2 Tenant backup power	1	Provision of designated space to tenants and service providers, for the placement of private generator / backup power can increase the resilience of the power system and reduce downtime
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the heatwaves
Communication systems	E1 Telecommunications equipment backup power	3	Provision of a building backup power source with capabilities to supply emergency power can protect

			telecommunications feeds / equipment from power failures due to either mains network outages or damage caused by extreme weather events
	C5 Climate control in telecommunications room		The indicator demand that climate control in a telecommunications room is provided by active air conditioning or mechanically forced ventilation
	A1 In-building mobile performance		A reliable reception of mobile can help ensure that emergency alert text messages are received
	A3 Backbone cabling		Provision of building-owned backbone cabling for the distribution of systems and services throughout the building can increase the resilience of the communication system and reduce down time
	A5 Riser in-building technology equipment space		The extra space can increase the resilience of the communication system and reduce down time
Human wellbeing and organization	A1 In-building mobile performance	1	A reliable reception of mobile signals can help ensure that emergency alert text messages are received. This can help the users taking protective measures[140]

10.10 Annex 10: Assessing the Inclusion of Climate Change Adaptation Measures in the Performance Requirements of The R2S Label

Table 61: Rating of the R2S adaptation requirements to the climate change hazard of flooding, flash floods and groundwater rise

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard flooding, flash floods and groundwater rise		Comments
	R2S indicator	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems		0	
Transportation and mobility	-	0	
Communication systems	CO5.1 Building wiring redundancy capability	2	The indicator demands a prevention of single point of failure. This increases the system resilience and reduce downtime
	RE2.1 Building Smart Network Resilience Capacity		The R2S require that the Smart Network supports network failure detection and self-healing mechanism. This can reduce downtime and improve the resilience of the system

	CO1.2 Redundancy of connection of the building to any type of external wired link		The R2S demand provision for redundant internal routing of external operator links. This can help increases the system resilience and reduce downtime
	IN2.2 Integration into the digital model (BIM)		The indicator requires that the digital model (BIM) integrates information about the location and state of equipment and sensors of the network
	CO5.2 Infrastructure power supply		The indicator demand to guarantee the continuity of Smart Network services, in the event of an indefinite power outage. This increases the system resilience to climate impact
Human wellbeing and organization	CO3.1 Nature and quality of wireless networks	1	The R2S require that the building has adequate coverage inside its various spaces, for the main radio networks (GSM, Wi-Fi, etc.). A reliable reception of mobile and Wi-Fi signals can help ensure that

			emergency alert text messages are received. This can help the users taking protective measures[140]

Table 62: Rating of the R2S adaptation requirements to the climate change hazard of heavy precipitation

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard heavy precipitation		Comments
	R2S indicator	Rating	
Structures	0	0	
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems		0	
Transportation and mobility	-	0	
Communication systems	CO5.1 Building wiring redundancy capability	2	The indicator demands a prevention of single point of failure. This increases the system resilience and reduce downtime
	RE2.1 Building Smart Network Resilience Capacity		The R2S require that the Smart Network supports network failure detection and self-healing mechanism. This can reduce downtime and improve the resilience of the system

	CO1.2 Redundancy of connection of the building to any type of external wired link		The R2S demand provision for redundant internal routing of external operator links. This help increases the system resilience and reduce downtime
	IN2.2 Integration into the digital model (BIM)		The indicator requires that the digital model (BIM) integrates information about the location and state of equipment and sensors of the network
	CO5.2 Infrastructure power supply		The indicator demand to guarantee the continuity of Smart Network services, in the event of an indefinite power outage This help increase the system resilience to climate impact
Human wellbeing and organization	CO3.1 Nature and quality of wireless networks	1	The R2S require that the building has adequate coverage inside its various spaces, for the main radio networks (GSM, Wi-Fi, etc.). A reliable reception of mobile and Wi-Fi signals can help ensure that emergency alert text

			messages are received. This can help the users taking protective measures[140]

Table 63: Rating of the R2S adaptation requirements to the climate change hazard of storm and wind

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of storm and wind		Comments
	R2S indicator	Rating	
Structures	-	0	
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems		0	
Transportation and mobility	-	0	
Communication systems	CO5.1 Building wiring redundancy capability	2	The indicator demands a prevention of single point of failure. This help increases the system resilience and reduce downtime
	RE2.1 Building Smart Network Resilience Capacity		The R2S require that the Smart Network supports network failure detection and self-healing mechanism. This can reduce downtime and improve the resilience of the system

	CO1.2 Redundancy of connection of the building to any type of external wired link		The R2S demand provision for redundant internal routing of external operator links. This help increase the system resilience and reduce downtime
	IN2.2 Integration into the digital model (BIM)		The indicator requires that the digital model (BIM) integrates information about the location and state of equipment and sensors of the network
	CO5.2 Infrastructure power supply		The indicator demand to guarantee the continuity of Smart Network services, in the event of an indefinite power outage This increase the system resilience to climate impact.
Human wellbeing and organization	CO3.1 Nature and quality of wireless networks	1	The R2S require that the building has adequate coverage inside its various spaces, for the main radio networks (GSM, Wi-Fi, etc.). A reliable reception of mobile and Wi-Fi signals can help ensure that emergency alert text

			messages are received. This can help the users taking protective measures[140]

Table 64: Rating of the R2S adaptation requirements to the climate change hazard of drought

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of drought		Comments
	R2S Indicator	Rating	
Structures	-	0	Drought can increase the risk of soil settling damage [135]
Water, wastewater, and sanitation systems	-	0	
Green and blue infrastructure	-	0	
Energy systems	-	n/a	In most cases, there is no direct risk at the energy sector of the building from the drought
Transportation and mobility	-	n/a	There is no direct risk at the transport sector of the building from the drought
Communication systems	-	n/a	There is no direct risk at the communication sector of the building from the drought
Human wellbeing and organization	CO3.1 Nature and quality of	1	The R2S require that the building

	wireless networks		has adequate coverage inside its various spaces, for the main radio networks (GSM, Wi-Fi, etc.). A reliable reception of mobile and Wi-Fi signals can help ensure that emergency alert text messages are received. This can help the users taking protective measures[140]

Table 65: Rating of the R2S adaptation requirements to the climate change hazard of warming trend and heatwave

Selected Key Urban sector as defined by the IPCC [85]	Performance requirements and Rating systems for the climate hazard of warming trend and heatwave		Comments
	R2S indicator	Rating	
Structures	-	0	
Water, wastewater, and sanitation systems	-	n/a	
Green and blue infrastructure	-	0	
Energy systems		0	
Transportation and mobility	-	n/a	

Communication systems	RE2.1 Building Smart Network Resilience Capacity	2	The R2S require that the Smart Network supports network failure detection and self-healing mechanism. This can reduce downtime and improve the resilience of the system
	IN2.2 Integration into the digital model (BIM)		The indicator requires that the digital model (BIM) integrates information about the location and state of equipment and sensors of the network
	CO5.2 Infrastructure power supply		The indicator demand to guarantee the continuity of Smart Network services, in the event of an indefinite power outage This increase the system resilience to climate impact
Human wellbeing and organization	CO3.1 Nature and quality of wireless networks	1	The R2S require that the building has adequate coverage inside its various spaces, for the main radio networks (GSM, Wi-Fi, etc.). A reliable reception of mobile and Wi-Fi signals can

			help ensure that emergency alert text messages are received. This can help the users taking protective measures[140]

10.11 Annex 11: Selected List of Climate Adaptation Tools and Platforms in Germany

Platform / Publication	Primary use	Web address
Deutsches klimaportal from the german weather service	The German Climate Portal provides interested users with current data and facts, latest applications, and information on projects and studies relating to climate and climate change throughout Germany and in the federal states	https://www.deutscheskimaportal.de/
Software tool CAESAR.	Simulation of cascade effects infrastructure failure	https://www.emi.fraunhofer.de/en/business-units/security/research/analysis-of-the-cascade-effects-in-supply-networkssoftwaretool-c.html
Klimalotse	Guide to Adaptation to the Consequences of Climate Change for Municipalities	https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse#Einf%C3%BChrung
Tatenbank	A repository of measures for adapting to the consequences of climate change in Germany. With search and filter options, and examples of good adaptation practice and	https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/tatenbank
Projekte und Studien	The aim of the database is to provide an overview of the research landscape on the topic of the consequences of climate change and adaptation to these consequences	https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/projekte-studien
KLiVO	The German Climate Precaution Portal bundles data and information on climate change as well as services for targeted adaptation to climate impacts	https://www.klivoportal.de/DE/Home/home_node.html
Stadt.Klima.Natur	A platform that contains a approaches for action, best practice examples" and providing targeted information and activating the municipalities in Bavaria	https://www.stadtklimanatur.bayern.de/
Bayerisches Klimainformationssystem	An internet information system with data on climate change and climate adaptation available in all Bavarian municipalities	https://klimainformationssystem.bayern.de/
UFZ Drought Monitor	The UFZ Drought Monitor provides daily information on drought and soil moisture throughout Germany.	https://www.ufz.de/index.php?en=37937
Länderübergreifendes Hochwasser Portal	The Transnational Flood Portal is a website to inform the population about flood warning situations in Germany and Switzerland as well as the border region of all German neighboring countries.	https://www.hochwasserzentralen.de/
Regionalen Klimaatlas Deutschland	Provide information about the current state of research on possible future climate change.	https://www.regionaler-klimaatlas.de/

10.12 Annex 12: Results of the IQRe Qualitative Vulnerability Assessment Obtained During the Site Visits of The Three-Case Study Sites.

10.12.1 Qualitative Vulnerability Assessment of The Gaustark Building.

Gebäude: JUZ Margaretendamm		Kommentare, Beobachtungen
Allge-meine Infos	Alter Gebäude(technik)	- Ca. in den 1940er-Jahren gebaut - Davor Lederfabrik - Seit 1977 Nutzung als Jugendzentrum - Halle 1977 neu angebaut (aktuell Skatehalle)
	Altlasten (z.B. Radon, Offenliegende Mineralwolle, Asbest) -> Gebäudescreening, Schadstoffanalyse	- Dach: Im ungenutzten Teil liegt Dämmung am Boden offen
	Raumluftqualität (z.B. Feuchteproblem, Ecken, Anschlüsse)	-EG: Angenehm im Sommer, heizt sich bei Nutzung vieler Personen stark auf, im Winter mit Heizungsnutzung ok - 1./2.OG Räume werden sehr warm im Sommer, können teils daher nicht genutzt werden (z.B. Büro, Sportraum) - Skatehalle: Wird sehr warm (auch im Winter)
	Zustand Kellerräume (nutzbar? feucht?)	- Räume im Keller werden als Proberaum, Tonstudio, WCs und Lagerräume genutzt - Größtenteils trochen, Decke im Herren-WC feucht
	Erfahrungen mit Wettereinflüssen (z.B. Hochwasser)	- Kanal fließt schlecht ab, Rückstau führt zu Verstopfungen
Bauwerk Bau-konstruk-tion KG 300	Gründung (KG 320)	
	Außenwände (KG 330)	- massive, 60cm dicke Außenwände im Altbau
	Außentüren und -fenster (KG 334) --> Verglasung	- Fensterfront Richtung Süd-West ausgerichtet - Kastenfenster, 2-Fach-Verglasung, alte Fenster, nur ganz zu öffnen/ kein Kipp möglich - Eingang Barrierefrei

		Kommentare, Beobachtungen
Bauwerk Bau-konstruk-tion KG 300	Sonnenschutz (KG 338)	- Skatehalle: Rolläden außen - Altbau: im EG innenliegender Sonnenschutz - Altbau 1./2.OG: Kein Sonnenschutz außer an zwei Fenstern zur Terrasse
	Innenwände (KG 340)	
	Decken (KG 350)	- teilweise feuchte Stellen (z.B. Herren-WC)
	Dächer (KG 360)	Hauptgebäude: - Schrägdach - nicht gedämmt, Dachfenster und Dach vor ca. 6-8 Jahren neu gemacht - gewisse Dämmung ist vorhanden, entspricht aber nicht den Standards Skatehalle
	Grundkonstruktion (KG 380)	- Skatehalle hat Holzbalkenträger, man könnte Dämmung anbringen
Bauwerk Techni-sche Anlagen KG 400	Wasser (Abwasser-, Wasseranlagen KG 410)	- Hebeanlage für Abwasser - Auch Regenwasser fließt in Hebeanlage, führt bei starkem Regen zu Verstopfung
	Wärmeversorgungs-anlagen (KG 420)	-Fernwärme - Heizkörper
	Lüftungsanlagen (KG 431)	- Lüftung nicht in Betrieb, nicht angeschlossen - Technik der Lüftung in Kellerraum, bei Regen läuft Wasser in diesen Raum

		Kommentare, Beobachtungen
Bauwerk Techni-sche Anlagen KG 400	Klima- und Kälteanlagen (KG 433/435)	- nicht vorhanden
	Starkstromanlagen (KG 440)	
	Gebäudeautomation (KG 480)	- nicht vorhanden
	Zerlegbarkeit/ Abmontierbarkeit der Gebäudetechnik Gebäudetechnik an verschiedenen Stellen: Dach, Keller, Räume, Revisionsschächte/ -klappen	
Außen-anlagen KG 500	Geländeflächen (KG 510)	- keine Grünflächen - nur sehr kleiner "Hinterhof", wird mit neuer Brandschutztreppe bebaut
	Befestigte Flächen (KG 520)	- Gesamter Außenbereich gepflastert
	Baukonstruktionen in Außenanlagen (KG 530)	- Terrasse im 1. OG morsch, darf nicht genutzt werden, keine Verschattung - Großes Interesse, Terrasse bespielen zu können - Brandschutztreppe ist geplant
	Technische Anlagen in Außenanlagen (KG 540)	- nicht vorhanden - Stromkabel über Loch in Außenwand nach außen verlegt

		Kommentare, Beobachtungen
Gesund-heit und Wohl-befinden	Fernmelde- und Informationstechnische Anlagen (KG 450)	- 2. OG kann wegen Brandschutz nicht genutzt werden (aktuell Lager) - Keine Rauchmelder oder Brandmeldeanlage
	Betriebliche/ Organisatorische Abläufe	- Wenig Wissen über Gebäude - Keine Fluchtpläne
Urbane Umge-bung	- Direkt an vielbefahrener Straße gelegen - In Wohngebiet - "Weit weg von allem", am Ende der Straße - 10 Minuten zu Fuß von Schule entfernt	
Transport	- Bushaltestelle vor der Tür - Keine Fahrradstellplätze	

Notizen
- Im Mai von neuer Leitung übernommen
- Zielgruppe: 10-15 Jährige, Kerngruppe 13 Jahre
- Nutzung: ca. 15 Jugendliche konstant, 2-3 unregelmäßig
- Offener Treff
- Kontakt mit der Schule
- Keller und DG nicht nutzbar, 2. OG wegen Brandschutz nicht nutzbar

10.12.2 Qualitative Vulnerability Assessment of The JO Building

Gebäude: JO		Kommentare, Beobachtungen
Allgemeine Infos	Alter Gebäude(technik)	2017
Allgemeine Infos	Altlasten (z.B. Radon, Offenliegende Mineralwolle, Asbest) -> Gebäudescreening, Schadstoffanalyse	keine
Allgemeine Infos	Raumluftqualität (z.B. Feuchteproblem, Ecken, Anschlüsse)	- Sehr warm im Sommer wenn Rollos nicht geschlossen - muss im Winter stark geheizt werden um nicht auszukühlen
Allgemeine Infos	Zustand Kellerräume (nutzbar? feucht?)	- Kein Keller vorhanden
Allgemeine Infos	Erfahrungen mit Wettereinflüssen (z.B. Hochwasser)	- Bei Regen sind die Toilettenfenster undicht
Bauwerk Baukonstruktion KG 300	Gründung (KG 320)	- Steht auf Kiesbett - Kiesstreifen um den Containerbau
Bauwerk Baukonstruktion KG 300	Außenwände (KG 330)	- Schwarz (!) - heizt sich extrem stark auf -> Verbrennungsgefahr
Bauwerk Baukonstruktion KG 300	Außentüren und -fenster (KG 334) --> Verglasung	- Thermofenster Richtung Westen - Fenster WCs undicht (Hausmeister kontaktiert) - Tür geht nicht automatisch zu, bleibt dadurch oft offen stehen

		Kommentare, Beobachtungen
Bauwerk Baukonstruktion KG 300	Sonnenschutz (KG 338)	- Außenrollos an allen Fenstern - Rolläden haben unterschiedliche Qualität, biegen sich zum Teil bei Hitze oder klemmen
Bauwerk Baukonstruktion KG 300	Innenwände (KG 340)	
Bauwerk Baukonstruktion KG 300	Decken (KG 350)	- Akustikdecke hat mehrere Löcher durch Billard-Kös
Bauwerk Baukonstruktion KG 300	Dächer (KG 360)	- Flachdach leicht abgeschrägt - Gedämmt - Regenrinne mit Fallrohren auf Rückseite des Gebäudes
Bauwerk Baukonstruktion KG 300	Grundkonstruktion (KG 380)	- Containerbau bestehend aus 9 Elementen
Bauwerk Technische Anlagen KG 400	Wasser (Abwasser-, Wasseranlagen KG 410)	- Leitung über die Schule (200m entfernt)
Bauwerk Technische Anlagen KG 400	Wärmeversorgungsanlagen (KG 420)	- Versorgung über die Schule - Pelletheizung - Computergesteuert - Ohne Heizung extrem kalt im Winter
Bauwerk Technische Anlagen KG 400	Lüftungsanlagen (KG 431)	- Keine mechanische Lüftung - Dunstabzugshaube in Küche zieht nach außen ab

		Kommentare, Beobachtungen
Bauwerk Technische Anlagen KG 400	Klima- und Kälteanlagen (KG 433/435)	- nicht vorhanden
Bauwerk Technische Anlagen KG 400	Starkstromanlagen (KG 440)	
Bauwerk Technische Anlagen KG 400	Gebäudeautomation (KG 480)	- nicht vorhanden
Bauwerk Technische Anlagen KG 400	Zerlegbarkeit/ Abmontierbarkeit der Gebäudetechnik Gebäudetechnik an verschiedenen Stellen: Dach, Keller, Räume, Revisionsschächte/ -klappen	- für Dauernutzung gedacht - keine eigene Gebäudetechnik, Anschluss über Schule, leicht rückbaubar
Außenanlagen KG 500	Geländeflächen (KG 510)	- Kiesstreifen um Container - Gepflasterter Vorplatz ohne Verschattung - keine eigenen Grünflächen - Zwei Palmen in Töpfen als einzige "Schattenspender"
Außenanlagen KG 500	Befestigte Flächen (KG 520)	- Mehrere Sportplätze um Gebäude verteilt
Außenanlagen KG 500	Baukonstruktionen in Außenanlagen (KG 530)	- Keine festen Anlagen - Kein fester Sonnenschutz vorhanden - Aktuell improvisiertes Textil-Segel
Außenanlagen KG 500	Technische Anlagen in Außenanlagen (KG 540)	-nicht vorhanden

		Kommentare, Beobachtungen
Gesundheit und Wohlbefinden	Fernmelde- und Informationstechnische Anlagen (KG 450)	- Glasfaserinternet - Demnächst Hotspot im Rahmen von Smart City Bamberg - Keine Rauchmelder oder Brandmeldeanlage
Gesundheit und Wohlbefinden	Betriebliche/ Organisatorische Abläufe	- Steckdosen vor Fenstern angebracht, wo man schlecht hinkommt, weil Dinge davor stehen - Auf gegenüberliegender Seite der Fenseterfront keine Steckdosen
Urbane Umgebung	- Vielzahl an Sportplätzen - Wiesen ohne Verschattung - Keine Bäume - Öffentliche Autostellplätze an der Straße	
Transport	- Mehrere Bushaltestellen in der Nähe - Fahrradstellplätze - Lage eher versteckt, aber bekannt bei den Jugendlichen	

Notizen
- Zielgruppe: 6-16 Jahre, Hauptgruppe 8-14 Jahre
- Lage versteckt, aber gute Bekanntheit, über Generationen gewachsen, "Geheimtipp" da Sportplätze länger offen als auf Schulgelände
- Informeller "Unisport" von Studierenden
- Im Sommer pro Tag 75-100 Leute, im Winter 15-20 Jugendliche pro Tag
- Problem mit Lärmbeschwerden der Anwohner, daher keine befestigte Überdachung/ Sonnenschutz im Außenbereich
- Marke Container ist KB-Container GmbH

10.12.3 Qualitative Vulnerability Assessment of The JUZ Building

Gebäude: JUZ Margaretendamm		Kommentare, Beobachtungen
Allgemeine Infos	Alter Gebäude(technik)	- Ca. in den 1940er-Jahren gebaut - Davor Lederfabrik - Seit 1977 Nutzung als Jugendzentrum - Halle 1977 neu angebaut (aktuell Skatehalle)
	Altlasten (z.B. Radon, Offenliegende Mineralwolle, Asbest) --> Gebäudescreening, Schadstoffanalyse	- Dach: Im ungenutzten Teil liegt Dämmung am Boden offen
	Raumluftqualität (z.B. Feuchteproblem, Ecken, Anschlüsse)	-EG: Angenehm im Sommer, heizt sich bei Nutzung vieler Personen stark auf, im Winter mit Heizungsnutzung ok - 1./2.OG Räume werden sehr warm im Sommer, können teils daher nicht genutzt werden (z.B. Büro, Sportraum) - Skatehalle: Wird sehr warm (auch im Winter)
	Zustand Kellerräume (nutzbar? feucht?)	- Räume im Keller werden als Proberaum, Tonstudio, WCs und Lagerräume genutzt - Größtenteils trochen, Decke im Herren-WC feucht
	Erfahrungen mit Wettereinflüssen (z.B. Hochwasser)	- Kanal fließt schlecht ab, Rückstau führt zu Verstopfungen
Bauwerk Baukonstruktion KG 300	Gründung (KG 320)	
	Außenwände (KG 330)	- massive, 60cm dicke Außenwände im Altbau
	Außentüren und -fenster (KG 334) ---> Verglasung	- Fensterfront Richtung Süd-West ausgerichtet - Kastenfenster, 2-Fach-Verglasung, alte Fenster, nur ganz zu öffnen/ kein Kipp möglich - Eingang Barrierefrei

		Kommentare, Beobachtungen
Bauwerk Baukonstruktion KG 300	Sonnenschutz (KG 338)	- Skatehalle: Rolläden außen - Altbau: im EG innenliegender Sonnenschuzt - Altbau 1./2.OG: Kein Sonnenschutz außer an zwei Fenstern zur Terrasse
	Innenwände (KG 340)	
	Decken (KG 350)	- teilweise feuchte Stellen (z.B. Herren-WC)
	Dächer (KG 360)	Hauptgebäude: - Schrägdach - nicht gedämmt, Dachfenster und Dach vor ca. 6-8 Jahren neu gemacht - gewisse Dämmung ist vorhanden, entspricht aber nicht den Standards
	Grundkonstruktion (KG 380)	- Skatehalle hat Holzbalkenträger, man könnte Dämmung anbringen
Bauwerk Technische Anlagen KG 400	Wasser (Abwasser-, Wasseranlagen KG 410)	- Hebeanlage für Abwasser - Auch Regenwasser fließt in Hebeanlage, führt bei starkem Regen zu Verstopfung
	Wärmeversorgungsanlagen (KG 420)	-Fernwärme - Heizkörper
	Lüftungsanlagen (KG 431)	- Lüftung nicht in Betrieb, nicht angeschlossen - Technik der Lüftung in Kellerraum, bei Regen läuft Wasser in diesen Raum

		Kommentare, Beobachtungen
Bauwerk Technische Anlagen KG 400	Klima- und Kälteanlagen (KG 433/435)	- nicht vorhanden
	Starkstromanlagen (KG 440)	
	Gebäudeautomation (KG 480)	- nicht vorhanden
	Zerlegbarkeit/ Abmontierbarkeit der Gebäudetechnik Gebäudetechnik an verschiedenen Stellen: Dach, Keller, Räume, Revisionsschächte/ -klappen	
Außenanlagen KG 500	Geländeflächen (KG 510)	- Keine Verschattung auf Terrasse - Einige hohe Bäume, die für EG Schatten spenden - Keine Grasflächen - Kiesbereich
	Befestigte Flächen (KG 520)	- Bei Regen sammelt sich Wasser im Pflasterbereich
	Baukonstruktionen in Außenanlagen (KG 530)	- Überdachung Terrasse aus Glas, keine Verschattung möglich - 3 Tische mit Bänken - Steinblock als Sitzelement - Ein Kunstelement
	Technische Anlagen in Außenanlagen (KG 540)	- Beleuchtung der Terrasse vorhanden - Kein Strom an Auto- bzw. Fahrradstellplätzen vorhanden

		Kommentare, Beobachtungen
Gesundheit und Wohlbefinden	Fernmelde- und Informationstechnische Anlagen (KG 450)	- Internet: Leitung von Stadtwerken, nicht auf aktuellem Stand - Keine Rauchmelder oder Brandmeldeanlage
	Betriebliche/ Organisatorische Abläufe	- Fluchtpläne nicht professionell erstellt (durch Praktikant) und fehlerhaft
Urbane Umgebung	- Gefälle zum Gebäude hin - 100m von Ufer entfernt - Großer kostenpflichtiger Parkplatz auf anderer Straßenseite	
Transport	- Bushaltestelle <5 Minuten entfernt - Zentral gelegen - 3 Autostellplätze	- Mehrere Fahrradstellplätze - Lastenfahrrad

Notizen

'- Zielgruppe: 11-18 Jahre und 18-27 Jahre (ältere Gruppe überrepräsentiert)
- Skaten wichtiges Thema
- Herbst/ Winter als Hauptsaison, Mai bis Sommer weniger los (Ferienzeit, Outdoormöglichkeiten als Alternative, starke Hitze in den Räumen)
- 1x im Monat finden Konzerte statt, Raum heizt sich dabei stark auf
- Fenster in Skatehalle sind Verletzungsgefahr, wenn sie geöffnet sind
- 1 barrierefreies WC im EG vorhanden, Zugang getrennt von Hauptgebäude und Skatehalle

10.13 Annex 13: Floor plans and Photo Documentation of the Case Study Sites

10.13.1 JUZ Building Floor Plans

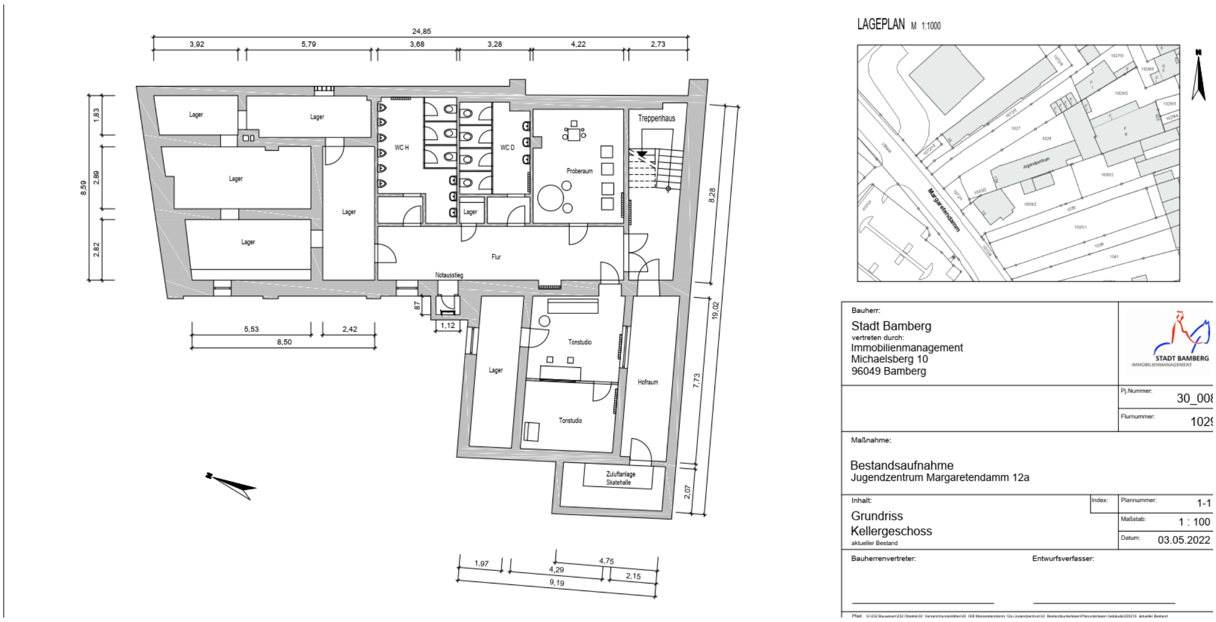


Figure 93: JUZ underground floor plan

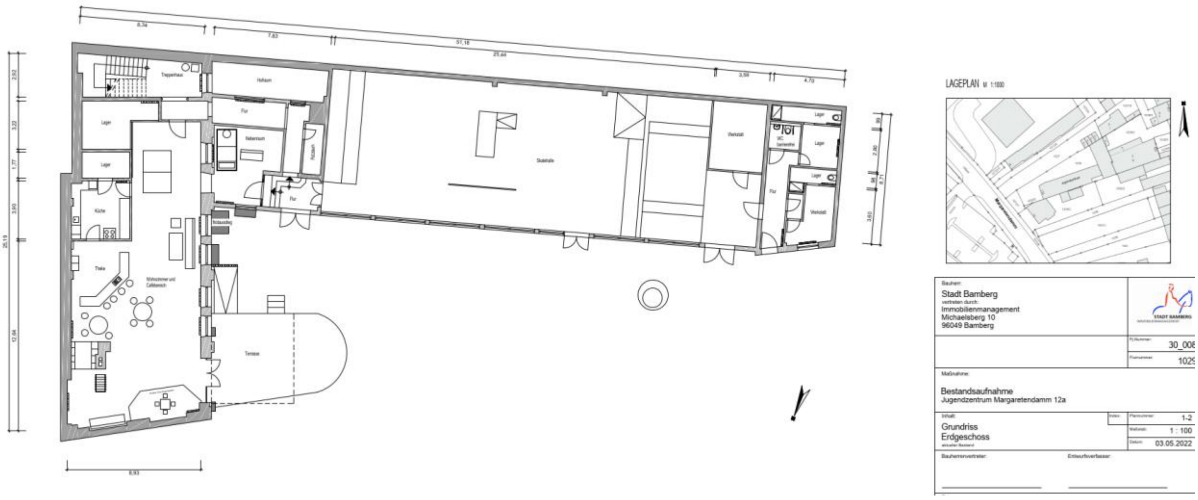


Figure 94: JUZ Ground floor plan

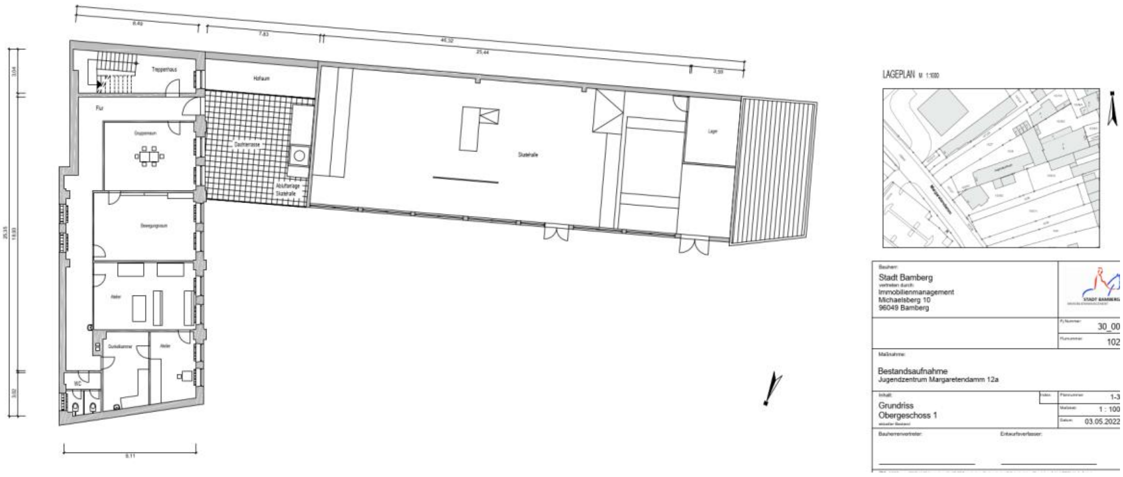


Figure 95:JUZ 1st floor plan

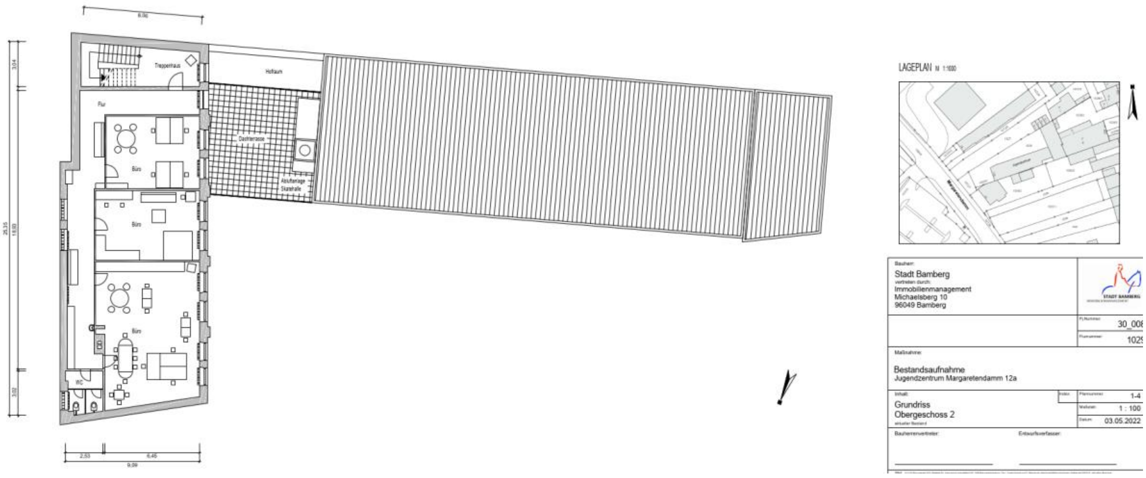


Figure 96: JUZ 2nd floor plan

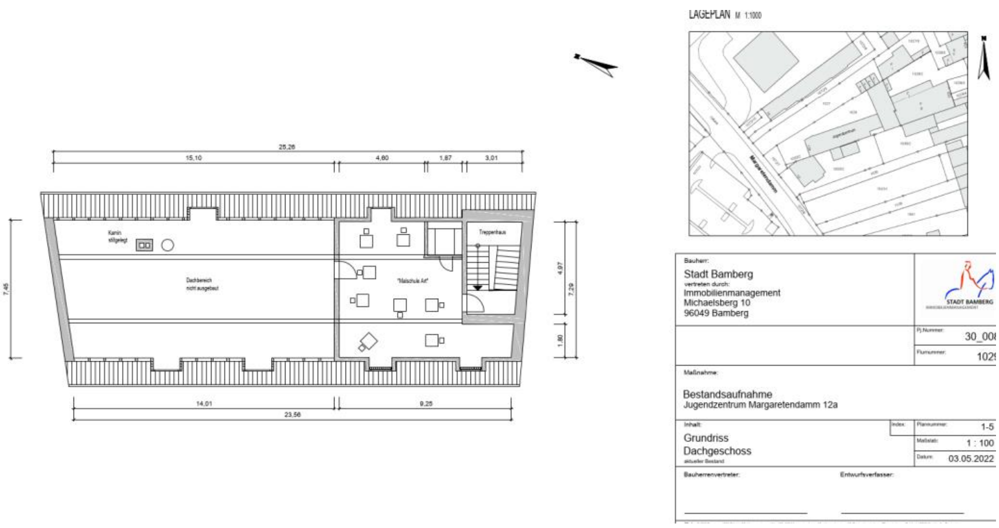


Figure 97: JUZ Attic floor plan

10.13.2 JUZ Building Photo Documentation

	
	
	
Photos showing the exterior of the JUZ youth centre and the attached skating hall, notice JUZ proximity to the river	

10.13.2.1 Structure sector (KG300)

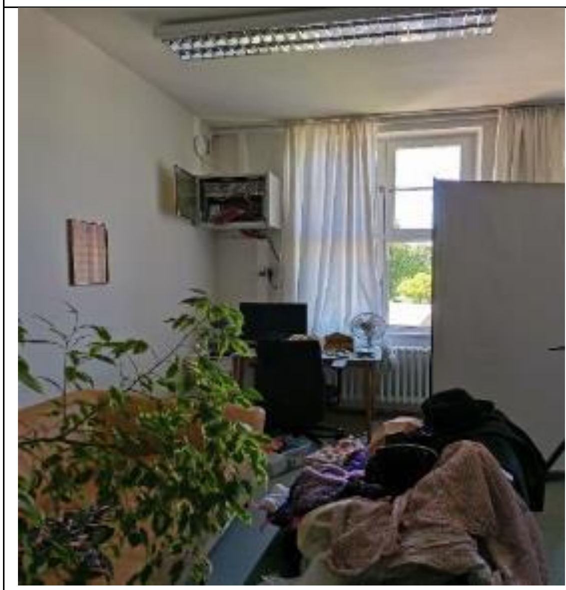



Photos showing the underground hall and part of the envelope impacted with water and moisture damage (relevant for the KPIs B2.1 Envelope moisture and rain protection and B2.6 Water Resistant Materials and finishes)


Photos showing the wall thickness and attic with floor insulation (partially damaged) (relevant to the KPI C1.2 Specific transmission heat loss of the building envelope)

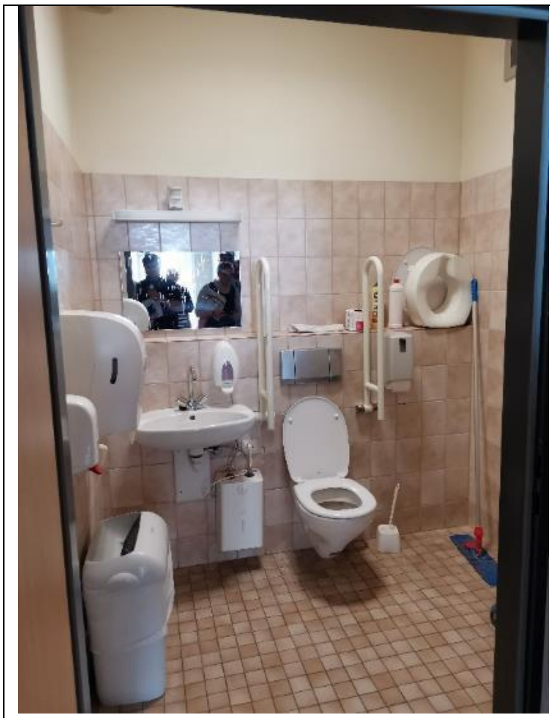

Photos showing the interior of the skate hall (relevant to the KPI C1.2 Specific transmission heat loss of the building envelope and B2.6 Water Resistant Materials and finishes)






Photos showing the limited natural cross ventilation options (relevant for the KPIs C1.4 Efficiency of natural ventilation and C5.1 Natural ventilation in telecommunications / control rooms)

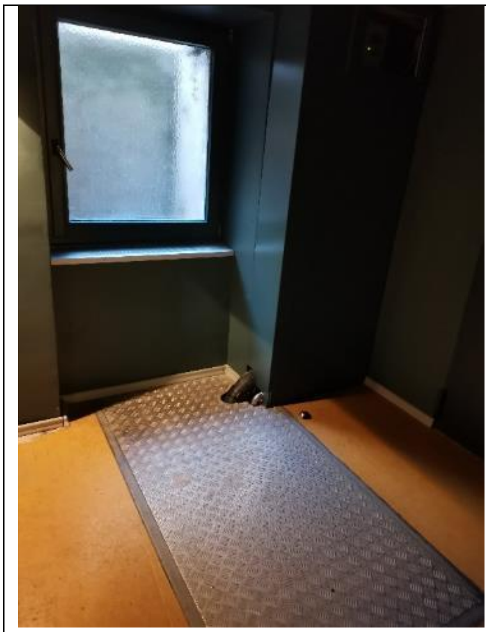
Phots showing the exterior of the envelope of the building (relevant for the KPIs B1.1, Hail and extreme precipitation safe windows and shutters, C1.1Total solar energy transmittance of glazed windows and sunshades, C1.3 Reflectivity of the building envelope and E1.1 Strom anchored external fixtures)

	
	
Limited barrier-free locations in the building, one single toilet located outside of the buildings and require a key (relevant to B1.2Barrier free building)	

Photos showing the cramped situation of the technical pathways and limited access to the technical rooms (relevant to the KPIs B5.3 Protected and diverse technical pathways and B5.4 Ease of access, maintenance of technical systems and rooms)

Photos from the technical rooms showing dampness and water leakage damage to the walls (relevant for the KPIB5.2 Leakage and rain proof technical rooms)

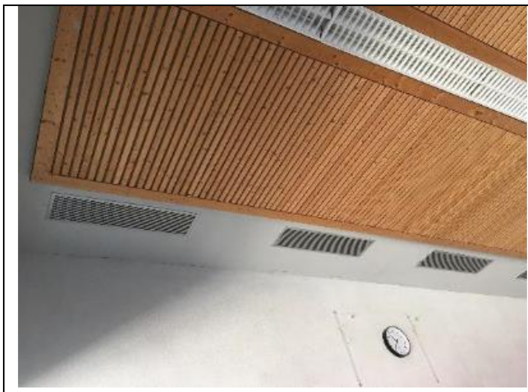
10.13.2.2 Water, wastewater and sanitation systems (KG 370-410)

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Photos showing the submersible sewage lifting pump that handle both waste and rainwater (relevant for KPIs B2.9 Backwater protection and B4.1 Separation of wastewater and rainwater)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">The majority of the toilets are located in the basement, and some are fitted with limited water saving fixtures (relevant for KPIs B2.8Drainage system design and D3.3 Water saving fixture)</td></tr>
</table>

Photos showing the cramped and complicated paths of the rains and wastewater pips as well as the unmaintained gutters (relevant for KPIs B5.2 Ease of maintenance/ retrofitting of Water, wastewater, and sanitation system and E5.1 Strom anchored external water supply and drainage systems)

10.13.2.3 Energy systems (KG 420 to 440)

Not all electrical sockets in the basement retain their original water covers, some are not water resistance, and some cables are totally exposed (relevant for the KPI B1.5Waterproof sockets and switches)

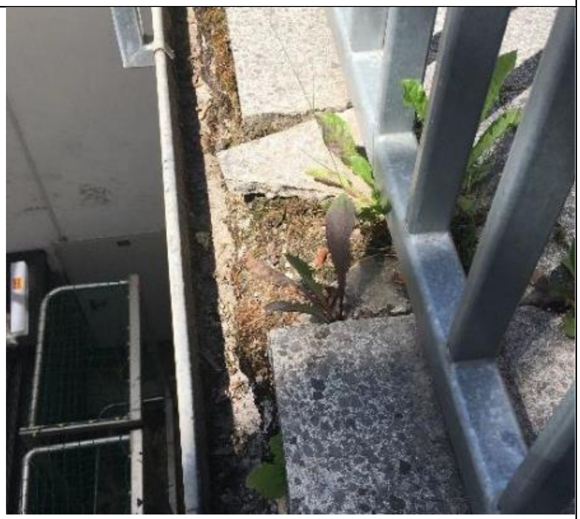
Despite the availability of a ventilation systems, they are not operating (relevant for the KPI C5.2Energy system that are protect from overheating)

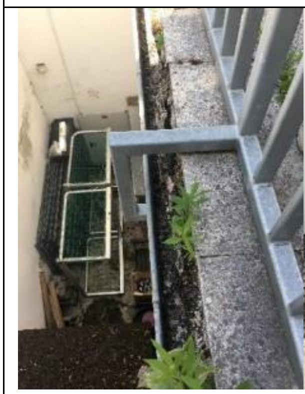
The 230m² roof of the skating hall is not used. If a 200m2 are covered with a PV (η:18%) a yearly energy generation of about 36,000 kWh can be expected, which is 135% of the average yearly energy consumption of the JUZ building (avg. 26,000 kWh.a). That would be more than enough to power the ventilation system, some AC systems as well as acting as emergency backup power system.

10.13.2.4 Wellbeing and Organization

Photos shoing the high internal thermal load of most of the rooms (relvant to the KPI C1.10 Internal loads and internal heat gain)

Emergency plans are not made according to standard, emergency exist in the basement is practically not usable (relevant for the KPIs B1.1 Availability of emergency response plan and evacuation routes for Hail, and extreme precipitation events)





Lack of maintenance resulting into multiple damages to the building technical and non-technical systems (relevant for the KPIs B2.1 maintenance of building structure against extreme precipitation threat and B2.2 maintenance of building technical systems against extreme precipitation threat)

10.13.2.5 Communication systems (KG 450, 480, 630)

	the main server is in one of the working rooms that is already experiencing massive overheating due to lack of solar control and high internal loads (relevant to the KPI the C5.2Climate control in telecommunications room)

10.13.2.6 Urban and spatial environment (KG 510 to 560)

Photos showing the outdoor areas of the JUZ building, notice the slop of the building parameter, the soil sealing and partial shading (relevant for the KPIs B2.12 Site perimeter Slope away from entrances and walking areas, B4.1Permeable Outdoor Surrounding Surfaces, C1.12 Outdoor shaded area , C1.13 Outdoor area provided with cooling elements such as water features, vegetation or fans, C1.14Shading of building(s) by deciduous trees and C1.15 Albedo paving surfaces)

10.13.3 GAUstark Building Floor Plans.

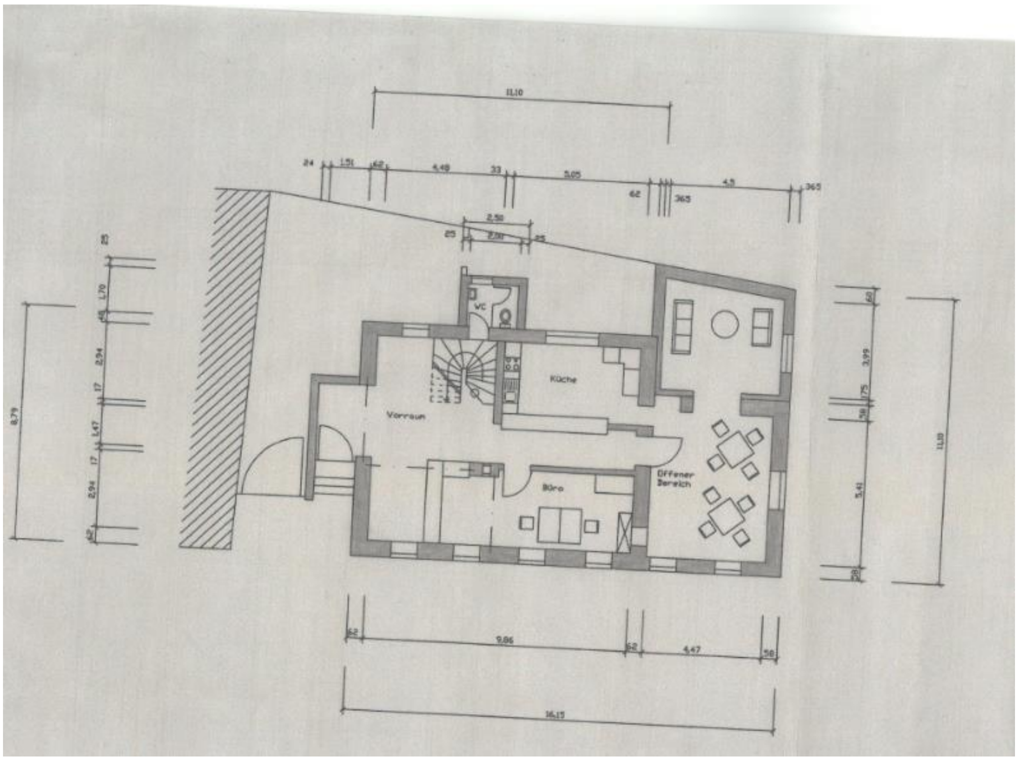


Figure 98: GAUstark Ground floor plan

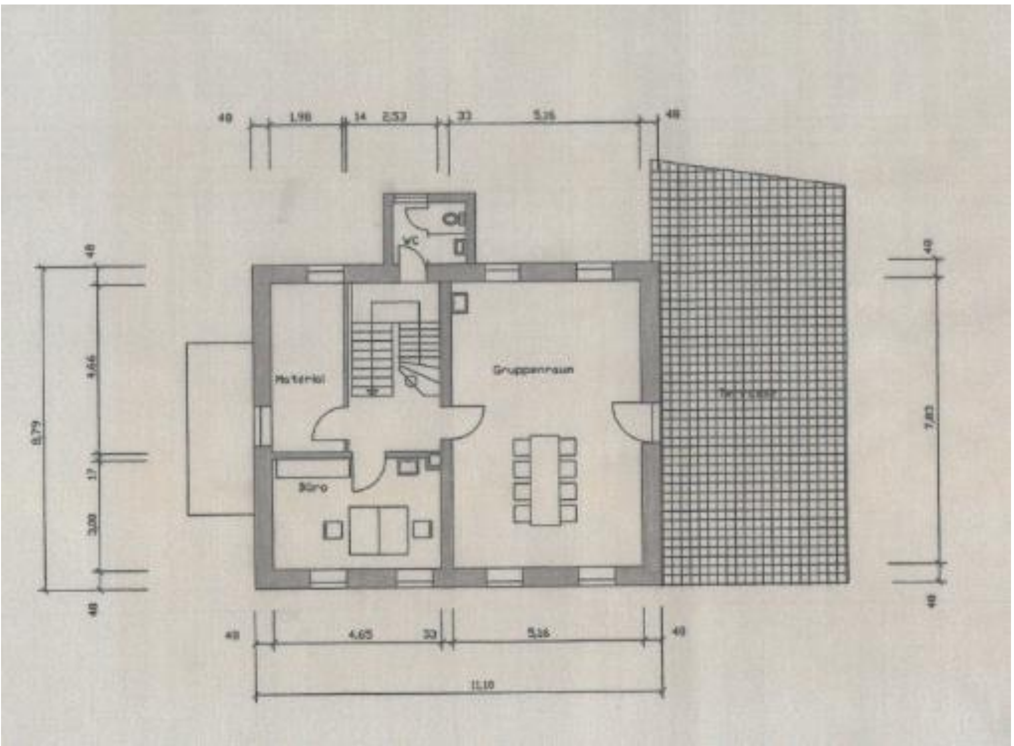


Figure 99: GAUstark 1st floor plan

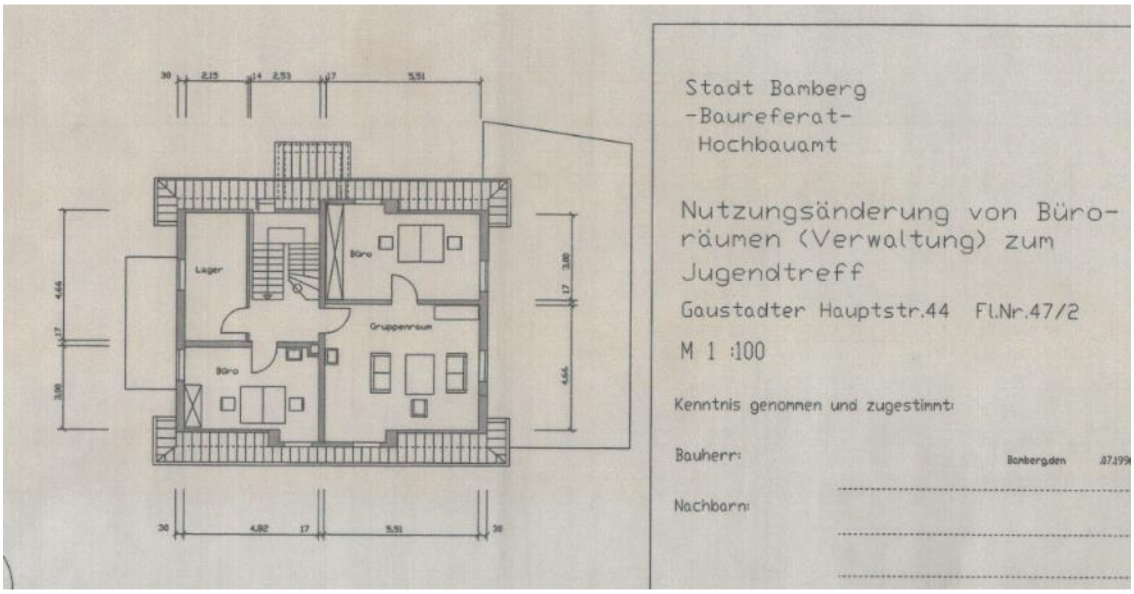


Figure 100: GAUstark 2nd floor plan

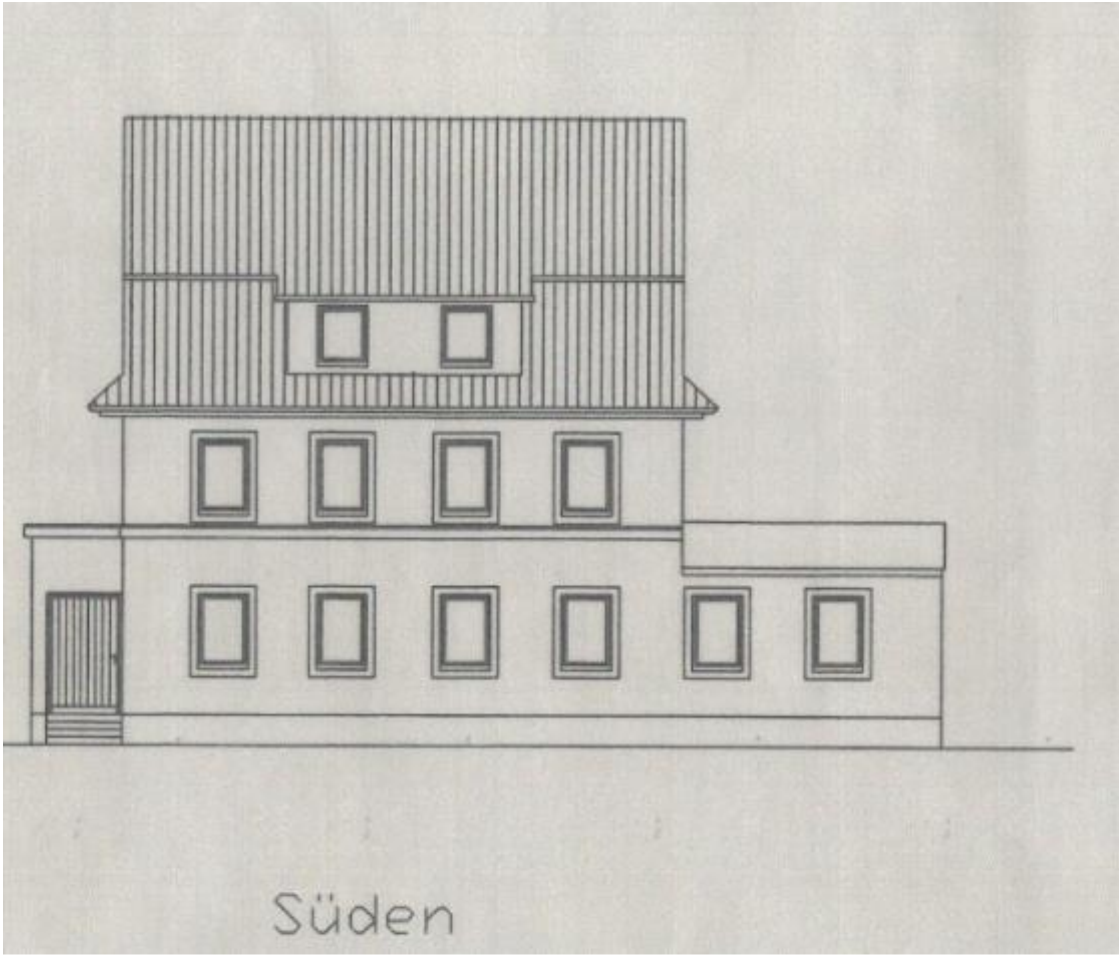
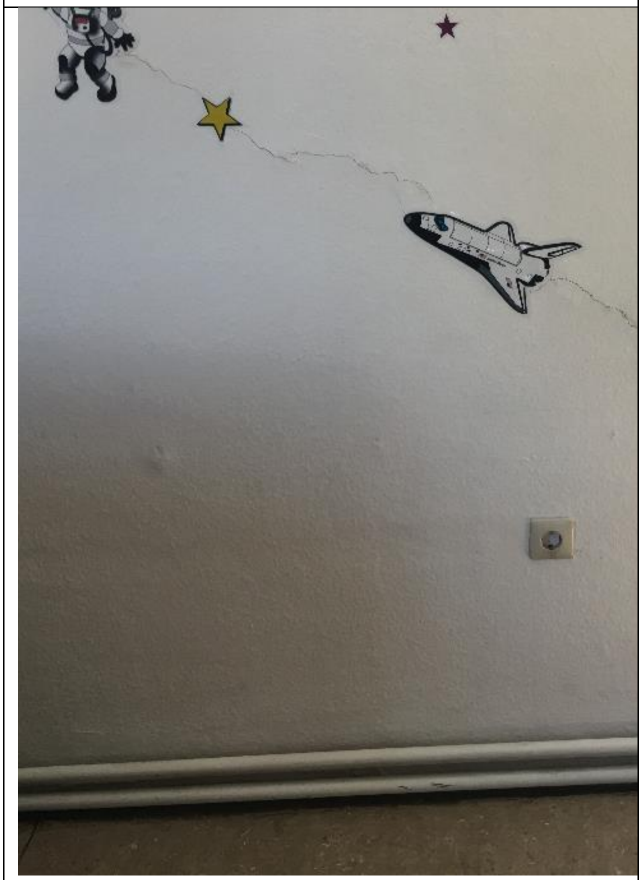


Figure 101: GAU stark south facade

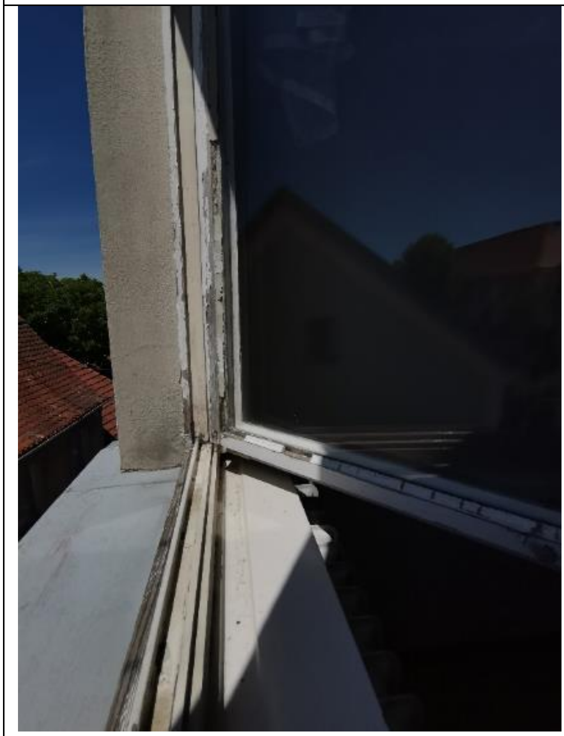
10.13.4 GAUstark Building Photo Documentation.

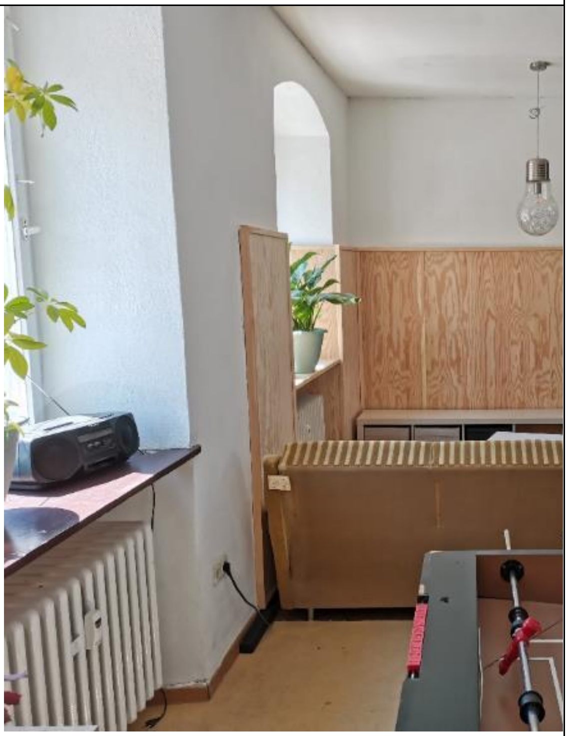
Photos showing the exterior of the GAUstark youth centre, the unusable terrace in 1st floor and the newly built fire escape that is accessible via the terrace in 1st floor

10.13.4.1 Structure sector



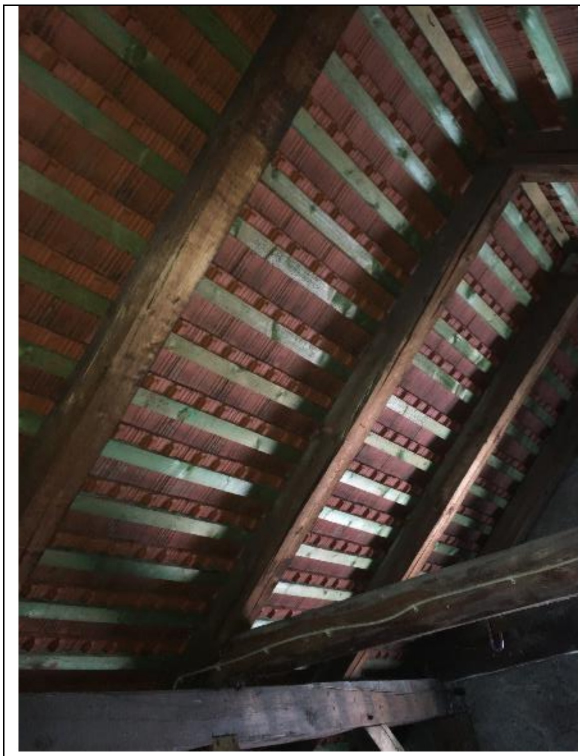
Photos showing the underneath of stairs, the underground storage, and part of the envelope. All showing signs of water and moisture damage (relevant for the KPIs B2.1Envelope moisture and rain protection and B2.6 Water Resistant Materials and finishes)



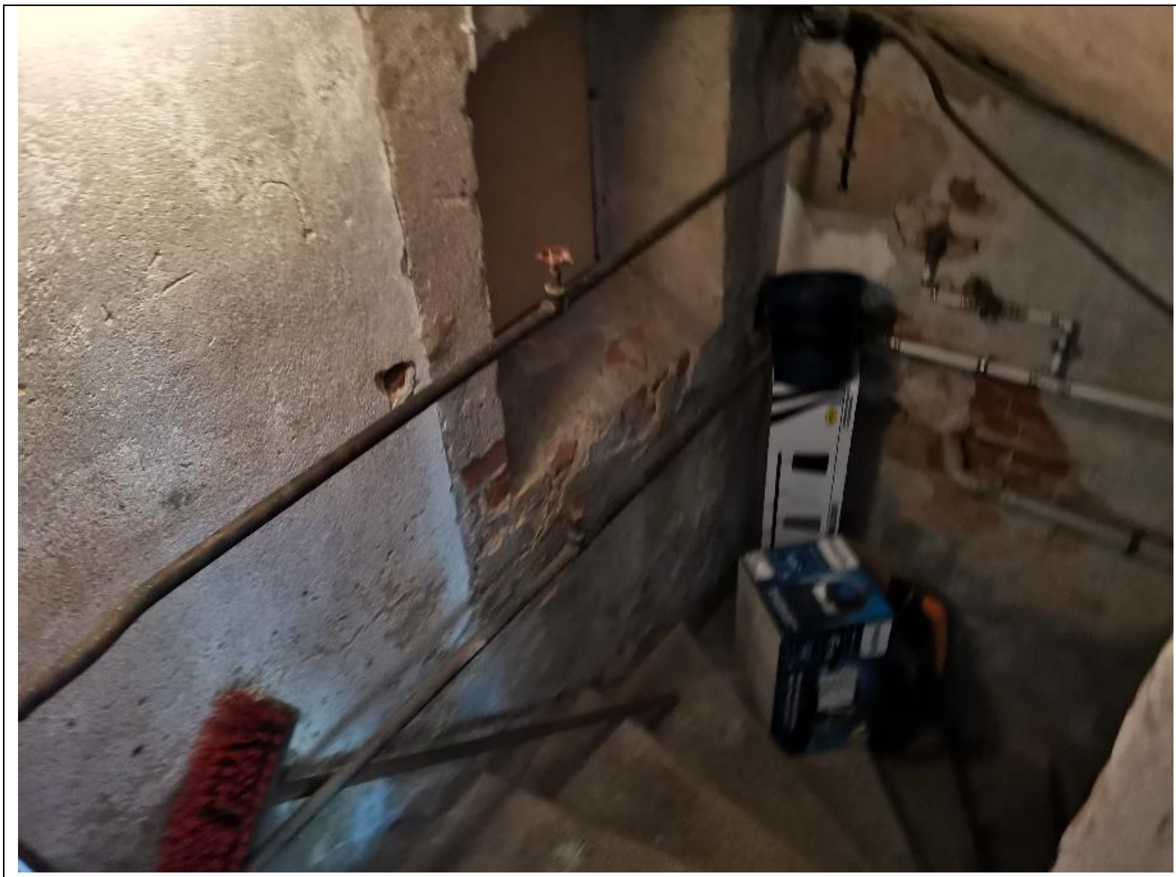


Photos showing the wall thickness, the damaged window frames, and uninsulated attic relevant to the KPI C1.2 Specific transmission heat loss of the building envelope)

Photos showing the good natural cross ventilation options (relevant for the KPIs C1.4 Efficiency of natural ventilation and C5.1 Natural ventilation in telecommunications / control rooms)



Phots showing the exterior of the envelope of the building, the partial solar shading and the new roofing in the attic and the entrance as well as the fire escape stairs (relevant for the KPIs B1.1, Hail and extreme precipitation safe windows and shutters, B1.2 Barrier free building) , C1.1Total solar energy transmittance of glazed windows and sunshades, C1.3 Reflectivity of the building envelope and E1.1 Strom anchored external fixtures)

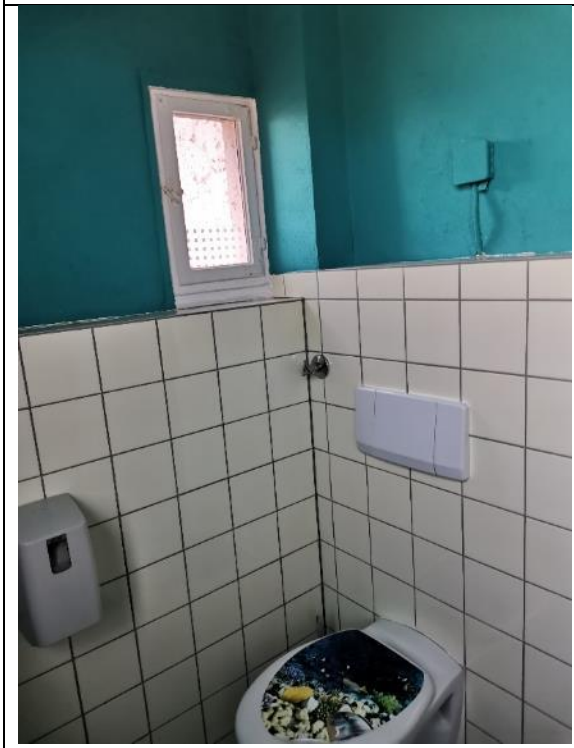


Photos showing the situation of the technical pathways and access to the technical rooms (relevant to the KPIs B5.3Protected and diverse technical pathways and B5.4 Ease of access, maintenance of technical systems and rooms)

Photos from the technical rooms showing dampness and water leakage damage to the walls (relevant for the KPIB5.2 Leakage and rain proof technical rooms)

10.13.4.2 Water, wastewater and sanitation systems (KG 370-410)

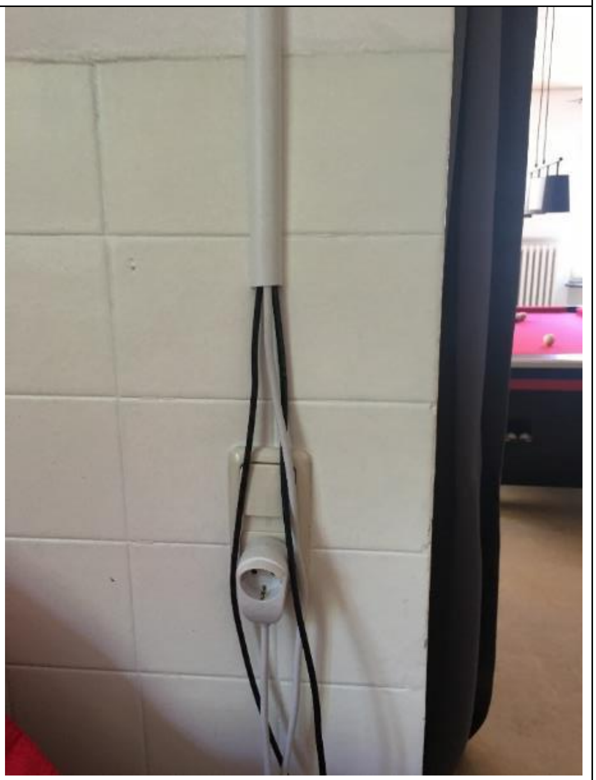
Photos showing the (relevant for KPIs B2.9 Backwater protection and B4.1 Separation of wastewater and rainwater)



All toilets are located in 1st and2nd floor the basement and non are fitted water saving fixtures (relevant for KPIs B2.8Drainage system design and, D3.3 Water saving fixture)

Photos showing the damaged and complicated paths of the rains and wastewater pips as well as the unmaintained gutters (relevant for KPIs B5.2 Ease of maintenance/ retrofitting of Water, wastewater, and sanitation system and E5.1 Strom anchored external water supply and drainage systems

10.13.4.3 Energy systems (KG 420 to 440)



Not all electrical sockets enjoy water covers, some are not water resistance, and some cables are totally exposed (relevant for the KPI B1.5Waterproof sockets switches, C5.3 Power backup systems, and B5.10Detecting faults of technical building systems)

10.13.4.4 Wellbeing and Organization

Photos shoing the moderate internal thermal load in most of the rooms (relvant to the KPI C1.10 Internal loads and internal heat gain)

Emergency exist is an ad-hoc stating from the 1st floor terrace and landing in cramped site (relevant for the KPIs B1.1 Availability of emergency response plan and evacuation routes for Hail, Snow and extreme precipitation events)

Lack of maintenance to the building technical and non-technical systems (relevant for KPIs B2.2 maintenance of building technical systems against extreme precipitation threat and C1.12 Maintenance of building technical systems against heatwave)

10.13.4.5 Urban and spatial environment (KG 510 to 560)



Photos showing the limited outdoor areas of the GAUstrak building, notice the asbestos external fence and the limtied space and shading (relevant for the KPIs B2.12 Site perimeter Slope away from entrances and walking areas, B4.1Permeable Outdoor Surrounding Surfaces, C1.12 Outdoor shaded area , C1.13 Outdoor area provided with cooling elements such as water features, vegetation or fans, B6.1 Toxin and plastic free outdoor structures and surfaces,and C1.15 Albedo paving surfaces)

10.13.5 JO Building Floor Plans

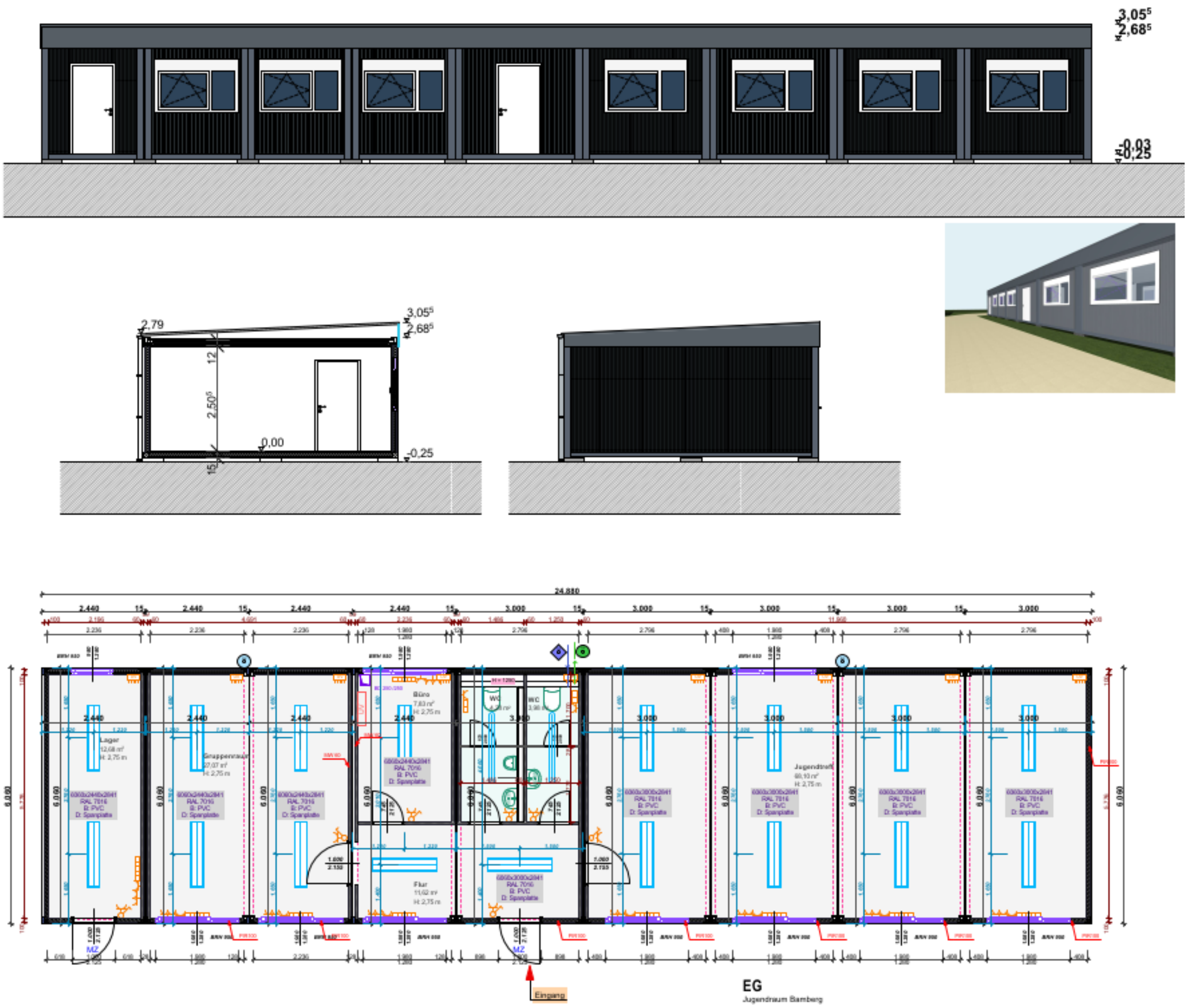


Figure 102: Floor plan, section and elevations of the JO youth centre containers building.

10.13.6 JO Building Photo Documentation

Photos showing the exterior of the JO youth centre, the lack of shading and black containers dominate the scene

10.13.6.1 Structure sector (KG300)

Photos showing signs of water and moisture damage in the toilets (relevant for the KPIs B2.1Envelope moisture and rain protection and B2.6 Water Resistant Materials and finishes)

Photos showing the good natural cross ventilation options (relevant for the KPIs C1.4 Efficiency of natural ventilation and C5.1 Natural ventilation in telecommunications / control rooms)

Phots showing the exterior of the envelope of the building, the solar shading (relevant for the KPIs B1.1, Hail and extreme precipitation safe windows and shutters, B1.2 Barrier free building), C1.1 Total solar energy transmittance of glazed windows and sunshades, C1.3 Reflectivity of the building envelope and E1.1 Strom anchored external fixtures)

Photos showing the situation of the technical pathways and access to the technical rooms (relevant to the KPIs B5.3Protected and diverse technical pathways and B5.4 Ease of access, maintenance of technical systems and rooms)

10.13.6.2 Water, wastewater, and sanitation systems (KG 370-410)

Photos showing the rainwater pipes (relevant for KPIs B2.9 Backwater protection and B4.1 Separation of wastewater and rainwater, (relevant for KPIs B5.2 Ease of maintenance/ retrofitting of Water, wastewater and sanitation system and E5.1 Strom anchored external water supply and drainage systems)

All toilets are located in the ground floor and are fitted water saving fixtures (relevant for KPIs B2.8 Drainage system design and, D3.3Water saving fixture)

10.13.6.3 Energy systems (KG 420 to 440)

Due to the high internal loads and low albedo of the building there is an urgent need for cooling. Using 50% of the roof space (ca. $70m^2$) could generate around 14,000 kWh/year (Total Energy Production = PV Area × Solar Radiation × Efficiency, Total Energy Production = $70m^2$ × 1,100 kWh/m^2/year × 0.18). That should be more than enough to cool the building during the summer (Cooling Load = U-value × Area × Temperature Difference U-value = 0.24 W/m^2. K (thermal transmittance) Area = $80m^2$ (room area)

Temperature Difference = Setpoint Temperature - Outside Temperature

Assuming a setpoint temperature of 22°C and an average outside temperature in Bamberg of 27°C:

Temperature Difference = 22°C - 27°C = -5°C

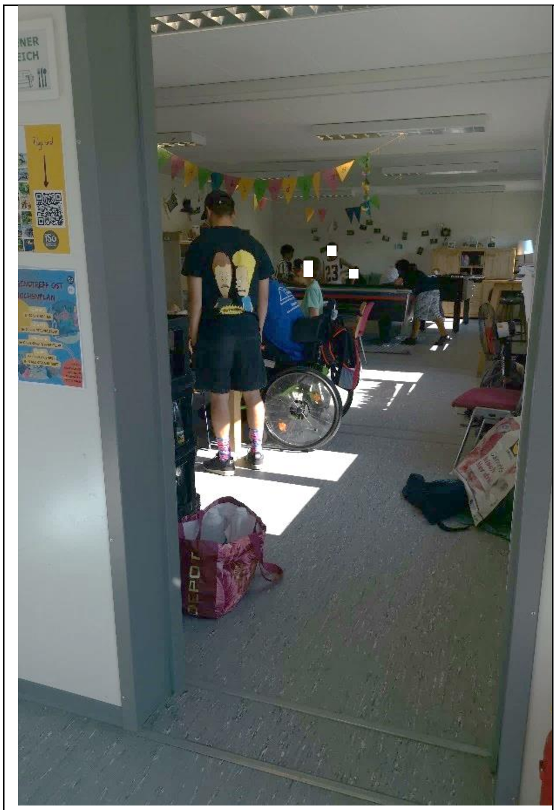
Cooling Load = 0.24 W/m². K × 80m² × (-5°C) = -96 watts per Kelvin or -96 W/K

Operational Duration = 8 hours/day × 5 days/week × 50 weeks/year = 2,000 hours/year

Total Energy Required for Cooling per Year = Cooling Load × Temperature Difference × Operational Duration

Total Energy Required for Cooling per Year = -96 W/K × -5 K × 2,000 hours/year = 960,000 watt-hours or 960 kilowatt-hours (kWh))

10.13.6.4 Wellbeing and Organization



Photos showing the high internal thermal load in JU centre (relevant to the KPI C1.10 Internal loads and internal heat gain)

Lack of maintenance to the building technical and non-technical systems, notice the damaged solar shutter due to excessive heat (relevant for KPIs B2.2 maintenance of building technical systems against extreme precipitation threat and C1.12 Maintenance of building technical systems against heatwave)

10.13.6.5 Urban and spatial environment (KG 510 to 560)

Photos showing the absece of solar and rain proection in outdoor areas of the JO center(relevant for the KPIs B2.12, Site perimeter Slope away from entrances and walking areas, B4.1Permeable Outdoor Surrounding Surfaces, C1.12 Outdoor shaded area , C1.13 Outdoor area provided with cooling elements such as water features, vegetation or fans, B6.1 Toxin and plastic free outdoor structures and surfaces,and C1.15 Albedo paving surfaces)

10.14 Annex 14: Results of End user Engagement During the Preparation Phase

10.14.1 Impressions From the JUZ Centre End-users

for the JUZ centre, the end users explicitly mentioned the training room, the studio on 1st floor, the administrative offices on the 2nd floor, and the painting room in the attic to be virtually unusable during the heat waves due to lack of effective ventilation and external shading. The over heating experience is worsened due to the installation of large electrical equipment such the server and the photocopy machine in some of these rooms. Moreover, there is lack of shaded spaces in the courtyard which as per the users force them to gather in skate hall which is perceived cooler due to its internal size, availability of external shading and light occupancy.

Regarding heavy precipitation, it was observed that during heavy rain events a water backup situation occurs in the basement and the water flows back from the city draining system into the toilets resulting into flooding the basement. Moreover, it was found that the gutters and drains are not regularly cleaned or maintained due to lack of responsibility. This led to the gutters to be often clogged causing water related damage to the building.

Regarding the user behaviour during emergency situations, it was revealed that the basement emergency exit was for most users not usable due to the hatch being heavy for most of the youth. Moreover, the hanged emergency evacuation plans were not accurate, and it was revealed that the users are not familiar with behaviour procedure during emergency and bad weather situations. The desire was expressed several times to develop a comprehensive rescue concept with emergency plans and to share it with the users.

10.14.2 Impressions From the JO Centre End-users

In the JO youth centre, the end users expressed that indoor spaces get very much overheated during the summer heatwaves periods, which can only be limitedly prevented by the existing external sun protection. The indoor overheating is aggravated due to high occupancy number and cooking in the kitchen which part of the main lounge room. The desire for thermal regulation options of the indoor spaces, for example through fans, has been expressed several times. The lack of any man made or natural shading in the outdoor area was also criticized. In addition, the black steel shell of the container building gets extremely hot in summer, which raises concerns among users of the risk of injury through touch. In addition to the lack of the ability to ensure good stay quality in the indoor or outdoor areas, the desire to be able to cool down oneself was also expressed, for example through shower facilities or water dispensers. This desire was particularly expressed in connection with the sports fields surrounding the youth centre, on which visitors are mainly active in the warm months.

Regarding heavy rain, it was found in the participation measures that there are no options in the youth centre to store dirty or wet clothes, shoes, or umbrellas. The outside parking areas for bikes is not covered and expose the bike to rain. There is no concept for warning about or dealing emergency or severe weather situation.

10.15 Annex 15: Example List of The Generic iQRe KPIs

The iQRe KPI are classified for each urban scale by urban sectors and organised based on selected sample of climatic hazards that are relevant to most German inland cities starting with issue (A) Flood hazard and concluding with Issue (E) Warming trend and heatwaves. The criteria and indicators are largely selected from the studied sustainability and smart building rating systems as well as other various official and scientific publications. Pleas be aware that this list of example key performance indicators is not meant to be an exhausted list of key performance indicators but rather collection of a sample of them that illustrate the general structure and of the KPIs in the iQRe system and demonstrate the breadth of the topic of climate adaptation in the built environment.

The iQRe Tool it self can be accessed here : https://mediatum.ub.tum.de/1728683

10.15.1 Building Scale

10.15.1.1 Structure sector (KG 300)

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.1	Occupancy above flood threshold
Intent		Protect building users against flood threat
Sector		Structure
Building Costs- DIN 276		KG300
Indicator		Elevation of lowest occupied floors in relation to flood threshold
Benchmark		The elevation of lowest occupied floor in CM is in relation to flood threshold (Recommended to be at least 30 Cm above a 100-year ARI (average recurrence interval) flood level)
Synergistic Factor		Medium
Criteria/ indicator source		Reducing Flood Losses Through the International Codes
Weblink		https://www.fema.gov/sites/default/files/2020-07/fema_reducing_flood_losses_rfl_5th-ed.pdf
Exposure value		Number of building user

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.2	Barrier free building
Intent		To improve the building occupant survivability in face of flood threat and ease rescue operation

Sector	Structure
Building Costs- DIN 276	KG300
Indicator	Degree of fulfilment of the DIN 18040 (Construction of accessible buildings)
Benchmark	
Synergistic Factor	High
Criteria/ indicator source	Hochwasserangepasste Bauweisen – Hochwasserschutz versus Barrierefreiheit
Weblink	https://link.springer.com/chapter/10.1007/978-3-658-21839-3_3
Exposure value	Number of building user

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Groundwater resilient fundament and basement
Intent		Protect the building fundament and basement against Groundwater penetration
Sector		Structure
Building Costs- DIN 276		KG320
Indicator		The application of the water-resistant concrete as per the DAfStb guidelines (DAfStb-Richtlinie Wasserundurchlässige Bauwerke aus Beton) or bitumen sealed layers (black tray) as per DIN 18533.
Benchmark		The holistic application of the groundwater protection above the groundwater water threshold ((Recommended to be at least 30 Cm above a 500-year ARI (average recurrence interval) ground water level)
Synergistic Factor		Low
Criteria/ indicator source		Hochwasserschutzfibel Objektschutz und bauliche Vorsorge
Weblink		https://www.fib-bund.de/Inhalt/Themen/Hochwasser/
Exposure value		Building value

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.2	Flood resilient fundament
Intent		Protect the building foundation against under-washing
Building Costs- DIN 276		KG320
Indicator		Depth of the foundation
Benchmark		The foundation should be 1m below the expected under-washing level.
Synergistic Factor		Low

Criteria/ indicator source	Niederösterreichischer Zivilschutzverband
Weblink	http://www.noezsv.at/noe/pages/startseite/zivilschutz-themen-a---z/hochwasser-und-haus.php
Exposure value	Building value

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.3	Flood resilience of exterior walls
Intent		Improve the building exterior resilience against flood and ground water threat
Building Costs- DIN 276		KG 330
Indicator		the degree of exterior wall materials fulfilment of the following eight indicators: • Stability of the strength properties • Dimensional and volume stability • Water absorption behaviour • Drying behaviour • Accessibility, disassembly, and recyclability • Resistance to pest attack • LCA and primary energy • Environmentally friendly
Benchmark		Ideally all eight indicators are fulfilled
Synergistic Factor		Medium
Criteria/ indicator source		Hochwasserschutzfibel Objektschutz und bauliche Vorsorge
Weblink		https://www.fib-bund.de/Inhalt/Themen/Hochwasser/
Exposure value		Area of exterior wall

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.4	Flood and moisture resilience of thermal insulation (KG 330)
Intent		Improve the performance of the building exterior thermal insulation flood and moisture threat
Building Costs- DIN 276		KG 330
Indicator		the degree of exterior wall materials fulfilment of the following eight indicators: • Stability of the strength properties • Dimensional and volume stability

	• Water absorption behaviour • Drying behaviour • Accessibility, disassembly, and recyclability • Resistance to pest and mold • LCA and primary energy • Environmentally friendly
Benchmark	Ideally all eight indicators are fulfilled
Synergistic Factor	Medium
Criteria/ indicator source	Hochwasserschutzfibel Objektschutz und bauliche Vorsorge
Weblink	https://www.fib-bund.de/Inhalt/Themen/Hochwasser/
Exposure value	Area of exterior wall

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.5	Water and moisture resilience of internal walls
Intent		Protect the internal walls from flood and moisture threat
Building Costs- DIN 276		KG340
Indicator		the resilience of internal walls, at or below the flood threshold, to flood and moisture
Benchmark		the degree of internal wall materials fulfilment of the following eight indicators: • Stability of the strength properties • Dimensional and volume stability • Water absorption behaviour • Drying behaviour • Accessibility, disassembly, and recyclability • Resistance to pest and mold • LCA and primary energy • Environmentally friendly
Synergistic Factor		Low
Criteria/ indicator source		Hochwasserschutzfibel Objektschutz und bauliche Vorsorge
Weblink		https://www.fib-bund.de/Inhalt/Themen/Hochwasser/
Exposure value		Area of internal wall below

Issue	A	Flood hazard

Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.6	Water and moisture resilience of floor slabs
Intent		Protect the building floor slabs from flood and moisture threat
Building Costs- DIN 276		KG 350
Indicator		the degree of floor slabs construction fulfilment of the Structural flood precautions guidelines (VdS 6002)
Benchmark		Ideally all indicators are fulfilled
Synergistic Factor		Medium
Criteria/ indicator source		Structural flood precautions; guideline with instructions for the selection of suitable types of construction and their structural implementation" (VdS 6002)
Weblink		https://www.gdv.de/gdv/themen/schaden-unfall/katalog-der-gegen-ueberflutung-widerstandsfaehigen-aussenwand-decken-und-fussboden-konstruktionen-62536
Exposure value		Building value

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.7	dynamic building envelope systems
Intent		Protect and repair the dynamic building envelope systems
Building Costs- DIN 276		KG 330-360
Indicator		The dynamic building envelope systems are able to report fault detection, predictive maintenance, real-time & historical sensor data
Benchmark		Ideally all four functions can be fulfilled indicators are fulfilled
Synergistic Factor		Low
Criteria/ indicator source		SRI (Smart readiness index)
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en#sri-digital-calculation-tools
Exposure value		Area of dynamic envelope

Issue	A	Flood hazard
Category	A6	Risk of damage and loss to an ecosystem due to flood
Criteria	A6.1	Pollutant free building materials
Intent		Protect and the surrounding ecosystem from contamination
Building Costs- DIN 276		KG 300
Indicator		The degree to which the used building materials are free from
Benchmark		Ideally all building materials are free from pollutants -

Synergistic Factor	Low
Criteria/ indicator source	QNG - Schadstoffvermeidung in Baumaterialien (ANF3-1, WG23, S.9)
Weblink	https://www.nachhaltigesbauen.de/fileadmin/pdf/QNG-BEG/QNG_Handbuch_Anlage-3_AnforderungenBund_v1-2.pdf
Exposure value	Weight of building materials

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, snow, and extreme precipitation
Criteria	B1.1	Hail and extreme precipitation safe windows and shutters
Intent		To protect the buildings user from Hail and extreme precipitation risks as well as increasing the safety of the users
Building Costs- DIN 276		KG 330
Indicator		The percentage area of envelope and roof openings and windows that are protected against hail damage (use of shutters or anti-hail grille)
Benchmark		For best performance, 100% of the building openings are protected against hail damage
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser ". Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Number of building user

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, snow, and extreme precipitation
Criteria	B1.2	Barrier free building
Intent		To improve the building occupant survivability in face of climatic threat and ease rescue operation
Building Costs- DIN 276		KG300
Indicator		Degree of fulfilment of the DIN 18040 (Construction of accessible buildings)
Benchmark		100% of the building spaces are Barrier free accessible
Synergistic Factor		High
Source		Hochwasserangepasste Bauweisen – Hochwasserschutz versus Barrierefreiheit
Weblink		https://link.springer.com/chapter/10.1007/978-3-658-21839-3_3
Exposure value		Number of building user

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, snow, and extreme precipitation
Criteria	B1.3	Hail, Snow, and extreme precipitation safe buildings extensions
Intent		To protect the user of the building extension areas such as balconies and roof terases from hail, snow, and extreme precipitation risks
Building Costs- DIN 276		KG 350
Indicator		The percentage area of balconies/roof terraces that are covered with hail and snow load resistant materials
Benchmark		100% of the area of the covered balconies/roof terraces are covered
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser ". Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Number of building user

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, snow, and extreme precipitation
Criteria	B1.4	Hail, snow, and extreme precipitation safety protection
Intent		To protect the buildings user from fallings snow and hail
Building Costs- DIN 276		KG 360
Indicator		The provisions of structural protective measures to ensure the sliding from snow/hail deposits to areas without danger to persons.
Benchmark		100% of the sliding areas for snow and hail are directed away from persons gathering areas
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser ". Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Number of building user

Issue	B	Extreme precipitation

Category	B2	Risk of asset damage and loss due to due to Hail, snow, and extreme precipitation
Criteria	B2.1	Envelope moisture and rain protection
Intent		To protect the building from the entrance of moisture and rain
Building Costs- DIN 276		KG 330-KG360
Indicator		adhering to the requirements of the norm 4108-3(Climate-related moisture protection) as well as testing the rain tightness of windows and doors according to the European norm of EN 1027 Moreover, it is required t show proof of adhering to the suggestion of the norm series DIN 18195 Waterproofing of buildings.
Benchmark		All building elements fulfil the requirements of DIN norm 4108-3, EN 1027 and the suggestion of the norm series DIN 18195
Synergistic Factor		Medium
Source		NaWoh 2.2.2 / WT12. Sealed Roof Building Resilience Index (BRI)
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.2	Hail resilience of the building envelope (KG 330-360)
Intent		To protect the buildings envelope from hail damage
Building Costs- DIN 276		KG 330 - 360
Indicator		The proportion and degree of the building envelope materials that are rated against hail https://www.hagelregister.at/hagelregister/
Benchmark		100% of the building envelope materials are H3 rated against hail damage
Synergistic Factor		High
Source		VdS 6100 : 2018-10 (01). Publikation der deutschen Versicherer. (GDV e.V.) zur Schadenverhütung. Gebäudeschutz vor Hagel
Weblink		https://www.gdv.de/resource/blob/51404/13469a60adc5b511a08fe9cf1da813f4/leitfaden---vds-gebaeudeschutz-vor-hagel-data.pdf
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.3	Building overhangs
Intent		To protect the buildings envelope from hail and extreme precipitation
Building Costs- DIN 276		KG 330-350

Indicator	% of the building sides protected by overhangs, that are least 50 cm on the the 'weather side
Benchmark	100% of the building sides protected by overhangs, that are least 50 cm
Synergistic Factor	Medium
Source	Bewertungssystem Nachhaltiges Bauen (BNB) © BMUB Version V 2015 A1Büro- und Verwaltungsgebäude
Weblink	https://www.bnb-nachhaltigesbauen.de/fileadmin/steckbriefe/verwaltungsgebaeude/neubau/v_2015/BNB_BN2015_415.pdf
Exposure value	Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.4	Air tightness of building envelope
Intent		To protect the building from water vapour condensation inside the construction
Building Costs- DIN 276		KG 330 - 360
Indicator		Air tightness of building envelope as per the results of a Differential pressure method according to DIN EN 13829 test or tracer gas method (indicator gas method) according to DIN EN ISO 12569 / VDI 4300-7
Benchmark		Fulfilment of the highest air tightness of the building envelope
Synergistic Factor		Low
Source		NaWoh 2.2.3
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.5	Ease of disassembly and recycling of building envelope
Intent		To improve the building resilience in regard to extreme precipitation damage
Building Costs- DIN 276		KG 330 - 360
Indicator		Share of the building envelope materials that are easy to replace
Benchmark		100% of the building envelope materials are easy to replace and recycle
Synergistic Factor		Medium
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen

Weblink	https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value	Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.6	Water Resistant Materials
Intent		to enable faster drying, reduce damage and mold
Building Costs- DIN 276		KG 330-KG360
Indicator		The resistant of materials and finishes of the building to water in areas susceptible to rain and flooding
Benchmark		all areas susceptible to rain and flooding, water resistant materials and finishes (wet proof) must be provided in the exposed lower building levels
Synergistic Factor		Low
Source		WT18. Water Resistant Materials Resilience Index (BRI)
Weblink		https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.4	Reporting information regarding performance of dynamic building envelope systems
Intent		To improve the building systems reliability and resilience against adverse climate impacts resilience in regard to extreme precipitation damage
Building Costs- DIN 276		KG 338
Indicator		the availability of a system that allow to indicate the position of each product, fault detection, predictive maintenance, real-time & historical sensor data can improve the reliability of the system and resilience against adverse climate impacts
Benchmark		100% of installed solar shading are fitted with predictive control
Synergistic Factor		Medium
Source		SRI (Smart readiness index)
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en#sri-digital-calculation-tools
Exposure value		Area dynamic building envelope systems

Issue	B	Extreme precipitation

Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.2	Water Leak and waterproof technical rooms
Intent		To ensure of building systems reliability and resilience against adverse climate impacts
Building Costs- DIN 276		KG 320-360
Indicator		The degree to which the technical rooms are protected from leak and moisture
Benchmark		All technical rooms are to protected from leak rain and moisture
Synergistic Factor		Medium
Source		WiredScore assessment C4
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Number of technical services in the building (HVAC and telecommunication)

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.3	protected and diverse technical pathways
Intent		To improve the building systems reliability and resilience against adverse climate impacts
Building Costs- DIN 276		KG 399
Indicator		The degree to which the technical pathways (ducts, entry points and shafts) are protected from the moisture, hail and rain
Benchmark		Ideally all 6 indicators are fulfilled. 1. technical pathways run in dedicated, secure pathway, 2. a physical separation of wired connectivity and services 3. Defined cabling route from the public realm to the building. 4. Multiple dedicated below-ground cable pathways is in place. 5. Provision of a cable and service riser/ shaft / duct that is protected within a closet or room on each floor and easily accessible by authorized users. 6. Service Installation on the façade are easily accessed and secured from the elements. 7. Provision of a reserved space in shafts for new services
Synergistic Factor		Medium
Source		WiredScore assessment
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Number of technical services in the building (HVAC, water and wastewater, and telecommunication)

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.4	Ease of access, maintenance of technical systems and rooms

Intent	To improve the building systems reliability and resilience against adverse climate impacts and reduce down-time
Building Costs- DIN 276	KG 330-360
Indicator	the accessibility, security, and capacity of technical rooms
Benchmark	All technical rooms are. : 1. Secured 2. easily accessible for maintenance, 3. have reserve capacity for expansion.
Synergistic Factor	Medium
Source	WiredScore assessment
Weblink	https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value	Number of technical services in the building (HVAC, water and wastewater, and telecommunication)

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.1	Strom anchored external fixtures
Intent		To reduce the inhabitant's risk to wind debris caused injuries
Building Costs- DIN 276		KG 330 - 360
Indicator		share of external fixtures and cladding materials that are safely anchored and high wind rated (e.g. HVAC equipment, lighting, solar panels, decorations, wall cladding, parapet, chimney and vegetation)
Benchmark		In Strong wind areas all external fixtures should be securely anchored to the building structure, foundation, or the ground
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://www.resilienceindex.org/resources
Exposure value		Number of users

Issue	c	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.2	Building susceptibility to vibration
Intent		To reduce the inhabitant's risk to wind and storm caused injuries
Building Costs- DIN 276		KG 300
Indicator		Building susceptibility to vibration

Benchmark	For buildings that are higher than 25m a proof about degree of Building susceptibility to vibration as per the DIN EN 1991-1-4:2010-1 – ideally zero
Synergistic Factor	High
Source	Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink	https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value	Number of users

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.1	Strom resilient primary structure
Intent		To improve the building resilience to wind damage
Building Costs- DIN 276		KG 330
Indicator		Primary Structure Wind Load Capacity
Benchmark		In Strong wind areas the primary structure should be able to withstand 290+ km/h windspeed
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://www.resilienceindex.org/resources
Exposure value		Building value

Issue	c	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.2	Strom resilient roof structure
Intent		To improve the building resilience to wind damage
Building Costs- DIN 276		KG 350-360
Indicator		Roof Structure Wind Load Capacity
Benchmark		In Strong wind areas the roof structure should be able to withstand 290+ km/h windspeed
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://www.resilienceindex.org/resources
Exposure value		Building value

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.3	Strom resilient window shutters and doors
Intent		To protect the building elements from wind damage
Building Costs- DIN 276		KG 330
Indicator		Share of installed shutters with Predictive control with self closing mechanism (e.g. based on weather forecast).
Benchmark		100% of installed solar shading are fitted with predictive control and self closing mechanism
Synergistic Factor		low
Source		SRI (Smart readiness index)
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en#sri-digital-calculation-tools
Exposure value		Window area

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.4	Strom resilient openings
Intent		To protect the building elements from wind damage
Building Costs- DIN 276		KG 320-360
Indicator		Share of building openings (e.g. windows, doors, curtain walls, and garage doors) or coverings which are larger than 1 m2 that are wind-rated and impact-resistant to total
Benchmark		All building openings larger than $1m^2$ are wind-rated and impact-resistant
Synergistic Factor		low
Source		Building Resilience Index (BRI)
Weblink		https://www.resilienceindex.org/resources
Exposure value		Building façade area

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.5	Airtight envelope
Intent		To protect the building elements from wind damage
Building Costs- DIN 276		KG 320-360
Indicator		The air tightness rating of the building envelope
Benchmark		Rating the building envelope air permeability according to DIN 4108-6 or DIN EN 832 using the DIN EN ISO 9972
Synergistic Factor		low

Source	§ 13 of the GEG
Weblink	https://www.gesetze-im-internet.de/geg/__13.html
Exposure value	Building envelope area

Issue	D	Drought and water scarcity
Category	D2	Risk of asset damage and loss due to drought
Criteria	D2.1	lateral loads restraint foundation and to moisture intrusion protection
Intent		To protect the building from the drought caused soils volumetric change due to variations in moisture content
Building Costs- DIN 276		KG 300-320
Indicator		The building soil type and the inclusion of lateral loads restraint foundation and moisture intrusion protection
Benchmark		Above norm safety margins of foundation
Synergistic Factor		High
Source		Queensland Building and Construction Commission 2022
Weblink		https://www.qbcc.qld.gov.au/resources/guide/guide-preventing-structural-damage
Exposure value		Building value

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss to an ecosystem possible due to drought
Criteria	D6.2	Embodied water in original construction materials
Intent		To reduce the water stress and use of water in construction
Building Costs- DIN 276		KG 300
Indicator		Potable water used in the production of original materials and products, in m3/m3 of gross area.
Benchmark		n/a
Synergistic Factor		High
Source		CESBA Med GF B.4.1
Weblink		https://cesba-med.interreg-med.eu/
Exposure value		Weight of constructing material

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.1	Total solar energy transmittance of glazed windows and sunshades (gtot-value)
Intent		Reduce users' exposure to excessive solar energy

Building Costs- DIN 276	KG 334-338
Indicator	Total solar energy transmittance of glazed windows and sunshades (g-value)
Benchmark	Total g-value should be below 0.2, ideally below 0.15
Synergistic Factor	Medium
Source	Protocollo ITACA
Weblink	http://download.acca.it/Files/Scheda/Itacus/SCHEDE-PROTOCOLLO-ITACA-RESIDENZIALE/B.6.4-Controllo-della-radiazione-solare-Protocollo-ITACA-Residenziale.pdf
Exposure value	Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.2	Specific transmission heat loss of the building envelope
Intent		Reduce excessive heat infiltration into the building
Building Costs- DIN 276		KG 330-360
Indicator		heat transfer coefficient of the building external envelope (U-value)
Benchmark		Ideally the building should show improvement in its thermal insulation that goes beyond the official U value requirement of the GEG
Synergistic Factor		High
Source		GEG §15 and §47
Weblink		https://www.gesetze-im-internet.de/geg/index.html#BJNR172810020BJNE001500000
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.3	Reflectivity of the building envelope
Intent		Reduce excessive heat absorption by the building
Building Costs- DIN 276		KG 335-364
Indicator		Albedo value of the building envelope
Benchmark		Ideally the Albedo of the building envelope should be greater than 0.7
Synergistic Factor		Medium
Source		Mansouri, Ouarda, Rafik Belarbi, and Fatiha Bourbia. "Albedo effect of external surfaces on the energy loads and thermal comfort in buildings." Energy procedia 139 (2017): 571-577.
Weblink		https://www.sciencedirect.com/science/article/pii/S1876610217356667

Exposure value	Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.4	Efficiency of natural ventilation
Intent		To increase the exploitation of cross ventilation (night cooling)
Building Costs- DIN 276		KG 334-362
Indicator		Share of rooms in which more than one opening for natural ventilation in the direction of prevailing wind is available to total windows
Benchmark		Ideally all rooms should have the possibility of taking advantage of cross wind ventilation
Synergistic Factor		Low
Source		Protocollo ITACA
Weblink		http://www.ager.puglia.it/documents/7241131/9869670/7.+Linee+guida+Strumento+di+qualit%C3%A0%20energetica+%28allegato+G+alla+DGR+n.+2272-2009%29.pdf/ccb85a04-389b-4382-aea0-c083feb3cddb
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.5	Window solar shading control
Intent		External solar shading control Can help optimize the building climatic performance
Building Costs- DIN 276		KG 334-362
Indicator		Share of rooms in which an external blind control is provided
Benchmark		Ideally all rooms should have external solar shading that is can be controlled
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E2	Risk of asset damage and loss due to Heatwave and warming trend
Criteria	E2.1	Thermal Expansion Coefficient
Intent		To reduce the asset damage in the building material due thermal expansion
Building Costs- DIN 276		KG 330-360

Indicator	the Average thermal coefficient of building materials in ppm/°C
Benchmark	Ideally the thermal coefficient of building materials in ppm/°C should be less than 15 ppm
Synergistic Factor	Low
Source	SRI
Weblink	https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value	Number of building users

Issue	E	Heatwave and warming trend
Category	E5	Risk of damage, disruption, or loss critical services due to Heatwave and warming trend
Criteria	E5.1	Natural ventilation in telecommunication and control rooms
Intent		To improve the resiliency and reliability of the building telecommunication systems
Building Costs- DIN 276		KG 330-360
Indicator		Availability of an efficient natural ventilation telecommunication and control rooms.
Benchmark		Ideally all rooms that host technical components that can be sensitive to heat are provided with means of effective natural ventilation
Synergistic Factor		Low
Source		WiredScore assessment
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Number of building technical services

10.15.1.2 Water, wastewater, and sanitation systems (KG 370-410)

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.3	Drinking Water Quality after flood
Intent		Ensure the drinking water quality
Building Costs- DIN 276		KG410
Indicator		Fulfilment of the water quality indicators outlined in the drinking water regulation TrinkwV after a flood event.
Benchmark		Fulfilment of the water quality indicators as per the TrinkwV
Synergistic Factor		Medium
Criteria/ indicator source		Trinkwasserverordnung - TrinkwV
Weblink		https://www.gesetze-im-internet.de/trinkwv_2001/BJNR095910001.html
Exposure value		Number of building user

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.8	Certified wastewater and sanitation system against flood
Intent		Protect the building and its users against flood threat
Building Costs- DIN 276		KG370
Indicator		Fulfilment of the certification requirements for the wastewater and sanitation systems as per DIN 1986-100:2016-12 - 14.9.3 Überflutungsnachweis
Benchmark		Ideally Fulfilment of the DIN 1986-100:2016-12 for 100-year ARI (average recurrence interval)
Synergistic Factor		Medium
Criteria/ indicator source		DIN 1986-100:2016-12
Weblink		https://www.beuth.de/de/norm/din-1986-100/264064948
Exposure value		Building value

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.9	Water, wastewater, and sanitation system resilience against flood
Intent		Protect the building and its users against flood threat
Building Costs- DIN 276		KG410
Indicator		Fulfilment of the following six indicators: – submersible sewage lifting pump with backup power. – Measure taken to ensure the wastewater and drinking water do not mix. – All pipes are fitted with closed cell insulation. – Anti-backflow valves for sewer pipes are installed. – Non-return valves (NRVs) for appliance waste-pipe are installed – Availability of bungs that can be fitted to toilets and sinks as a flood-resistance measure to restrict the ingress of backflow water through these channels
Benchmark		Ideally Fulfilment of all indicators
Synergistic Factor		Medium
Criteria/ indicator source		Barsley, Edward, ed. Retrofitting for flood resilience: A guide to building & community design. Routledge, 2020.
Weblink		https://www.taylorfrancis.com/books/mono/10.4324/9780429347986/retrofitting-flood-resilience-edward-barsley
Exposure value		Building value

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.1	Ease of maintenance/ retrofitting of building Water, wastewater, and sanitation systems
Intent		Protect the Water, wastewater, and sanitation systems against flood threat
Building Costs- DIN 276		KG410
Indicator		– the lines for water supply and wastewater are routed in easily accessible supply shafts or ducts. – The sanitary fixtures are equipped with inspection flaps, if necessary (for bath and shower tubs) e.g., for cleaning the siphon
Benchmark		Fulfilment of both recommendations
Synergistic Factor		Medium
Criteria/ indicator source		NaWoH 2.2.6
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to Hail, Snow, and extreme precipitation
Criteria	B2.7	capacity of water drainage system
Intent		To ensure that the building drainage system is designed to handle excess amount of rainwater
Building Costs- DIN 276		KG 326/363
Indicator		The capacity of the water drainage system
Benchmark		The water drainage system is be higher than specified in the Norm EN 12056-3 : 2000
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Envelope area

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation

Criteria	B2.8	Drainage system design
Intent		To protect the building from damage of rainwater
Building Costs- DIN 276		KG 410
Indicator		% water drainage system that is gravity based
Benchmark		100% of the water drainage system is a gravity-based drainage systems
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.9	Backwater protection
Intent		To protect the building from damage of rainwater
Building Costs- DIN 276		KG 410
Indicator		The availability of automatic Backflow water trap with emergency protection and a submersible sewage lifting pump with backup power
Benchmark		The depth, capacity, and availability of automatic Backflow water trap with emergency protection
Synergistic Factor		Low
Source		Leitfaden Starkregen – Objektschutz und bauliche Vorsorge
Weblink		https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/sonderveroeffentlichungen/2018/leitfaden-starkregen-dl.pdf?__blob=publicationFile&v=1
Exposure value		Building underground and ground level area

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to Hail, Snow, and extreme precipitation
Criteria	B3.6	Frost protected water supply and wastewater system
Intent		To protect the building water and wastewater system from damage of cold snaps and snow
Building Costs- DIN 276		KG 410
Indicator		The length of water and wastewater pipes that are protected from frost
Benchmark		100% of the water and wastewater pipes are protect from frost

Synergistic Factor	Low
Source	Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink	https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value	Number of building user

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to Hail, Snow, and extreme precipitation
Criteria	B3.7	Ease of maintenance/ retrofitting of building Water, wastewater, and sanitation systems
Intent		Reduce the Water, wastewater, and sanitation systems downtime
Building Costs- DIN 276		KG410
Indicator		• the lines for water supply and wastewater are routed in easily accessible supply shafts or ducts. • The sanitary fixtures are equipped with inspection flaps, if necessary (for bath and shower tubs) e.g., for cleaning the siphon
Benchmark		Fulfilment of both recommendations
Synergistic Factor		Medium
Source		NaWoH 2.2.6
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value		Number of users

Issue	B	Extreme precipitation
Category	B4	Risk of infrastructure damage or loss due to Hail, Snow, and extreme precipitation
Criteria	B4.1	Separation of wastewater and rainwater
Intent		To reduce the load on wastewater infrastructure from excess amount of rain water
Building Costs- DIN 276		KG 410
Indicator		The degree of separation of rain and wastewater in the drainage system
Benchmark		100% of the drainage system separate wastewater and rainwater
Synergistic Factor		Low
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen

Weblink	https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value	Number of connections to water and wastewater infrastructure

Issue	B	Extreme precipitation
Category	B4	Risk of infrastructure damage or loss due to Hail, Snow, and extreme precipitation
Criteria	B4.2	Stormwater Management
Intent		To reduce the load on wastewater infrastructure from excess amount of rain water
Building Costs- DIN 276		KG 410
Indicator		The availability of Rainwater management (roof greening, rainwater retention, rainwater Infiltration)
Benchmark		Over 60 % of the rainwater is collected via Rainwater management system
Synergistic Factor		high
Source		Hatzfeld, F., & Kurz, S. (2010). Klimaangepasstes Bauen-Kriteriensteckbrief „Widerstandsfähigkeit gegen Naturgefahren: Wind, Starkregen, Hagel, Schnee/feuchte Winter und Hochwasser “. Hg. v. Bundesinstitutes für Bau-, Stadt- und Raumforschung BBSR im Bundesamt für Bauwesen und Raumentwicklung (BBR). Aachen
Weblink		https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/2NachhaltigesBauenBauqualitaet/2010/KriterienHagel/Endbericht.pdf;jsessionid=FEB10CDBA090807CA700067E085307FE.live11311?__blob=publicationFile&v=1
Exposure value		Number of connections to water and wastewater infrastructure

Issue	B	Extreme precipitation
Category	B5	Risk of damage and loss of natural resources due to hazard due to Hail, Snow, and extreme precipitation
Criteria	B5.1	Rainwater collection
Intent		To reduce the rainwater runoff and load on water sources
Building Costs- DIN 276		KG 410
Indicator		% of Rainwater collection
Benchmark		Over 50 % of the rainwater is collected
Synergistic Factor		high
Source		BNK 3.4.1 Use of water saving fittings
Weblink		https://bau-irn.com/bnk-system-qng/bnk-qng-kriteriensteckbriefe
Exposure value		Amount of rainwater

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.1	Strom anchored external water supply and drainage systems
Intent		To reduce the risk of loss of water supply and wastewater system to strong wind
Building Costs- DIN 276		KG 410/412
Indicator		Length of external water and wastewater fixtures and safely anchored and high wind rated.
Benchmark		In Strong wind areas all external fixtures should be securely anchored to the building structure, foundation, or the ground
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://www.resilienceindex.org/resources
Exposure value		Length of exposed water and wastewater fixtures and pipelines

Issue	D	Drought and water scarcity
Category	D1	Inhabitants' health and safety risk due to drought
Criteria	D1.1	Water hygiene
Intent		To ensure potable water quality
Building Costs- DIN 276		KG 410
Indicator		Drinking water quality.
Benchmark		as per the BNK Index
Synergistic Factor		Low
Source		BNK 1.1.2
Weblink		https://bau-irn.com/bnk-system-qng/bnk-qng-kriteriensteckbriefe
Exposure value		Number of building user

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.2	Potable Water usage index
Intent		To reduce potable water consumption
Building Costs- DIN 276		KG 410
Indicator		Drinking water demand and wastewater volume
Benchmark		as per the DGNB Index
Synergistic Factor		High
Source		DGNB Neubau kleine Wohngebäude, Version 2013.2 ENV 2.2.1 The water usage index

Weblink	https://www.dgnb.de/de/verein/publikationen/bestellung/downloads/DGNB_Kriterienkatalog_Neubau_EV_2018.pdf
Exposure value	Water use index

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.3	Water saving fixture
Intent		To reduce potable water consumption
Building Costs- DIN 276		KG 410
Indicator		Availability of Water saving fixture
Benchmark		as per the BNK index
Synergistic Factor		High
Source		BNK Einsatz von Wassersparamaturen 3.4.1.
Weblink		https://bau-irn.com/bnk-system-qng/bnk-qng-kriteriensteckbriefe
Exposure value		Water use index

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.4	Rain and Gray water re-use
Intent		To reduce potable water consumption
Building Costs- DIN 276		KG 410
Indicator		% of rain water collected on site or Gray water resued to total water consumption
Benchmark		
Synergistic Factor		High
Source		D3.4.1 - CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Water use index

10.15.1.3 Energy systems (KG 420 to 440)

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.2	Energy systems located above flood threshold
Intent		Protect energy systems from flood threat

Building Costs- DIN 276	KG420-440
Indicator	Elevation of mechanical/electrical Equipment
Benchmark	mechanical/electrical equipment are elevated at least 3 m above the nearest sea/lake/river level to avoid high flood events
Synergistic Factor	Low
Criteria/ indicator source	Building Resilience Index (BRI)
Weblink	https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value	Number of building systems

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.3	Ease of maintenance/ retrofitting of building energy systems
Intent		Reduce downtime of the energy systems
Building Costs- DIN 276		KG420-440
Indicator		Accessibility, usability, and resiliency of electric cabling
Benchmark		All The electrical lines are routed in easily accessible supply shafts or ducts. Inspection flaps of the shafts are installed on each floor. Collecting and risers are accessible behind demountable cladding. Reserves are provided for electrical and media lines (empty pipes vertical/horizontal and/or reserves in the shaft).
Synergistic Factor		Medium
source		NaWoH 2.2.6
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value		Number of users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.5	Waterproof sockets and switches
Intent		Protect users from electrical shock caused by water and rain threat
Building Costs- DIN 276		KG440
Indicator		Share of Waterproof sockets and switches in areas that are exposed to rainwater access or ground water rise
Benchmark		All The electrical sockets and switches in areas that are exposed to rainwater access or ground water rise are ip66 Waterproof rated
Synergistic Factor		Low
Source		DIN EN 60529

Weblink	https://www.din.de/de/meta/suche/62730!search?query=DIN+EN+60529
Exposure value	Number of users

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.8	E-3 Storage of (locally generated) electricity
Intent		To ensure energy supply for vital system during network downtime
Building Costs- DIN 276		KG420-440
Indicator		Amount of local energy generated and stored that can used or exported
Benchmark		All The vital HVAC and electrical system can be supplied using local generated energy
Synergistic Factor		High
Source		SRI
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value		Building energy demand

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.9	Support of(micro)grid operation modes
Intent		To ensure energy supply for vital system during network downtime
Building Costs- DIN 276		KG420-440
Indicator		Support of(micro)grid operation modes
Benchmark		All The vital HVAC and electrical system support connection to local microgrids and can import or export energy
Synergistic Factor		High
Source		SRI
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value		Building energy demand

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.10	MC-4 Detecting faults of technical building systems
Intent		To ensure the correct operation of energy dependant systems
Building Costs- DIN 276		KG420-440

Indicator	Share of building technical systems that provide fault detection and provide support to the diagnosis of these faults
Benchmark	All The vital HVAC and electrical system support detecting faults
Synergistic Factor	Medium
Source	SRI
Weblink	https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value	Building energy demand

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.2	energy supply lines protected from wind
Intent		To reduce the risk of loss of energy supply due to strong wind
Building Costs- DIN 276		KG 420-440
Indicator		Rated power of external energy supply line and fixtures that are safely anchored or buried underground.
Benchmark		In Strong wind areas all external power and energy lines should be securely anchored or run underground
Synergistic Factor		High
Source		WiredScore
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Building energy demand

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.6	Cooling and ventilation system capacity
Intent		
Building Costs- DIN 276		KG 330-340
Indicator		Capacity of cooling and ventilation systems
Benchmark		Ideally all rooms should have cooling and ventilation systems have cooling capacity that is 10% over ideal capacity
Synergistic Factor		Low
Source		SRI
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E4	Risk of infrastructure damage or loss due to Heatwave and warming trend
Criteria	E4.1	Energy efficiency rating of Cooling system
Intent		To improve the resiliency and reliability Energy infrastructure
Building Costs- DIN 276		KG 430-440
Indicator		Energy efficiency rating of Cooling system.
Benchmark		Ideally all cooling and ventilation systems are A rated
Synergistic Factor		Medium
Source		
Weblink		
Exposure value		Building energy demand in summer time

Issue	E	Heatwave and warming trend
Category	E5	Risk of damage, disruption, or loss critical services due to Heatwave and warming trend
Criteria	E5.2	Energy system that are protect from overheating
Intent		To improve the resiliency and reliability of the building energy systems
Building Costs- DIN 276		KG 420-440
Indicator		Availability of an efficient climate control system in rooms hosting energy systems.
Benchmark		Ideally all rooms that host technical components that can be sensitive to heat are provided with means of effective climate control
Synergistic Factor		Low
Source		WiredScore assessment
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Building energy demand in summertime

Issue	E	Heatwave and warming trend
Category	E5	Risk of damage, disruption, or loss critical services due to Heatwave and warming trend
Criteria	E5.3	Power backup systems
Intent		To improve the resiliency and reliability of the building energy systems
Building Costs- DIN 276		KG 420-440
Indicator		Share of vital systems provided with a power back up.
Benchmark		Ideally all vital systems are provided with a power back up system that is running on local generated energy
Synergistic Factor		Low
Source		WiredScore assessment

Weblink	https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value	Building energy demand in summertime

10.15.1.4 Wellbeing and Organization

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.4	Availability of emergency response plan and evacuation routes for flood events
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG600
Indicator		Emergency response plan and evacuation routes for flood events are updated in timely interval
Benchmark		emergency response plan and evacuation routes for flood events are updated annually
Synergistic Factor		High
Criteria/ indicator source		
Weblink		
Exposure value		Number of building users

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.5	Availability of emergency response training for users and behaviour during flood events
Intent		Protect building users against flood threat
Building Costs- DIN 276		
Indicator		Share of building users that underwent of emergency response training and behaviour during flood events
Benchmark		All building users should be trained on how to act during flood events
Synergistic Factor		high
Criteria/ indicator source		
Weblink		
Exposure value		Number of building users

Issue	A	Flood hazard

Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.6	Availability of emergency alarm from flood events
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG 456
Indicator		Share or rooms fitted with emergency alarm during flood events
Benchmark		All rooms should be fitted with emergency alarm to warn the users during flood events
Synergistic Factor		High
Criteria/ indicator source		
Weblink		
Exposure value		Number of building users

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.10	maintenance of building structure against flood
Intent		Protect the building and its users against flood threat
Building Costs- DIN 276		KG300
Indicator		maintenance of building structure against flood are occurring in regular time interval
Benchmark		Ideally Predicative maintenance against flood is occurring yearly
Synergistic Factor		High
Criteria/ indicator source		
Weblink		
Exposure value		Building value

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.11	maintenance building technical systems against flood
Intent		Protect the building and its users against flood threat
Building Costs- DIN 276		KG300
Indicator		maintenance of building technical systems flood are occurring in regular time interval
Benchmark		Ideally maintenance of technical systems against flood is occurring yearly
Synergistic Factor		High
Criteria/ indicator source		

Weblink	
Exposure value	Building value

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.3	Predictive maintenance for flood threatened technical systems
Intent		increase the resilience of the building systems from flood threat
Building Costs- DIN 276		KG400
Indicator		Share of technical systems in flood threat areas that provide predictive maintenance information
Benchmark		All systems that are in flood threat areas are able to predict when a piece of equipment might fail and help in self
Synergistic Factor		High
Criteria/ indicator source		Smart Score
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building systems

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.4	System alarms for flood threatened technical systems
Intent		increase the resilience of the building systems from flood threat
Building Costs- DIN 276		KG400
Indicator		Share of technical systems in flood threat areas that provide real time system alarm when technical building system fails
Benchmark		All systems that are in flood threat areas can provide real time system alarm
Synergistic Factor		Low
Criteria/ indicator source		Smart Score
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building systems

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.6	Availability of emergency response plan and evacuation routes for Hail, Snow, and extreme precipitation events
Intent		Protect users from against Hail, Snow, and extreme precipitation threat

Building Costs- DIN 276	KG600
Indicator	Emergency response plan and evacuation routes for Hail, Snow, and extreme precipitation events are updated in timely interval
Benchmark	emergency response plan and evacuation routes for Hail, Snow, and extreme precipitation events are updated annually
Synergistic Factor	High
Source	
Weblink	
Exposure value	Number of building users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.7	Availability of emergency response training for users and behaviour during Hail, Snow, and extreme precipitation events
Intent		Protect users from against Hail, Snow, and extreme precipitation threat
Building Costs- DIN 276		
Indicator		Share of building users that underwent of emergency response training and behaviour for extreme precipitation events
Benchmark		All building users should be trained on how to act during extreme precipitation events
Synergistic Factor		high
Source		
Weblink		
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.8	Availability of alarm system during Hail, Snow, and extreme precipitation events
Intent		Protect users from against Hail, Snow, and extreme precipitation threat
Building Costs- DIN 276		KG 456
Indicator		Share or rooms fitted with emergency alarm during extreme precipitation event
Benchmark		All rooms should be fitted with emergency alarm to warn the users during extreme precipitation event
Synergistic Factor		high
Source		
Weblink		
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.10	maintenance of building structure against extreme precipitation threat
Intent		Protect the building and its users against extreme precipitation threat
Building Costs- DIN 276		KG300
Indicator		maintenance of building structure extreme precipitation threat are occurring in regular time interval
Benchmark		Ideally maintenance against extreme precipitation threat is occurring yearly
Synergistic Factor		
Source		High
Weblink		
Exposure value		Building value

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.11	maintenance of building technical systems against extreme precipitation threat
Intent		Protect the building technical systems against extreme precipitation threat
Building Costs- DIN 276		KG400
Indicator		maintenance of building technical systems against extreme precipitation threat are occurring in regular time interval
Benchmark		Ideally maintenance of technical systems against extreme precipitation threat is occurring yearly
Synergistic Factor		
Source		High
Weblink		
Exposure value		Value of Building Technical systems

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.5	Predictive maintenance for extreme precipitation threatened technical systems
Intent		increase the resilience of the building systems
Building Costs- DIN 276		KG 400
Indicator		Share of technical systems in extreme precipitation threat areas that provide predictive maintenance information
Benchmark		All systems that are in extreme precipitation threat areas are able to predict when a piece of equipment might fail and help in self diagnosis
Synergistic Factor		Medium

Source	Smart score
Weblink	https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value	Number of building systems

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation
Criteria	B3.6	System alarms for extreme precipitation threatened technical systems
Intent		increase the resilience of the building systems
Building Costs- DIN 276		KG 400
Indicator		Share of technical systems in extreme precipitation threat areas that provide real time system alarm when technical building system fails
Benchmark		All systems that are in extreme precipitation threat areas are able to provide real time system alarm
Synergistic Factor		Low
Source		Smart score
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building systems

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.3	Availability of emergency response plan and evacuation routes for storm events
Intent		To Protect building users against storm threat
Building Costs- DIN 276		KG 600
Indicator		Emergency response plan and evacuation routes for storm events are updated in timely interval
Benchmark		emergency response plan and evacuation routes for flood storm are updated annually
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.4	Availability of emergency response training for users and behaviour during storm events
Intent		To Protect building users against storm threat

Building Costs- DIN 276	
Indicator	Share of building users that underwent of emergency response training and behaviour during storm events
Benchmark	All building users should be trained on how to act during storm events
Synergistic Factor	high
Source	
Weblink	
Exposure value	Number of building users

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.5	Availability of emergency alarm for storm events
Intent		To Protect building users against storm threat
Building Costs- DIN 276		KG 456
Indicator		Share or rooms fitted with emergency alarm during storm events
Benchmark		All rooms should be fitted with emergency alarm to warn users during storm events
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.6	Availability of emergency alarm for storm events
Intent		To Protect building users against storm threat
Building Costs- DIN 276		
Indicator		Share or rooms fitted with emergency alarm during storm events
Benchmark		All rooms should be fitted with emergency alarm to warn users during storm events
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.6	maintenance of building structure against storm threat
Intent		To Protect the building and its users against wind damage
Building Costs- DIN 276		KG 300
Indicator		Maintenance of building structure to storm threat are occurring in regular time interval
Benchmark		Ideally maintenance against storm threat is occurring yearly
Synergistic Factor		High
Source		
Weblink		
Exposure value		Building value

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.7	maintenance of building technical systems against storm threat
Intent		To Protect the building technical systems against wind damage
Building Costs- DIN 276		KG 400
Indicator		Maintenance of building technical systems to storm threat are occurring in regular time interval
Benchmark		Ideally maintenance of building technical systems against storm threat is occurring yearly
Synergistic Factor		High
Source		
Weblink		
Exposure value		Value of Building Technical systems

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.3	Predictive maintenance for storm threatened technical systems
Intent		increase the resilience of the building systems
Building Costs- DIN 276		KG 400
Indicator		Share of technical systems in storm threat areas that provide predictive maintenance information
Benchmark		All systems that are in storm threat areas are able to predict when a piece of equipment might fail and help in self diagnosis

Synergistic Factor	Medium
Source	Smart score
Weblink	https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value	Number of building systems

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.4	System alarms for storm threatened technical systems
Intent		increase the resilience of the building systems
Building Costs- DIN 276		KG 400
Indicator		Share of technical systems in storm threat areas that provide real time system alarm when technical building system fails
Benchmark		All systems that are in storm threat areas are able to provide real time system alarm
Synergistic Factor		Low
Source		Smart score
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building systems

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.5	Water reporting
Intent		To reduce potable water consumption
Building Costs- DIN 276		KG 600
Indicator		Availability of solution to track the building's water consumption in real time and inform the end users
Benchmark		All water use area is fitted with a solution to track water consumption
Synergistic Factor		High
Source		Smart score
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Water consumption per user

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.6	Water use awareness
Intent		To reduce potable water consumption

Building Costs- DIN 276	KG 600
Indicator	Availability of training and information to reduce water use
Benchmark	All users are informed about how to use water in sustainable manner
Synergistic Factor	High
Source	
Weblink	
Exposure value	Number of users

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.7	Water leakage alarm
Intent		To reduce potable water consumption
Building Costs- DIN 276		
Indicator		Share of water installations that provide real time system alarm when leaking
Benchmark		All water water installations are monitored to prevent leaking
Synergistic Factor		Low
Source		
Weblink		
Exposure value		Number of water pipes

Issue	D	Drought and water scarcity
Category	D5	Risk of damage and loss of natural resources to drought
Criteria	D5.8	Water system maintenance
Intent		To reduce potable water consumption
Building Costs- DIN 276		
Indicator		Share of water installations are regularly maintained to reduce leakage
Benchmark		All water water installations are regularly maintained at least once every 3 months
Synergistic Factor		Low
Source		
Weblink		
Exposure value		Number of water pipes

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants health and safety risk due to Heatwave and warming trend

Criteria	E1.8	Wellbeing reporting
Intent		To avoid users overheating
Building Costs- DIN 276		
Indicator		Share of rooms fitted with temperature monitoring
Benchmark		All rooms are fitted with a solution to track and report on the building's user's wellbeing in real-time
Synergistic Factor		Medium
Source		SmartScore
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.9	Comfort optimization
Intent		To allow the user to adjust the temperature and avoid overheating
Building Costs- DIN 276		KG 430-440
Indicator		Share or rooms in which the user can adjust and control the thermal conditions
Benchmark		All rooms are fitted with a solution so that user can optimize comfort conditions in
Synergistic Factor		Medium
Source		SmartScore
Weblink		https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.10	internal loads and internal heat gain
Intent		To reduce the risk of overheating
Building Costs- DIN 276		
Indicator		Share of rooms in which occupancy and internal loads are low
Benchmark		All rooms should be optimally occupied and not overloaded
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.12	Maintenance of building technical systems against heatwave
Intent		To reduce the risk of users overheating and ensure optimal operating condition of cooling and ventilation systems
Building Costs- DIN 276		KG 400
Indicator		maintenance of building of cooling, ventilation and solar protection systems are occurring in regular time interval
Benchmark		Ideally maintenance of cooling, ventilation and solar protection systems is occurring yearly before the summer
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants health and safety risk due to Heatwave and warming trend
Criteria	E1.13	response training for users and behaviour rules during heatwaves events
Intent		To reduce the risk of users overheating
Building Costs- DIN 276		
Indicator		Share of building users that underwent of response training and behaviour rules during heatwaves events
Benchmark		All building users should be trained on how to act during heatwave events
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E3	Risk of damage, disruption, or loss critical services due to hazard due to Heatwave and warming trend
Criteria	E3.1	Predictive maintenance for cooling and ventilation systems
Intent		To ensure optimal operation of cooling and ventilation systems
Building Costs- DIN 276		KG 400
Indicator		Share of cooling and ventilation systems that provide predictive maintenance information
Benchmark		All cooling and ventilation systems areas can predict when a piece of equipment might fail and help in self diagnosis
Synergistic Factor		Medium

Source	Smart score
Weblink	https://wiredscore.com/scorecard/smartscore/UF/uf5/uf5-6/?lang=EN
Exposure value	Number of building users

10.15.1.5 Communication systems (KG 450, 480, 630)

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.11	Nature and quality of wireless networks In flood threatened areas
Intent		Reduce the risk of users to flood
Building Costs- DIN 276		KG400
Indicator		Share of rooms in flood threat areas that has adequate coverage, for the main radio networks (GSM, Wi-Fi, etc.)
Benchmark		All rooms that are in flood threat areas has adequate coverage, for the main radio networks (GSM, Wi-Fi, etc.)
Synergistic Factor		High
Criteria/ indicator source		R2S
Weblink		https://www.smartbuildingsalliance.org/en/project/r2s-frame-of-reference
Exposure value		Number of building users

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to hazard due to flood
Criteria	A3.6	Building Smart Network Resilience Capacity In flood threatened areas
Intent		Reduce the risk of users to flood
Building Costs- DIN 276		KG400
Indicator		Share of smart networks in flood threat areas that supports network failure detection and self-healing mechanism
Benchmark		All rooms that are in flood threat areas network failure detection and self-healing mechanism
Synergistic Factor		High
Criteria/ indicator source		R2S
Weblink		https://www.smartbuildingsalliance.org/en/project/r2s-frame-of-reference
Exposure value		Number of smart networks

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to hail and extreme precipitation

Criteria	B3.9	Reporting information regarding performance of dynamic building envelope systems
Intent		To improve the building systems reliability and resilience against adverse climate impacts resilience in regard to extreme precipitation damage
Building Costs- DIN 276		KG 338
Indicator		the availability of a system that allow to indicate the position of each product, fault detection, predictive maintenance, real-time & historical sensor data can improve the reliability of the system and resilience against adverse climate impacts
Benchmark		100% of installed solar shading are fitted with predictive control
Synergistic Factor		Medium
Source		SRI (Smart readiness index)
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en#sri-digital-calculation-tools
Exposure value		Area dynamic building envelope systems

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to hail and extreme precipitation
Criteria	B1.12	Nature and quality of wireless networks in hail and extreme precipitation threated areas
Intent		Reduce the risk of users regarding extreme precipitation damage
Building Costs- DIN 276		KG 450
Indicator		Share of rooms in extreme precipitation threat areas that has adequate coverage, for the main radio networks (GSM, Wi-Fi, etc.)
Benchmark		All rooms that are in extreme precipitation areas has adequate coverage, for the main radio networks (GSM, Wi-Fi, etc.)
Synergistic Factor		High
Source		R2S
Weblink		https://www.smartbuildingsalliance.org/en/project/r2s-frame-of-reference
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.6	Communication lines protected from wind
Intent		To reduce the risk of loss of connection due to strong wind
Building Costs- DIN 276		KG 450-480
Indicator		Share of external Communication lines that are safely anchored or buried underground.
Benchmark		In Strong wind areas all Communication lines should be securely anchored or run underground

Synergistic Factor	High
Source	WiredScore
Weblink	https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value	Building energy demand

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.115	Predictive blind control
Intent		To reduce the risk of overheating
Building Costs- DIN 276		KG 300
Indicator		Share of windows that are fitted with Predictive blind control (e.g. based on weather forecast)
Benchmark		All windows that are fitted with Predictive blind control
Synergistic Factor		High
Source		SRI
Weblink		https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E3	Risk of damage, disruption, or loss critical services due to hazard due to Heatwave and warming trend
Criteria	E3.2	Climate control in telecommunications room
Intent		To reduce the risk of systems overheating
Building Costs- DIN 276		KG 400
Indicator		Share of telecommunications room that have an active climate control
Benchmark		Ideally every telecommunications room have an active climate control is provided by active air conditioning or mechanically forced ventilation
Synergistic Factor		High
Source		WiredScore assessment
Weblink		https://wiredscore.com/scorecard/wiredscore-office-development/b/b3/?lang=EN
Exposure value		Number of building users

10.15.1.6 Urban and spatial environment (KG 510 to 560)

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.7	emergency meeting points in outdoor areas
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG 563
Indicator		Availability of emergency meeting points in outdoor areas that are above flood threshold
Benchmark		emergency meeting points are barrier free and above flood threshold
Synergistic Factor		High
Criteria/ indicator source		
Weblink		
Exposure value		Number of building users

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.8	site perimeter Slope
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG 530
Indicator		Share of site perimeter area that is sloped Slope that away from the Building
Benchmark		More than 60% of the building site perimeter is primarily sloped to drain water away
Synergistic Factor		High
Criteria/ indicator source		Building Resilience Index (BRI)
Weblink		https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.9	Outdoor protected areas against Hail, Snow, and extreme precipitation
Intent		Protect users from against Hail, Snow, and extreme precipitation threat
Building Costs- DIN 276		KG 540
Indicator		Availability and capacity of covered space in the outdoor that offer protection against extreme precipitation threat
Benchmark		Availability and capacity of covered space in the outdoor that offer protection against extreme precipitation threat

Synergistic Factor	high
Source	
Weblink	
Exposure value	Number of building users

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B2.12	site perimeter Slope away from entrances ad walking areas
Intent		Protect the building against extreme precipitation threat
Building Costs- DIN 276		KG530
Indicator		Share of site that is sloped Slope that away from the building entrances and main walkways
Benchmark		100% of the site is sloped Slope that away from the building entrances and main walkways
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value		Value of Building

Issue	B	Extreme precipitation
Category	B4	Risk of infrastructure damage or loss due to Hail, Snow, and extreme precipitation
Criteria	B4.3	Permeable Outdoor Surrounding Surfaces
Intent		To reduce the load on wastewater infrastructure from excess amount of rainwater
Building Costs- DIN 276		KG530
Indicator		Share of outdoor surfaces are designed/built permeable as to function as Sustainable Urban Drainage Systems
Benchmark		Ideally 80 outdoor surfaces are designed/built permeable as to function as Sustainable Urban Drainage Systems
Synergistic Factor		High
Source		Building Resilience Index (BRI)
Weblink		https://assets.ctfassets.net/7q5irs6y1cem/2jv4CcNbbZ6TAnTlFrYKyg/54576271fce571dd6474073fc174fa69/BRI_User_Guide_v.1.3.0.pdf
Exposure value		Outdoor area

Issue	B	Extreme precipitation
Category	B6	Risk of damage and loss to an ecosystem due to Hail, Snow, and extreme precipitation
Criteria	B6.1	Toxin and plastic free outdoor structures and surfaces
Intent		To reduce the infiltration of toxins and plastic in ground and surface water due water runoff
Building Costs- DIN 276		KG530/540
Indicator		Share of Toxin and plastic free outdoor structures and surfaces
Benchmark		All outdoor structures and surfaces are Toxin and plastic free
Synergistic Factor		Low
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.7	Availability of areas in the outdoor protected from strong wind
Intent		To Protect building users against storm threat
Building Costs- DIN 276		
Indicator		Availability and capacity of covered space in the outdoor that offer protection against storm threat
Benchmark		Availability and capacity of covered space in the outdoor that offer protection against storm threat
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C2	Risk of asset damage and loss due to Storm and wind hazard
Criteria	C2.7	outdoor features and furniture elements that are safely anchored
Intent		To Protect building elements against storm threat
Building Costs- DIN 276		530-560
Indicator		Share of external fixtures (e.g., HVAC equipment, lighting, solar panels, decorations, and vegetation) are securely anchored to the building structure, foundation, or the ground.
Benchmark		All external fixtures (e.g., HVAC equipment, lighting, solar panels, decorations, and vegetation) are securely anchored to the building structure, foundation, or the ground.

Synergistic Factor	High
Source	Building Resilience Index (BRI)
Weblink	https://www.resilienceindex.org/resources
Exposure value	Building value

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss to an ecosystem due to drought
Criteria	D6.1	permeable paving or landscaping
Intent		To reduce ground water stress and rainwater runoff
Building Costs- DIN 276		KG 530
Indicator		percentage of precipitation that is available to recharge groundwater through permeable paving or landscaping
Benchmark		100 precipitation is available to recharge groundwater through permeable paving or landscaping
Synergistic Factor		High
Source		C.4.1 - CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Rain amount on the outdoor area

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.12	Outdoor shaded area
Intent		To reduce the risk of overheating
Building Costs- DIN 276		KG 530
Indicator		Availability and capacity of covered space in the outdoor that offer protection against direct solar exposure
Benchmark		Availability and capacity of covered space in the outdoor that offer protection against direct solar exposure
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend

Criteria	E1.13	Outdoor area provided with cooling elements such as water features, vegetation, or fans
Intent		To reduce the risk of overheating
Building Costs- DIN 276		KG 540
Indicator		Availability of outdoor cooling elements such as water features, vegetation
Benchmark		Availability of outdoor cooling elements such as water features, vegetation
Synergistic Factor		Low
Source		
Weblink		
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.14	Shading of building(s) by deciduous trees.
Intent		To encourage the use of trees for sequestration of carbon dioxide, and to reduce energy use for cooling of the building, by evapotranspiration and shading the building during the hot season
Building Costs- DIN 276		KG 570
Indicator		Share of native trees retained or planted, measured as percent of building frontage facing the equator, at a height of 5 m.
Benchmark		Full coverage of buidling façade with native trees
Synergistic Factor		High
Source		A.1.6 - CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of building users

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.15	Albedo paving surfaces
Intent		To reduce the risk of overheating and UHI
Building Costs- DIN 276		KG 530
Indicator		Average albedo of building and paving surfaces exposed to direct sunlight
Benchmark		Ideally the Albedo of the building envelope should be greater than 0.7
Synergistic Factor		High
Source		F.1.11 - CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/

Exposure value	Number of building users

10.15.1.7 Transport and mobility

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.9	road and car parking that are designed to act as temporary flood storage areas
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG 543
Indicator		Share of site perimeter area that is sloped Slope that away from the building
Benchmark		More than 60% of the building site perimeter is primarily sloped to drain water away
Synergistic Factor		High
Criteria/ indicator source		Designing for exceedance in urban drainage – good
Weblink		Balmforth, D. (2006). Designing for exceedance in urban drainage: good practice. London: CIRIA. http://observatoriaigua.uib.es/repositori/suds_ciria_12.pdf
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.10	Provision of communal transportation system(s).
Intent		Protect users from against Hail, Snow, and extreme precipitation threat
Building Costs- DIN 276		-
Indicator		Availability and distance of the communal transportation system(s) from main entrance
Benchmark		Access to communal transportation system(s) within 300 meters
Synergistic Factor		Low
Source		FASUDIR D2.4
Weblink		http://sbe16torino.org/papers/SBE16TO_ID026.pdf
Exposure value		Number of building users

Issue	B	Extreme precipitation
Category	B1	Inhabitants' health and safety risk due to Hail, Snow, and extreme precipitation
Criteria	B1.11	temporary parking lot for deliveries, maintenance, and emergency services
Intent		Protect users from against Hail, snow, and extreme precipitation threat

Building Costs- DIN 276	-
Indicator	Availability of temporary parking lot for deliveries, maintenance, and emergency services
Benchmark	Availability of temporary parking lot for deliveries, maintenance, and emergency services next to the building main entrance
Synergistic Factor	Medium
Source	NaWoH 1.1.4-1
Weblink	https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value	Number of building users

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to due to Hail, Snow, and extreme precipitation
Criteria	B1.12	Covered parking spaces for cars and other mobility systems to protect from hail
Intent		Protect users' assets from Hail, Snow, and extreme precipitation damage
Building Costs- DIN 276		KG 540
Indicator		Availability and capacity of covered parking spaces for cars and other mobility systems in the outdoor that offer protection against extreme precipitation threat
Benchmark		Availability and capacity of covered parking spaces for cars and other mobility systems in the outdoor that offer protection against extreme precipitation threat and are within 35m from entrance
Synergistic Factor		Low
Source		NaWoh 1.1.4-3
Weblink		https://www.nawoh.de/uploads/pdf/kriterien/v_3_1/2_Technische_Qualitaet.pdf
Exposure value		Number of parking spaces

10.15.1.8 Green and blue infrastructure (KG 570-580)

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.10	Green and blue areas used as flood control and temporary flood storage areas
Intent		Protect building users against flood threat
Building Costs- DIN 276		KG 570-580
Indicator		Share of green and blue areas used as flood control and temporary flood storage areas
Benchmark		More than 80%
Synergistic Factor		High
Criteria/ indicator source		Designing for exceedance in urban drainage – good
Weblink		Balmforth, D. (2006). Designing for exceedance in urban drainage: good practice. London: CIRIA. http://observatoriaigua.uib.es/repositori/suds_ciria_12.pdf

Exposure value	Number of building users

Issue	B	Extreme precipitation
Category	B4	Risk of infrastructure damage or loss due to Hail, Snow, and extreme precipitation
Criteria	B4.4	Green and blue areas used to retain excess rainwater
Intent		To reduce water runoff
Building Costs- DIN 276		Kg 570-580
Indicator		Share of green and blue areas used retain excess water to total areas
Benchmark		80% green and blue areas used retain excess rainwater
Synergistic Factor		Medium
Source		
Weblink		
Exposure value		Site area

Issue	C	Storm and wind hazard
Category	C1	Inhabitants' health and safety risk due to Storm and wind hazard
Criteria	C1.8	Trees at risk of falling due to storm hazard
Intent		To Protect building users against storm threat
Building Costs- DIN 276		
Indicator		Share of Trees over 5m in high that are at risk of falling on building
Benchmark		Ideally no trees are at risk of falling
Synergistic Factor		High
Source		
Weblink		
Exposure value		Number of building users

Issue	C	Storm and wind hazard
Category	C3	Risk of damage, disruption, or loss critical services due to Storm and wind hazard
Criteria	C3.5	Trees at risk of falling of power, communication or water and wastewater lines due to storm hazard
Intent		To protect critical services from storm and wind risk
Building Costs- DIN 276		
Indicator		Share of Trees that are at risk of falling on building technical system lines
Benchmark		Ideally no trees are at risk of falling on any of the building technical system lines
Synergistic Factor		High

Source	
Weblink	
Exposure value	Number of building users

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss to an ecosystem possible due to drought
Criteria	D6.3	Drought Tolerant Plants species
Intent		To reduce the water stress and use of water in construction
Building Costs- DIN 276		KG 570
Indicator		Share of drought tolerant Plants to total Plants
Benchmark		All Plants are drought tolerant
Synergistic Factor		High
Source		
Weblink		
Exposure value		Share of green areas

Issue	E	Heatwave and warming trend
Category	E1	Inhabitants' health and safety risk due to Heatwave and warming trend
Criteria	E1.16	Vegetated walls and other building surfaces
Intent		To reduce the risk of overheating and UHI
Building Costs- DIN 276		KG 570
Indicator		Aggregate area of building walls and building roof surfaces that are covered with vegetation
Benchmark		Ideally 50% are covered
Synergistic Factor		High
Source		F.3.8 - CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of building users

10.15.2 Neighbourhood Scale

10.15.2.1 Structures

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Commercial properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.2	Residential properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.3	Culturally significant properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services due to a heatwave
Criteria	A3.1	Mission critical properties located in river/coastal floodplain
Intent		To reduce critical buildings exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Hail, Snow and extreme precipitation
Criteria	B1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks of hail, snow and extreme precipitation
Source		
Weblink		
Exposure value		Number of neighbourhood inhabitant's

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to avalanche
Criteria	B2.1	Developed area located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of buildings

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to landslide
Criteria	B2.2	Developed area located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of buildings

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.1	Commercial properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard

Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.2	Residential properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.3	Culturally significant properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption or loss critical services due to a heatwave
Criteria	C3.1	Mission critical properties located in wildfire risk zone
Intent		To reduce critical building's exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Re-use of rainwater in residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of residential buildings in neighbourhood

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources

Criteria	D6.1	Re-use of rainwater in non-residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of non-residential buildings in neighbourhood

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks storm and wind
Source		
Weblink		
Exposure value		Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Commercial properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of commercial properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.2	Residential properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of residential properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.3	Culturally significant properties at risk of overheating

Intent	To reduce the number of buildings at risk of overheating
Source	
Weblink	
Exposure value	Number of culturally significant properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.4	Mission critical properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of mission critical properties in neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Commercial properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.2	Residential properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.3	Culturally significant properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework

Weblink	https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value	Number of buildings in neighbourhood

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services due to a heatwave
Criteria	A3.1	Mission critical properties located in river/coastal floodplain
Intent		To reduce critical buildings exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in neighbourhood

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Hail, Snow and extreme precipitation
Criteria	B1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks of hail, snow and extreme precipitation
Source		
Weblink		
Exposure value		Number of neighbourhood inhabitant's

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to avalanche
Criteria	B2.1	Developed area located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of buildings

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to landslide
Criteria	B2.2	Developed area located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918

Exposure value	Number of buildings

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.1	Commercial properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.2	Residential properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C1.3	Culturally significant properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption or loss critical services due to a heatwave
Criteria	C3.1	Mission critical properties located in wildfire risk zone
Intent		To reduce critical building's exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings in neighbourhood

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Re-use of rainwater in residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of residential buildings in neighbourhood

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Re-use of rainwater in non-residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of non-residential buildings in neighbourhood

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks storm and wind
Source		
Weblink		
Exposure value		Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Commercial properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of commercial properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.2	Residential properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of residential properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.3	Culturally significant properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of culturally significant properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.4	Mission critical properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of mission critical properties in neighbourhood

10.15.2.2 Water, wastewater, and sanitation systems

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Drainage system reserves
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Length of drainage system

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services to flood
Criteria	A3.1	Sewerage and drainage network at risk from climate hazards
Intent		To reduce wastewater and drainage disruption due to flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings connected to the sewerage and drainage network

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.2	Water treatment facilities in floor risk zone
Intent		To reduce water treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw5-water-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of buildings connected to water network

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.3	Wastewater treatment facilities in floor risk zone
Intent		To reduce wasterwater treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw4-wastewater-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of buildings connected to the sewerage and drainage network

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.1	Sewerage and drainage network at risk from climate hazards
Intent		To reduce wastewater and drainage network risk due to flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Length of sewerage and drainage network

Issue	A	Flood hazard

Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.2	Water treatment facilities in floor risk zone
Intent		To reduce water treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw5-water-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of water treatment plants

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.3	Wastewater treatment facilities in floor risk zone
Intent		To reduce wastewater treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw4-wastewater-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of wastewater treatment plants

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.1	Water consumption in residential building
Intent		To make efficient use of water resources
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of residential buildings

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.2	Water consumption in non-residential building
Intent		To make efficient use of water resources
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of non-residential buildings

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought

Criteria	D3.3	Water consumption for irrigation
Intent		To make efficient use of water resources
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Irrigated area

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.4	leakage and losses to water supply
Intent		To make efficient use of water resources
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw6-water-leakage-and-losses/
Exposure value		Number of consumers

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.5	Provision of split grey / potable water services
Intent		To make efficient use of water resources
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of consumers

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.6	Water leakage sensors
Intent		To make efficient use of water resources
Source		
Weblink		
Exposure value		Number of buildings

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.1	leakage and losses to water supply

Intent	To make efficient use of water resources
Source	ClimateXChange, Scotland's centre of expertise on climate change
Weblink	https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw6-water-leakage-and-losses/
Exposure value	Treated water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.2	Water conserved through reuse, awareness, water efficient appliances
Intent		To make efficient use of water resources
Source		French National Climate Change Impact Adaptation Plan 2011-2015. Annex II. Detailed action sheets
Weblink		https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/me/me-guides-manuals-reports/giz2014-en-climate-adaptation-indicator-repository.pdf
Exposure value		Treated water volume

10.15.2.3 Energy systems

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.1	Power stations located in areas at flood risk
Intent		To reduce the risk of flood on power supply
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value		Number of power stations

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.2	Power sub-stations located in areas at flood risk
Intent		To reduce the risk of flood on power supply
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be5-electricity-substations-located-in-areas-at-flood-risk/
Exposure value		Number of power sub-stations

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to flood
Criteria	A3.1	Power stations located in areas at flood risk
Intent		To increase the power supply resilience
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value		Number of service subscriber

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption, or loss critical services due to flood
Criteria	A3.2	Power sub-stations located in areas at flood risk
Intent		To increase the power supply resilience
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption, or loss critical services due to Hail, Snow and extreme precipitation
Criteria	B3.1	Hail, Snow, and extreme precipitation resilient solar energy system
Intent		To increase the power supply resilience
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services due to avalanche
Criteria	B3.2	Power station located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services due to landslide
Criteria	B3.3	Power station located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage or loss due to Hail, Snow and extreme precipitation
Criteria	B5.1	Hail, Snow, and extreme precipitation resilient solar energy system
Intent		To improve the solar energy systems preparedness and resilience for Hail, Snow and extreme precipitation
Source		
Weblink		
Exposure value		Number of PV power units

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage or loss due to avalanche
Criteria	B5.2	Power station located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of power station

Issue	B	Extreme precipitation
Category	B3	Risk of infrastructure damage or loss due to landslide
Criteria	B5.3	Power station located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of power station

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption, or loss critical services due to wildfire
Criteria	C3.1	Power stations located in areas at risk of wildfire
Intent		To increase the power supply resilience
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption, or loss critical services due to wildfire
Criteria	C3.2	Power sub-stations located in areas at risk of wildfire
Intent		To increase the power supply resilience
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	C	Wildfire hazard
Category	C5	Risk of infrastructure damage or loss due to wildfire
Criteria	C5.1	Power stations located in areas at risk of wildfire
Intent		To reduce the risk of wildfire on power supply
Source		
Weblink		
Exposure value		Number of power stations

Issue	C	Wildfire hazard
Category	C5	Risk of infrastructure damage or loss due to wildfire
Criteria	C5.2	Power sub-stations located in areas at risk of wildfire
Intent		To reduce the risk of wildfire on power supply
Source		
Weblink		
Exposure value		Number of power stations

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services to wind hazard

Criteria	E3.1	transmission towers distribution poles at risk of wind and storm
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption, or loss critical services to wind hazard
Criteria	E3.1	Underground transmission lines
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E5	Risk of infrastructure damage or loss to wind hazard
Criteria	E5.1	transmission towers distribution poles at risk of wind and storm
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Number of service transmission towers, distribution poles

Issue	E	Storm and wind hazard
Category	E5	Risk of infrastructure damage or loss to wind hazard
Criteria	E5.2	Underground transmission lines
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Length of transmission lines

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption, or loss critical services due heatwave

Criteria	F3.1	Commercial properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of commercial properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption, or loss critical services due heatwave
Criteria	F3.2	Residential properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of residential properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption or loss critical services due heatwave
Criteria	F3.3	Culturally significant properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of culturally significant properties in neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption or loss critical services due heatwave
Criteria	F3.4	Mission critical properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of mission critical properties in neighbourhood

10.15.2.4 Wellbeing and Organization

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.1	Commercial properties located in river/coastal floodplain
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of users of Commercial properties

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.2	Residential properties located in river/coastal floodplain
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of residential properties occupant

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.3	Culturally significant properties located in river/coastal floodplain
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of users of culturally significant properties

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood
Criteria	A1.4	Mission critical properties located in river/coastal floodplain
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of users of Mission critical properties

Issue	C	Wildfire hazard

Category	C1	Inhabitants' health and safety risk due to wildfire
Criteria	C1.1	Commercial properties located in wildfire risk zone
Intent		To reduce user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of users of Commercial properties

Issue	C	Wildfire hazard
Category	C1	Inhabitants' health and safety risk due to wildfire
Criteria	C1.2	Residential properties located in wildfire risk zone
Intent		To reduce user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of residential properties occupant

Issue	C	Wildfire hazard
Category	C1	Inhabitants' health and safety risk due to wildfire
Criteria	C1.3	Culturally significant properties located in wildfire risk zone
Intent		To reduce user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of users of culturally significant properties

Issue	C	Wildfire hazard
Category	C1	Inhabitants' health and safety risk due to wildfire
Criteria	C1.4	Mission critical properties located in wildfire risk zone
Intent		To reduce critical building user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of users of Mission critical properties

Issue	D	Drought and water scarcity
Category	D1	Inhabitants' health and safety risk due to water scarcity
Criteria	D1.1	Customers and zones vulnerable to supply deficit

Intent	To reduce exposure to water scarcity
Source	ClimateXChange, Scotland's centre of expertise on climate change
Weblink	https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw7-customers-and-zones-vulnerable-to-supply-deficit/
Exposure value	Number of subscribers

Issue	E	Storm and wind hazard
Category	E1	Inhabitants' health and safety risk due to wind
Criteria	E1.1	Adverse wind conditions at grade around
Intent		To protect the users from storm and wind risk
Source		
Weblink		
Exposure value		Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants' health and safety risk due to heatwave
Criteria	F1.1	Commercial properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of users of Commercial properties

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants' health and safety risk due to heatwave
Criteria	F1.2	Residential properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of residential properties occupant

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants' health and safety risk due to heatwave
Criteria	F1.3	Culturally significant properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating

Source	
Weblink	
Exposure value	Number of users of culturally significant properties

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants' health and safety risk due to heatwave
Criteria	F1.4	Mission critical properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of users of mission critical properties

10.15.2.5 Communication systems

10.15.2.6 Urban and spatial environment

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Developed area located in river/coastal floodplain
Intent		To reduce asset exposure to a flood damage
Source		European Environment Agency (EEA)
Weblink		https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/climatic-threats/flooding
Exposure value		Area of the neighbourhood

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.2	Soil sealing
Intent		To reduce asset exposure to a flood damage
Source		FASUDIR
Weblink		https://cordis.europa.eu/project/id/609222
Exposure value		Area of neighbourhood

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Hail, Snow and extreme precipitation
Criteria	B1.1	Pathways that can be used in winter / snow season
Intent		To protect the users of open spaces from risks of hail, snow and extreme precipitation
Source		Urban Design of Winter Cities Winter Season Connectivity for Soft Mobility
Weblink		http://ltu.diva-portal.org/smash/get/diva2:1240262/FULLTEXT02.pdf
Exposure value		Length of pathways in the neighbourhood

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to avalanche
Criteria	B2.1	Developed area located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Area of the neighbourhood

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to landslide
Criteria	B2.2	Developed area located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Area of the neighbourhood

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C2.1	Developed area located in wildfire risk zone
Intent		To reduce asset exposure to a wildfire hazard
Source		European Environment Agency (EEA)
Weblink		http://www.eea.europa.eu/dataand-maps/data/urban-atlas
Exposure value		Area of the neighbourhood

Issue	D	Drought and water scarcity

Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Recharge of groundwater through permeable paving or landscaping
Intent		To improve the permeability of the area
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Area of the neighbourhood

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Pathways wind comfort rating
Intent		To protect the users of open spaces from risks storm and wind
Source		Assessing wind comfort in urban planning
Weblink		https://journals.sagepub.com/doi/10.1068/b35154
Exposure value		Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Cool roof area
Intent		To reduce the exposure to heatwave
Source		ANSI/ASHRAE/IES Standard90.1-2010 Performance Rating Method Reference
Weblink		https://www.ashrae.org/technical-resources/bookstore/standard-90-1
Exposure value		Roof area in the neighbourhood

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.2	Share of urban green spaces
Intent		To reduce heat island effect
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.3	Outdoor thermal comfort indicator

Intent	To reduce the risk of overheating
Source	Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink	https://edepot.wur.nl/262828
Exposure value	Number of neighbourhood inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.4	Albedo of building and paving surfaces
Intent		To reduce the risk of overheating
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of neighbourhood inhabitant's

10.15.2.7 Transport and mobility

Issue	A	Flood hazard
Category	A1	Inhabitants health and safety risk due to flood
Criteria	A1.1	road and car parking that are designed to act as temporary flood storage areas
Intent		To reduce inhabitant's exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of inhabitants

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.1	Risk of traffic disruption as a result of flooding
Intent		To reduce traffic disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bt17-risk-of-traffic-disruption-as-a-result-of-flooding/
Exposure value		average daily traffic volume

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood

Criteria	A3.2	Disruption risk to railway services as a result of flooding
Intent		To reduce traffic disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bt9-disruption-risk-to-railway-services-as-a-result-of-flooding/
Exposure value		Rail network length

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.1	Road network at risk of flooding
Intent		To reduce road network exposure to a flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bt2-road-network-at-risk-of-flooding/
Exposure value		Road network length

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.2	Rail network at risk of flooding
Intent		To reduce rail network exposure to a flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bt8-railway-network-at-risk-of-flooding/
Exposure value		Rail network length

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services to avalanche
Criteria	B3.1	Road at risk to Avalanche
Intent		To reduce road network exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Road length

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services to landslide

Criteria	B3.2	Road at risk to landslide
Intent		To reduce road network exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Road length

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage to avalanche
Criteria	B3.1	Road at risk to Avalanche
Intent		To reduce road network exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Road length

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage to landslide
Criteria	B3.2	Road at risk to landslide
Intent		To reduce road network exposure to an landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Road length

Issue	C	Wildfire hazard
Category	C1	Inhabitants health and safety risk due to wildfire
Criteria	C1.1	Safe access to water resources needed for wildfire suppression
Intent		To reduce user's exposure to a wildfire hazard
Source		Federal Emergency Management Agency, U.S. Department of Homeland Security
Weblink		https://www.fema.gov/media-library-data/20130726-1728-25045-1351/home_builders_guide_to_construction_in_wildfire_zones.pdf
Exposure value		Road length

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire

Criteria	C2.1	Safe access to water resources needed for wildfire suppression
Intent		To reduce user's exposure to a wildfire hazard
Source		Federal Emergency Management Agency, U.S. Department of Homeland Security
Weblink		https://www.fema.gov/media-library-data/20130726-1728-25045-1351/home_builders_guide_to_construction_in_wildfire_zones.pdf
Exposure value		Road length

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption or loss critical services to wildfire
Criteria	C3.1	Risk of traffic disruption as a result of wildfire
Intent		To reduce traffic disruption due to a wildfire hazard
Source		
Weblink		
Exposure value		average daily traffic volume

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to storm and wind
Criteria	E3.1	Risk of rail traffic disruption as a result of storm
Intent		To reduce traffic disruption due to a storm
Source		
Weblink		
Exposure value		Rail network length

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants' health and safety risk due to heatwave
Criteria	F1.1	Cool pavement
Intent		To reduce the heat island effect
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Area of road

10.15.2.8 Green and blue infrastructure

Issue	A	Flood hazard
Category	A1	Inhabitants' health and safety risk due to flood

Criteria	A1.1	Green and blue areas used as flood control
Intent		To reduce inhabitant's exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of inhabitants

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of buildings

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of infrastructure facilities

Issue	B	Extreme precipitation
Category	B4	Risk of infrastructure damage to extreme precipitation
Criteria	B4.1	land lost to soil erosion
Intent		To reduce soil erosion exposure
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Soil area

Issue	C	Wildfire hazard
Category	C4	Risk of damage and loss to an ecosystem due to wildfire
Criteria	C4.1	Areas covered by vegetation affected by plagues or fires
Intent		To reduce ecosystem exposure to a wildfire hazard

Source	Adaptation M&E indicator system of Mexico
Weblink	https://www.adaptationcommunity.net/?wpfb_dl=221
Exposure value	Area of green vegetation

Issue	D	Drought and water scarcity
Category	D1	Inhabitants health and safety risk due due to drought
Criteria	D1.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Number of inhabitants

Issue	D	Drought and water scarcity
Category	D4	Risk of damage and loss to an ecosystem due to drought
Criteria	D4.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Trees at risk of falling due to storm hazard
Intent		To protect the users from storm and wind risk

Source	
Weblink	
Exposure value	Number of inhabitant's

Issue	E	Storm and wind hazard
Category	E2	Risk of asset damage and loss due to wind
Criteria	E2.1	Trees at risk of falling due to storm hazard on buildings
Intent		To protect the assets from storm and wind risk
Source		
Weblink		
Exposure value		Number of buildings

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.2	Trees at risk of falling due to storm hazard on rail roads
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Length of rail network

Issue	E	Storm and wind hazard
Category	E5	infrastructure damage or loss due to wind
Criteria	E5.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		

Exposure value	length of power lines

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Tree coverage for shade and management of local ambient temperatures
Intent		To reduce the risk of overheating To reduce ambient temperatures
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of inhabitant’s

10.15.3 District scale

10.15.3.1 Structures

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Properties located in river/coastal floodplain
Intent		To reduce building exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Hail, Snow and extreme precipitation
Criteria	B1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks of hail, snow and extreme precipitation
Source		
Weblink		
Exposure value		Number of settlement inhabitant’s

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to avalanche
Criteria	B2.1	Developed area located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of buildings

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to landslide
Criteria	B2.2	Developed area located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of buildings

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C2.1	Properties located in wildfire risk zone
Intent		To reduce building exposure to a wildfire hazard
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of buildings

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Re-use of rainwater in residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of residential buildings in settlement

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.2	Re-use of rainwater in non-residential properties
Intent		To reduce water stress by improving water use efficiency in commercial buildings
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of non-residential buildings in settlement

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Weather protection structure in open spaces
Intent		To protect the users of open spaces from risks storm and wind
Source		
Weblink		
Exposure value		Number of settlement inhabitant’s

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Properties at risk of overheating
Intent		To reduce the number of buildings at risk of overheating
Source		
Weblink		
Exposure value		Number of properties in the settlement

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.1	barrier free public properties
Intent		To ensure that safety and rescue is possible to all users
Source		CESBA Alps
Weblink		https://www.alpine-space.eu/project/cesba-alps/
Exposure value		Number of public properties in the settlement

10.15.3.2 Water, wastewater, and sanitation systems

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Drainage system reserves
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Length of drainage system

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.1	Sewerage and drainage network at risk from climate hazards
Intent		To reduce wastewater and drainage disruption due to flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of building connected to the sewerage and drainage network

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.2	Water treatment facilities in floor risk zone
Intent		To reduce water treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw5-water-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of building connected to water network

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services to flood
Criteria	A3.3	Wastewater treatment facilities in floor risk zone
Intent		To reduce wasterwater treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw4-wastewater-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of building connected to the sewerage and drainage network

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.1	Sewerage and drainage network at risk from climate hazards
Intent		To reduce wastewater and drainage network risk due to flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Length of sewerage and drainage network

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.2	Water treatment facilities in floor risk zone
Intent		To reduce water treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw5-water-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of water treatment plants

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.3	Wastewater treatment facilities in floor risk zone
Intent		To reduce wastewater treatment disruption due to flood damage
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw4-wastewater-treatment-works-in-areas-at-flood-risk/
Exposure value		Number of waste water treatment plants

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.1	Water consumption in domestic use
Intent		To make efficient use of water resources
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw8-domestic-water-usage/
Exposure value		Number of domestic building

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.2	Water consumption in non-domestic use
Intent		To make efficient use of water resources
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw9-non-domestic-water-usage/
Exposure value		Number of non-domestic users

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.3	water exploitation index
Intent		To make efficient use of water resources
Source		EUROSTAT
Weblink		https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rd220
Exposure value		Number of inhabitants

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.4	leakage and losses to water supply
Intent		To make efficient use of water resources
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw6-water-leakage-and-losses/
Exposure value		Number of consumers

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.5	Provision of split grey / potable water services
Intent		To make efficient use of water resources
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/
Exposure value		Number of consumers

Issue	D	Drought and water scarcity
Category	D3	Risk of damage, disruption or loss critical services due to drought
Criteria	D3.6	Water leakage sensors
Intent		To make efficient use of water resources
Source		
Weblink		
Exposure value		Number of buildings

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.1	leakage and losses to water supply
Intent		To make efficient use of water resources
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw6-water-leakage-and-losses/
Exposure value		Treated water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.2	Water conserved through reuse, awareness, water efficient appliances
Intent		To make efficient use of water resources
Source		French National Climate Change Impact Adaptation Plan 2011-2015. Annex II. Detailed action sheets
Weblink		https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/me/me-guides-manuals-reports/giz2014-en-climate-adaptation-indicator-repository.pdf
Exposure value		Treated water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.3	water exploitation index
Intent		To reduce water scarcity
Source		EUROSTAT
Weblink		https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rd220
Exposure value		Drink water volume

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to cascading risk
Criteria	G1.1	Quality of drinking water
Intent		To ensure safe access to domestic water
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/natural-environment/water-quality-and-availability/
Exposure value		Number of inhabitants

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to cascading risk
Criteria	G1.2	Water and wastewater coverage
Intent		To ensure safe access to domestic water
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/natural-environment/water-quality-and-availability/

Exposure value	Number of buildings

Issue	G	compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G1.1	Share of Wastewater treatment
Intent		To ensure safe treatment of waste water
Source		Adaptation M&E indicator system of Mexico
Weblink		https://www.adaptationcommunity.net/?wpfb_dl=221
Exposure value		Wastewater volume

10.15.3.3 Energy systems

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.1	Power stations located in areas at flood risk
Intent		To reduce the risk of flood on power supply
Source		ClimateXChange, Scotland’s centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value		Number of power stations

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage or loss due to flood
Criteria	A5.2	Power sub-stations located in areas at flood risk
Intent		To reduce the risk of flood on power supply
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be5-electricity-substations-located-in-areas-at-flood-risk/
Exposure value		Number of power sub-stations

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services due to flood
Criteria	A3.1	Power stations located in areas at flood risk
Intent		To increase the power supply resilience

Source	ClimateXChange, Scotland's centre of expertise on climate change
Weblink	https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value	Number of service subscriber

Issue	A	Flood hazard
Category	A3	Risk of damage, disruption or loss critical services due to flood
Criteria	A3.2	Power sub-stations located in areas at flood risk
Intent		To increase the power supply resilience
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be1be2be3-major-power-stations-in-areas-at-flood-risk/
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services due to Hail, Snow and extreme precipitation
Criteria	B3.1	Hail, Snow and extreme precipitation resilient solar energy system
Intent		To increase the power supply resilience
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services due to avalanche
Criteria	B3.2	Power station located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of service subscriber

Issue	B	Extreme precipitation
Category	B3	Risk of damage, disruption or loss critical services due to landslide
Criteria	B3.3	Power station located in landslide risk zone

Intent	To reduce exposure to a landslide
Source	Conference of European directors of roads
Weblink	https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value	Number of service subscriber

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage or loss due to Hail, Snow and extreme precipitation
Criteria	B5.1	Hail, Snow and extreme precipitation resilient solar energy system
Intent		To improve the solar energy systems preparedness and resilience for Hail, Snow and extreme precipitation
Source		
Weblink		
Exposure value		Number of PV power units

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage or loss due to avalanche
Criteria	B5.2	Power station located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of power station

Issue	B	Extreme precipitation
Category	B3	Risk of infrastructure damage or loss due to landslide
Criteria	B5.3	Power station located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of power station

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption or loss critical services due to wildfire
Criteria	C3.1	Power stations located in areas at risk of wildfire

Intent	To increase the power supply resilience
Source	
Weblink	
Exposure value	Number of service subscriber

Issue	C	Wildfire hazard
Category	C3	Risk of damage, disruption or loss critical services due to wildfire
Criteria	C3.2	Power sub-stations located in areas at risk of wildfire
Intent		To increase the power supply resilience
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	C	Wildfire hazard
Category	C5	Risk of infrastructure damage or loss due to wildfire
Criteria	C5.1	Power stations located in areas at risk of wildfire
Intent		To reduce the risk of wildfire on power supply
Source		
Weblink		
Exposure value		Number of power stations

Issue	C	Wildfire hazard
Category	C5	Risk of infrastructure damage or loss due to wildfire
Criteria	C5.2	Power sub-stations located in areas at risk of wildfire
Intent		To reduce the risk of wildfire on power supply
Source		
Weblink		
Exposure value		Number of power stations

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services to wind hazard
Criteria	E3.1	transmission towers distribution poles at risk of wind and storm
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU

Weblink	https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value	Number of service subscriber

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services to wind hazard
Criteria	E3.1	Underground transmission lines
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E5	Risk of infrastructure damage or loss to wind hazard
Criteria	E5.1	transmission towers distribution poles at risk of wind and storm
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Number of service transmission towers, distribution poles

Issue	E	Storm and wind hazard
Category	E5	Risk of infrastructure damage or loss to wind hazard
Criteria	E5.2	Underground transmission lines
Intent		To reduce the risk of power disruption due wind and storm hazard
Source		Climate change and critical infrastructure – storms, JRC , EU
Weblink		https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113721/eur_29411_en_storms_ci.pdf
Exposure value		Length of transmission lines

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption or loss critical services due heatwave
Criteria	F3.1	Non-residential properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med

Weblink	https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value	Number of non-residential buildings

Issue	F	Extreme temperature and warming trend
Category	F3	Risk of damage, disruption or loss critical services due heatwave
Criteria	F3.2	Residential properties cooling energy demand
Intent		To reduce the need of energy for cooling
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of residential properties

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.1	Total GHG Emissions from primary energy used in building operations
Intent		To reduce the GHG Emissions
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of inhabitants

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.2	Total GHG Emissions from primary energy used in municipal services
Intent		To reduce the GHG Emissions
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of inhabitants

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk

Criteria	G1.3	GHG emissions from energy embodied in construction materials used for construction, maintenance or replacement(s)
Intent		To reduce the GHG Emissions
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of inhabitants

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.4	Fuel poverty
Intent		To reduce inhabitants' risk of fuel poverty
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/crs61-number-of-households-in-fuel-poverty/
Exposure value		Number of households

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.1	Renewable energy in total final thermal energy consumption
Intent		To incentive the consumption and production of renewable energy
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of service subscriber

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.2	Renewable energy in total final electrical energy consumption
Intent		To minimise the total greenhouse gas emissions from buildings' operations.
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of service subscriber

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.3	Share of Renewable energy produced on site for thermal energy consumption
Intent		To incentive the consumption and production of renewable energy
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of service subscriber

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.4	Share of Renewable energy produced on site for electrical energy consumption
Intent		To incentive the consumption and production of renewable energy
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of service subscriber

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.5	Renewable energy storage capacity for electrical energy consumption
Intent		To incentive the consumption and production of renewable energy
Source		NewTREND
Weblink		http://newtrend-project.eu/wp-content/uploads/2015/11/NewTREND_WP2_D2.2_KPI_GB04_V5.2.pdf
Exposure value		Number of service subscriber

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.6	Residential building energy performance rating
Intent		To incentive low energy buildings
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf

Exposure value	Number of residential buildings

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.7	Non-residential building energy performance rating
Intent		To incentive low energy non-residential buildings
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of non-residential buildings

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.8	building with smart energy meters
Intent		To better match the energy production with consumption
Source		SmartCEPS
Weblink		https://abud.hu/portfolio/smartceps/
Exposure value		Number of service subscribers

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.9	building connected to a smart grid
Intent		To better match the energy production with consumption
Source		SmartCEPS
Weblink		https://abud.hu/portfolio/smartceps/
Exposure value		Number of service subscribers

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.10	Electrical peak demand for building operations
Intent		To incentive the consumption and production of renewable energy
Source		CESBA MED
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf

Exposure value	Number of service subscribers

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.10	Power supply disruption due to climate impact
Intent		To improve the power supply reliability
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/be15-electricity-supply-disruption-caused-by-severe-weather-events/
Exposure value		Number of service subscribers

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.11	Uptake of domestic energy efficiency measures
Intent		Increase resilience of power and energy networks
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/crs64-uptake-of-domestic-energy-efficiency-measures/
Exposure value		Area of the built environment

10.15.3.4 Wellbeing and Organization

Issue	A	Flood hazard
Category	A1	Inhabitants health and safety risk due to flood
Criteria	A1.1	Inhabitants using properties located in river/coastal floodplain
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of inhabitants

Issue	A	Flood hazard
Category	A1	Inhabitants health and safety risk due to flood
Criteria	A1.2	number of inhabitants suffering from health impact/ losses due to flood event
Intent		To reduce inhabitant's exposure to a flood damage
Source		2013 UK Adaptation Monitoring and Evaluation Framework

Weblink	https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value	Number of inhabitants

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Avalanche
Criteria	B1.1	properties located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of inhabitants

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to Avalanche
Criteria	B1.2	number of inhabitants suffering from health impact/ losses due Avalanche
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of inhabitants

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to landslide
Criteria	B1.3	properties located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Number of inhabitants

Issue	B	Extreme precipitation
Category	B1	Inhabitants health and safety risk due to landslide
Criteria	B1.4	number of inhabitants suffering from health impact/ losses due landslide
Intent		To reduce exposure to a andslide
Source		Conference of European directors of roads

Weblink	https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value	Number of inhabitants

Issue	C	Wildfire hazard
Category	C1	Inhabitants health and safety risk due to wildfire
Criteria	C1.1	Inhabitants using properties located in wildfire risk zone
Intent		To reduce user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of inhabitants

Issue	C	Wildfire hazard
Category	C1	Inhabitants health and safety risk due to wildfire
Criteria	C1.2	number of inhabitants suffering from health impact/ losses due to wildfire risk zone
Intent		To reduce user's exposure to a wildfire hazard
Source		
Weblink		
Exposure value		Number of inhabitants

Issue	D	Drought and water scarcity
Category	D1	Inhabitants health and safety risk due to water scarcity
Criteria	D1.1	Customers and zones vulnerable to supply deficit
Intent		To reduce exposure to water scarcity
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/bw7-customers-and-zones-vulnerable-to-supply-deficit/
Exposure value		Number of subscribers

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	number of inhabitants suffering from health impact/ losses due to storm hazard
Intent		To protect the users from storm and wind risk
Source		
Weblink		

Exposure value	Number of inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Number of user of properties at risk of overheating
Intent		To reduce the number of building user at risk of overheating
Source		
Weblink		
Exposure value		Number of inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.2	number of inhabitants suffering from health impact/ losses due to heatwave
Intent		To reduce the number of building users at risk of overheating
Source		
Weblink		
Exposure value		Number of inhabitant's

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.1	air quality index
Intent		To monitor and improve the air quality
Source		SmartCEPS
Weblink		https://abud.hu/portfolio/smartceps/
Exposure value		Number of inhabitant's

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.2	Uptake of climate change warning
Intent		To raise the climate change adaption
Source		
Weblink		
Exposure value		Number of inhabitant's

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.2	Uptake of climate change warning
Intent		To raise the climate change hazard awareness
Source		ClimateXChange, Scotland's centre of expertise on climate change
Weblink		https://www.climatexchange.org.uk/research/indicators-and-trends/indicators/crs34-number-of-registrations-for-flood-warningsalerts/
Exposure value		Number of inhabitant's

Issue	G	compound hazard
Category	G2	Risk of asset damage and loss due to cascading risk
Criteria	G2.5	Funding for climate change-adapted construction and refurbishment
Intent		To facilitate transition to smart resilient city
Source		Schönthaler, K. et al. (2011). Establishment of an Indicator Concept for the German Strategy on Adaptation to Climate Change. German Federal Environment Agency
Weblink		https://www.adaptationcommunity.net/?wpfb_dl=221
Exposure value		Number of buildings in the settlement

10.15.3.5 Communication systems

Issue	G	compound hazard
Category	G2	Risk of asset damage and loss due to cascading risk
Criteria	G2.4	Climate change awareness
Intent		To warn and prepare inhabitants to climate risks
Source		2013 UK Adaptation Monitoring and Evaluation Framework
Weblink		https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/tp_3-2018
Exposure value		Number of buildings in the settlement

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss of critical services due to a cascading risk
Criteria	G3.2	Connection to highspeed internet
Intent		To ensure that buildings are connected to highspeed internet service
Source		SmartCEPS
Weblink		https://abud.hu/portfolio/smartceps/
Exposure value		Number of properties in the settlement

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss of critical services due to a cascading risk
Criteria	31.2	Coverage of 4G network
Intent		To ensure that connection to highspeed internet service
Source		SmartCEPS
Weblink		
Exposure value		Area of settlement

10.15.3.6 Urban and spatial environment

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Developed area located in river/coastal floodplain
Intent		To reduce asset exposure to a flood damage
Source		European Environment Agency (EEA)
Weblink		https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation/climatic-threats/flooding
Exposure value		Area of the settlement

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.2	Soil sealing
Intent		To reduce asset exposure to a flood damage
Source		FASUDIR
Weblink		https://cordis.europa.eu/project/id/609222
Exposure value		Area of neighbourhood

Issue	B	Extreme precipitation
Category	B1	due to Hail, Snow and extreme precipitation
Criteria	B1.1	Pathways that can be used in winter / snow season
Intent		To protect the users of open spaces from risks of hail, snow and extreme precipitation
Source		Urban Design of Winter Cities Winter Season Connectivity for Soft Mobility
Weblink		http://ltu.diva-portal.org/smash/get/diva2:1240262/FULLTEXT02.pdf
Exposure value		Length of pathways in the settlement

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to avalanche
Criteria	B2.1	Developed area located in Avalanche risk
Intent		To reduce exposure to an avalanche
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Area of the settlement

Issue	B	Extreme precipitation
Category	B2	Risk of asset damage and loss due to landslide
Criteria	B2.2	Developed area located in landslide risk zone
Intent		To reduce exposure to a landslide
Source		Conference of European directors of roads
Weblink		https://climate-adapt.eea.europa.eu/metadata/organisations/conference-of-european-directors-of-roads/11270918
Exposure value		Area of the settlement

Issue	C	Wildfire hazard
Category	C2	Risk of asset damage and loss due to wildfire
Criteria	C2.1	Developed area located in wildfire risk zone
Intent		To reduce asset exposure to a wildfire hazard
Source		European Environment Agency (EEA)
Weblink		http://www.eea.europa.eu/dataand-maps/data/urban-atlas
Exposure value		Area of the settlement

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources
Criteria	D6.1	Recharge of groundwater through permeable paving or landscaping
Intent		To improve the permeability of the area
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Area of the settlement

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Pathways wind comfort rating
Intent		To protect the users of open spaces from risks storm and wind
Source		Assessing wind comfort in urban planning
Weblink		https://journals.sagepub.com/doi/10.1068/b35154
Exposure value		Number of settlement inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Cool roof area
Intent		To reduce the exposure to heatwave
Source		ANSI/ASHRAE/IES Standard90.1-2010 Performance Rating Method Reference
Weblink		https://www.ashrae.org/technical-resources/bookstore/standard-90-1
Exposure value		Roof area in the settlement

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.2	Share of urban green spaces
Intent		To reduce heat island effect
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of settlement inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.3	Outdoor thermal comfort indicator
Intent		To reduce the risk of overheating
Source		Urban Vulnerability Indicators. A joint report of ETC-CCA and ETC-SIA
Weblink		https://edepot.wur.nl/262828
Exposure value		Number of settlement inhabitant's

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.4	Albedo of building and paving surfaces
Intent		To reduce the risk of overheating
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of settlement inhabitant’s

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.1	Barrier-free accessibility in local outdoor public areas
Intent		To ensure that safety and rescue is possible to all users
Source		CESBA MED SNT Generic Framework
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of settlement inhabitant’s

Issue	G	compound hazard
Category	G1	Inhabitants health and safety risk due to a cascading risk
Criteria	G1.2	Safety assembly zones
Intent		To ensure that safety and rescue is possible to all users
Source		Environmental Guidelines for Settlements Planning and Management.
Weblink		https://digitallibrary.un.org/record/64035?ln=en
Exposure value		Number of settlement inhabitant’s

Issue	G	compound hazard
Category	G3	Risk of damage, disruption or loss critical services due to a cascading risk
Criteria	G3.1	Connection to basic municipal services
Intent		To ensure that connection to the essential municipal services (water, wastewater, power and energy)
Source		SmartCEPS
Weblink		https://abud.hu/portfolio/smartceps/
Exposure value		Area of n settlement

10.15.3.7 Transport and mobility

Issue	A	Flood hazard
Category	A1	Inhabitants health and safety risk due to flood
Criteria	A1.1	Green and blue areas used as flood control
Intent		To reduce inhabitant's exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of inhabitants

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of buildings

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of infrastructure facilities

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage to extreme precipitation
Criteria	B5.1	land lost to soil erosion
Intent		To reduce soil erosion exposure
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Soil area

Issue	C	Wildfire hazard
Category	C4	Risk of damage and loss to an ecosystem due to wildfire
Criteria	C4.1	Areas covered by vegetation affected by plagues or fires
Intent		To reduce ecosystem exposure to a wildfire hazard
Source		Adaptation M&E indicator system of Mexico
Weblink		https://www.adaptationcommunity.net/?wpfb_dl=221
Exposure value		Area of green vegetation

Issue	D	Drought and water scarcity
Category	D1	Inhabitants' health and safety risk due due to drought
Criteria	D1.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Number of inhabitants

Issue	D	Drought and water scarcity
Category	D4	Risk of damage and loss to an ecosystem due to drought
Criteria	D4.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Trees at risk of falling due to storm hazard
Intent		To protect the users from storm and wind risk
Source		
Weblink		
Exposure value		Number of inhabitant’s

Issue	E	Storm and wind hazard
Category	E2	Risk of asset damage and loss due to wind
Criteria	E2.1	Trees at risk of falling due to storm hazard on buildings
Intent		To protect the assets from storm and wind risk
Source		
Weblink		
Exposure value		Number of buildings

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.2	Trees at risk of falling due to storm hazard on rail roads
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Length of rail network

Issue	E	Storm and wind hazard
Category	E5	infrastructure damage or loss due to wind

Criteria	E5.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		length of power lines

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Tree coverage for shade and management of local ambient temperatures
Intent		To reduce the risk of overheating To reduce ambient temperatures
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Number of inhabitant's

Issue	G	Compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.1	Condition of surface freshwater systems
Intent		To preserve the quality of surface freshwater
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Freshwater volume

Issue	G	Compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.2	Condition of groundwater and subsurface aquifers
Intent		To preserve the quality of groundwater and subsurface aquifers
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Groundwater volume

Issue	G	Compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.3	Contamination status of undeveloped land
Intent		To prevent the contamination of the land
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Undeveloped land area

10.15.3.8 Green and blue infrastructure

Category	A1	Inhabitants health and safety risk due to flood
Criteria	A1.1	Green and blue areas used as flood control
Intent		To reduce inhabitant's exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of inhabitants

Issue	A	Flood hazard
Category	A2	Risk of asset damage and loss due to flood
Criteria	A2.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of buildings

Issue	A	Flood hazard
Category	A5	Risk of infrastructure damage and loss due to flood
Criteria	A5.1	Green and blue areas used as flood control
Intent		To reduce asset exposure to a flood damage
Source		Designing for exceedance in urban drainage – good practice
Weblink		https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C635&Category=BOOK
Exposure value		Number of infrastructure facilities

Issue	B	Extreme precipitation
Category	B5	Risk of infrastructure damage to extreme precipitation
Criteria	B5.1	land lost to soil erosion
Intent		To reduce soil erosion exposure
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/fileadmin/user_upload/Sites/Efficient_Buildings/Projects/CESBA_MED/D.3.4.1_-_CESBA_MED_Generic_Framework.pdf
Exposure value		Soil area

Issue	C	Wildfire hazard
Category	C4	Risk of damage and loss to an ecosystem due to wildfire
Criteria	C4.1	Areas covered by vegetation affected by plagues or fires
Intent		To reduce ecosystem exposure to a wildfire hazard
Source		Adaptation M&E indicator system of Mexico
Weblink		https://www.adaptationcommunity.net/?wpfb_dl=221
Exposure value		Area of green vegetation

Issue	D	Drought and water scarcity
Category	D1	Inhabitants health and safety risk due due to drought
Criteria	D1.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Number of inhabitants

Issue	D	Drought and water scarcity
Category	D4	Risk of damage and loss to an ecosystem due to drought
Criteria	D4.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	D	Drought and water scarcity
Category	D6	Risk of damage and loss of natural resources due to drought
Criteria	D6.1	Groundwater development stress
Intent		Guidance for rational groundwater development planning and management
Source		UNESCO
Weblink		http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf
Exposure value		Ground water volume

Issue	E	Storm and wind hazard
Category	E1	Inhabitants health and safety risk due to wind
Criteria	E1.1	Trees at risk of falling due to storm hazard
Intent		To protect the users from storm and wind risk
Source		
Weblink		
Exposure value		Number of inhabitant's

Issue	E	Storm and wind hazard
Category	E2	Risk of asset damage and loss due to wind
Criteria	E2.1	Trees at risk of falling due to storm hazard on buildings
Intent		To protect the assets from storm and wind risk
Source		
Weblink		
Exposure value		Number of buildings

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Number of service subscriber

Issue	E	Storm and wind hazard
Category	E3	Risk of damage, disruption or loss critical services due to wind
Criteria	E3.2	Trees at risk of falling due to storm hazard on rail roads
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		Length of rail network

Issue	E	Storm and wind hazard
Category	E5	infrastructure damage or loss due to wind
Criteria	E5.1	Trees at risk of falling due to storm hazard power lines
Intent		To protect critical services from storm and wind risk
Source		
Weblink		
Exposure value		length of power lines

Issue	F	Extreme temperature and warming trend
Category	F1	Inhabitants health and safety risk due to heatwave
Criteria	F1.1	Tree coverage for shade and management of local ambient temperatures
Intent		To reduce the risk of overheating To reduce ambient temperatures
Source		CESBA Med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/CESBA%20Alps
Exposure value		Number of inhabitant's

Issue	G	Compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.1	Condition of surface freshwater systems
Intent		To preserve the quality of surface freshwater
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/CESBA%20Alps
Exposure value		Freshwater volume

Issue	G	Compound hazard

Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.2	Condition of groundwater and subsurface aquifers
Intent		To preserve the quality of groundwater and subsurface aquifers
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/CESBA%20Alps
Exposure value		Groundwater volume

Issue	G	Compound hazard
Category	G4	Risk of damage and loss to an ecosystem due to a cascading risk
Criteria	G4.3	Contamination status of undeveloped land
Intent		To prevent the contamination of the land
Source		CESBA med
Weblink		https://cesba-med.interreg-med.eu/results/deliverables/CESBA%20Alps
Exposure value		Undeveloped land area

10.16 Annex 16: Results of the iQRe Climate Change risk Assessment in The Three-case Study Sites

Left click on the Excel icon to open the chose object and open the corresponding file.

10.16.1 GAUstark Building Climate Change Risk Assessment.

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.1 Structure sector

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.2 Water, wastewater, and sanitation systems (KG 370-410)

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.3 Energy systems (KG 420 to 440)

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.4 Wellbeing and Organization

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.5 Communication systems (KG 450, 480, 630)

iQRe_Tool
v1.3_BS_Risk score_(

10.16.1.6 Urban and spatial environment (KG 510 to 560)

iQRe_Tool
v1.3_BS_Risk score_(

10.16.2 Jo Building Climate Change Risk Assessment

iQRe_Tool
v1.3_BS_Risk score_(

10.16.2.1 Structure sector

iQRe_Tool
v1.3_BS_Risk score_(

10.16.2.2 Water, wastewater, and sanitation systems (KG 370-410)

iQRe Tool
v1.3_bldg_Risk score

10.16.2.3 Energy systems (KG 420 to 440)

iQRe Tool
v1.3_bldg_Risk score

10.16.2.4 Wellbeing and Organization

iQRe Tool
v1.3_bldg_Risk score

10.16.2.5 Communication systems (KG 450, 480, 630)

iQRe Tool
v1.3_bldg_Risk score

10.16.2.6 Urban and spatial environment (KG 510 to 560)

iQRe Tool
v1.3_bldg_Risk score

10.16.3 JUZ Building Climate Change Risk Assessment.

iQRe_Tool
v1.3_BS_Risk score_J

10.16.3.1 Structure sector

iQRe Tool
v1.3_bldg_Risk score

10.16.3.2 Water, wastewater, and sanitation systems (KG 370-410)

iQRe Tool
v1.3_bldg_Risk score

10.16.3.3 Energy systems (KG 420 to 440)

iQRe Tool
v1.3_bldg_Risk score

10.16.3.4 Wellbeing and Organization

iQRe Tool
v1.3_bldg_Risk score

10.16.3.5 Communication systems (KG 450, 480, 630)

iQRe Tool
v1.3_bldg_Risk score

10.16.3.6 Urban and spatial environment (KG 510 to 560)

iQRe Tool
v1.3_bldg_Risk score

10.17 Annex 17: List of Climate Risks Adaptation Solutions For The Three Youth Centres per Hazard and Sector.

Nr.	Adaptation Solutions	Addressed Risk	Implementation			
			Synergy effect[9]	Mitigation effect[10]	Time[11]	Estimated Cost[12]
Extreme Precipitation						
Structure sector						
1	Retrofitting the windows		Moderate	+	Long	€€€
2	Installing exterior shutters		High	+	Mid	€€€
3	Green roof		High	+	Long	€€€
4	Waterproof and moisture resistant interior finishes		Low	0	Mid	€€
5	Waterproof and moisture resistant exterior finishes		Low	0	Mid	€€
6	water and moisture sealing of technical rooms		Low	0	Short	€
7	Air and moisture sealing of Building envelope		Moderate	+	Mid	€€
Energy sector						
8	Installation of waterproof sockets and switches		Low	0	Short	€
9	Support of Micro-grid energy exchange		Moderate	+	Mid	€€€
10	Retrofit technical systems with fault detection and fault diagnosis		Low	0	Mid	€€
11	Local energy storage system		Moderate	+	Short	€€
Water and wastewater sector						
12	Backwater protection		Low	0	Short	€€

[9] The synergy effect indication is based on rough estimation that would vary from one location to the other
[10] The assessment is made based on rough estimation and is used to provide a simple generalized assumption of the impact of solution on the GHG mitigation effort.
[11] The classification of the time needed for implementation (long, mid (midterm) and short) is used to provide a general estimation that can vary greatly from one site to the other and can vary greatly in range between several days to several months
[12] The cost indication is based on general estimation and used to show a general range that can vary greatly in sum and is very much dependent on the specifics of each site.

Extreme Precipitation						
13	Rain and wastewater separation		Moderate	0	Mid	€€€
14	Increase capacity of water drainage system		Low	-	Long	€€€
15	Install rainwater collection and management system (green roof, rainwater retention, etc.,)		High	+	Mid	€€
16	Reuse gray water		Moderate	+	Long	€€€
17	Sump water pump with battery backup		Low	-	Short	€
Wellbeing and Organization						
18	Emergency response plan and evacuation routes are actual and updated in timely interval		High	+	Short	€
19	Install emergency alarm system		High	+	Short	€
20	Providing regular emergency response training and behavior rules for extreme precipitation events		High	+	Short	€€
21	Carrying out maintenance of building structure in regular time interval		High	+	Short	€
22	Carrying out maintenance of building technical system in regular time interval		High	+	Short	€
23	Retrofit building technical systems to provide predictive maintenance information		Moderate	+	Mid	€€€
24	Install System alarms for technical systems in extreme precipitation threatened areas		Moderate	0	Short	€
Communication systems						
25	Reporting information regarding performance of dynamic building envelope systems		Moderate	+	Mid	€€
26	Improve and expand coverage of Wi-Fi and mobile networks		Moderate	0	Short	€
Urban and spatial environment						
27	Provide Hail, Snow, and extreme precipitation protected outdoor areas		Moderate	0	Mid	€€
28	Slope the site away from entrance and walking areas away		Moderate	0	Long	€€€
29	Improve permeability of outdoor areas		Moderate	+	Mid	€€
30	Replace Toxin and plastic based outdoor structures and surfaces		Low	+	Long	€€€

Nr.	Adaptation Solutions	Addressed Risk	Implementation: Synergy effect	Implementation: Mitigation effect	Implementation: Time	Implementation: Estimated Cost
Extreme Precipitation						
31	Provide an outdoor emergency meeting point		High	+	short	€
Structure sector						
32	Retrofit the windows to reduce solar gains		Moderate	+	Long	€€€
33	Install exterior shutters with shading control		High	+	Mid	€€€
34	Insulating the building envelope		High	+	Long	€€€
35	Install UV-blocking window film		Low	+	Short	€
36	implementing a green wall		High	+	Long	€€€
37	Install natural ventilation in critical technical rooms		Low	0	Mid	€€
Energy sector						
38	Install power backup systems		Moderate	0	Short	€€
39	Install climate control system in rooms hosting energy systems		Low	-	Short	€
40	Install Cooling and ventilation system		Low	-	Long	€€€
41	Reactivate existing ventilation system		Moderate	-	Short	€
42	Install PV panels to generate local electricity and reduce summer peak load and cover cooling demand		High	+	Mid	€€€
43	Increase electrical load capacity		Low	-	long	€€€
Wellbeing and Organization						
44	Carry out Predictive maintenance for cooling and ventilation systems		Moderate	+	Short	€
45	Introduce response training for users and behavior rules during heatwaves events in regular time interval		High	+	Short	€
46	Maintain cooling and ventilation systems in regular time interval		High	+	Short	€
47	Reduce occupancy and internal loads during summer		High	+	Short	€

Extreme Precipitation						
48	Provide users with means to adjust the temperature and avoid overheating		Low	0	Long	€€€
49	Fit rooms with temperature monitoring		Moderate	0	Short	€
Communication systems						
50	Install smart window and shutters system with predictive functions		High	+	Long	€€€
51	Install smart cooling systems with automatic temperature and ventilation regulation		High	+	Long	€€€
52	Fit communication rooms with climate control systems		Low	-	Short	€
53	Provide alarm system for overheating events		Low	0	Mid	€€
Urban and spatial environment						
54	Improve the Albedo paving surfaces to reduce overheating and UHI effect		High	0	Long	€€€
55	Provide Shading of building(s) by deciduous trees		High	+	Long	€€€
56	Install cooling elements such as water features, vegetation in outdoor areas		Low	0	Mid	€€
57	Provide shaded outdoor areas		High	0	Mid	€€
Drought and water scarcity						
Nr.	Adaptation Solutions	Addressed Risk	Implementation			
			Synergy effect	Mitigation effect	Time	Estimated Cost
Water and wastewater sector						
58	Retrofit sinks and toilets with water saving fixture		Moderate	+	Long	€€€
59	Install systems for Rain and Gray water re-use		High	+	Long	€€€
60	Install water leakage monitoring systems		Moderate	+	Mid	€€€
61	Install Water-efficient appliances		Low	+	Short	€
Wellbeing and Organization						
62	Conduct regular Water system maintenance		High	0	Short	€
63	Water leakage alarm systems		Moderate	+	Mid	€€€
64	Introduce training and information to reduce water use		High	+	short	€
65	Introduce solution to track the building's water consumption in real time and inform the end users		Moderate	+	Short	€€
Urban and spatial environment						
66	Replace outdoor surface with permeable paving or landscaping		High	0	Long	€€€

Extreme Precipitation						
Storm and wind hazard						
			Implementation			
Nr.	Adaptation Solutions	Addressed Risk	Synergy effect	Mitigation effect	Time	Estimated Cost
Wellbeing and Organization						
67	Conducting emergency response training for users including behavior rules during storm events		High	0	Short	€
68	Installing an emergency alarm for storm events		High	0	Short	€
69	Conducting periodic maintenance of building structure to prepare against a storm event		High	0	Short	€
70	Conducting periodic maintenance of building technical systems to prepare against a storm event		High	+	Short	€

10.17.1 Selected List of Climate Change Adaptation Solution For JUZ Center

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Extreme Precipitation								
Structure Sector								
3	Install Green roof		High	+	Major	Long	€€€	***
4	Waterproof and moisture resistant interior finishes		Low	0	Moderate	Mid	€€	*
7	Air and moisture sealing of Building envelope		Moderate	+	Moderate	Mid	€€	**
Energy Sector								
8	Installation of waterproof sockets and switches		Low	0	Major	Short	€	***
9	Support of Micro-grid energy exchange		Moderate	+	Low	Mid	€€€	*
11	Local energy storage system		Moderate	+	Low	Short	€€	*
Water and wastewater sector								
12	Backwater protection		Low	0	Major	Short	€€	***
17	Sump water pump with battery backup		Low	-	Low	Short	€	**
Wellbeing and Organization								
18	Emergency response plan and evacuation routes are actual and updated in timely interval		High	+	Major	Short	€	***
19	Install emergency alarm system		High	+	Major	Short	€	***
20	Providing regular emergency response training and behavior rules for extreme precipitation events		High	+	Major	Short	€€	***
21	Carrying out maintenance of building structure in regular time interval		High	+	Major	Short	€	***
22	Carrying out maintenance of building technical system in regular time interval		High	+	Major	Short	€	***
Communication systems								
26	Improve and expand coverage of Wi-Fi and mobile networks		Moderate	0	Moderate	Short	€	**
Urban and spatial environment								
27	Provide Hail, Snow, and extreme precipitation protected outdoor areas		Moderate	0	Moderate	Mid	€€	***
31	Provide an outdoor emergency meeting point		High	+	Major	short	€	***

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Heatwave and warming trend								
Structure Sector								

Extreme Precipitation								
35	Install UV-blocking window film		Low	+	Major	Short	€	***
36	implementing a green wall		High	+	Major	Long	€€€	***
Energy Sector								
38	Install power backup systems		Moderate	0	Moderate	Short	€€	*
40	Install Cooling and ventilation system		Low	-	Major	Long	€€€	***
41	Reactivate existing ventilation system		Moderate	-	Moderate	Short	€	**
42	Install PV panels to generate local electricity and reduce summer peak load and cover cooling demand		High	+	Major	Mid	€€€	***
Wellbeing and Organization								
45	Introduce response training for users and behavior rules during heatwaves events in regular time interval		High	+	Major	Short	€	***
46	Maintain cooling and ventilation systems in regular time interval		High	+	Low	Short	€	***
47	Reduce occupancy and internal loads during summer		High	+	Major	Short	€	***
49	Fit rooms with temperature monitoring		Moderate	0	Major	Short	€	**
Communication systems								
52	Fit communication rooms with climate control systems		Low	-	Low	Short	€	*
Urban and spatial environment								
54	Improve the Albedo paving surfaces to reduce overheating and UHI effect		High	0	Moderate	Long	€€€	***
56	Install cooling elements such as water features, vegetation in outdoor areas		Low	0	Moderate	Mid	€€	**
57	Provide shaded outdoor areas		High	0	Major	Short	€€	**

Drought and water scarcity

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Water and wastewater sector								
61	Install Water-efficient appliances		Low	+	Low	short	€	*
Wellbeing and Organization								
62	Conduct regular Water system maintenance		High	0	Major	short	€	***
64	Introduce training and information to reduce water use		High	+	Major	short	€	***
65	Introduce solution to track the building's water consumption in real time and inform the end users		Moderate	+	Major	Short	€€	***
Urban and spatial environment								

Storm and wind hazard

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Wellbeing and Organization								

Extreme Precipitation								
67	Conducting emergency response training for users including behavior rules during storm events		High	0	Moderate	short	€	***
68	Installing an emergency alarm for storm events		High	0	Moderate	short	€	***
69	Conducting periodic maintenance of building structure to prepare against a storm event		High	0	Moderate	short	€	***

10.17.2 Selected List of Climate Change Adaptation Solution For Jo Centre

Extreme Precipitation

Nr.	Adaptation Solutions	Addressed Risk	Implementation: Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Structure Sector								
1	Retrofitting the windows to eliminate leakage		Low	+	Low	Long	€	**
Energy Sector								
Water and wastewater sector								
Wellbeing and Organization								
18	Emergency response plan and evacuation routes are actual and updated in timely interval		High	+	Major	Short	€	***
19	Install emergency alarm system		High	+	Major	Short	€	***
20	Providing regular emergency response training and behavior rules for extreme precipitation events		High	+	Major	Short	€€	***
21	Carrying out maintenance of building structure in regular time interval		High	+	Major	Short	€	***
22	Carrying out maintenance of building technical system in regular time interval		High	+	Major	Short	€	***
Communication systems								
Urban and spatial environment								
27	Provide Hail, Snow, and extreme precipitation protected outdoor areas		Major	0	Major	Mid	€€	***
31	Provide an outdoor emergency meeting point		High	0	Major	short	€	***

Heatwave and warming trend

Nr.	Adaptation Solutions	Addressed Risk	Implementation: Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Structure Sector								
36	implementing a green wall		High	+	Major	Mid	€€€	***
Energy Sector								
40	Install Cooling and ventilation system		Low	-	Major	Short	€€	***
42	Install PV panels to generate local electricity and reduce summer peak load and cover cooling demand		High	+	Major	Mid	€€€	***
Wellbeing and Organization								
45	Introduce response training for users and behavior rules during heatwaves events in regular time interval		High	+	Major	Short	€	***
46	Maintain cooling and ventilation systems in regular time interval		High	+	Low	Short	€	***
47	Reduce occupancy and internal loads during summer		High	+	Major	Short	€	***

Extreme Precipitation								
49	Fit rooms with temperature monitoring		Moderate	0	Major	Short	€	**
Communication systems								
Urban and spatial environment								
54	Improve the Albedo paving surfaces to reduce overheating and UHI effect		Moderate	0	Moderate	Mid	€€€	**
56	Install cooling elements such as water features, vegetation in outdoor areas		Low	0	Moderate	Mid	€€	**
57	Provide shaded outdoor areas		High	0	Major	Mid	€€	**

Drought and water scarcity

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Water and wastewater sector								
Wellbeing and Organization								
62	Conduct regular Water system maintenance		High	0		short	€	***
64	Introduce training and information to reduce water use		High	+	Moderate	short	€	***
Urban and spatial environment								

Storm and wind hazard

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Wellbeing and Organization								
67	Conducting emergency response training for users including behavior rules during storm events		High	0	Moderate	short	€	***
69	Conducting periodic maintenance of building structure to prepare against a storm event		High	0	Moderate	short	€	***
70	Conducting periodic maintenance of building technical systems to prepare against a storm event		High	+	Low	short	€	***

10.17.3 Selected List of Climate Change Adaptation Solution For the GAUstark Centre

Extreme Precipitation									
Nr.	Adaptation Solutions	Addressed Risk	Implementation						
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Structure Sector									
1	Retrofitting the windows to eliminate leakage		Moderate	+	Major	Long	€€€	**
2	Installing exterior shutters		High	+	Major	Mid	€€€	***
5	Waterproof and moisture resistant exterior finishes		Low	0	Moderate	Mid	€€	*
6	water and moisture sealing of technical rooms		Low	0	Low	Short	€	***
Energy Sector									
8	Installation of waterproof sockets and switches		Low	0	Low	Short	€	***
9	Support of Micro-grid energy exchange		Moderate	+	Low	Mid	€€€	*
Water and wastewater sector									
13	Rain and wastewater separation		Moderate	0	Major	Mid	€€€	***
15	Install rain water collection and management system (green roof, rainwater retention, etc.,)		High	+	Major	Mid	€€	**
16	Reuse gray water		Moderate	+	Moderate	Long	€€€	**
Wellbeing and Organization									
18	Emergency response plan and evacuation routes are actual and updated in timely interval		High	+	Major	Short	€	***
19	Install emergency alarm system		High	+	Major	Short	€	***
20	Providing regular emergency response training and behavior rules for extreme precipitation events		High	+	Major	Short	€	***
21	Carrying out maintenance of building structure in regular time interval		High	+	Major	Short	€	***
22	Carrying out maintenance of building technical system in regular time interval		Moderate	+	Moderate	Mid	€	***
Communication systems									
Urban and spatial environment									
27	Provide Hail, Snow, and extreme precipitation protected outdoor areas		Moderate	0	Moderate	Mid	€€	***
30	Replace Toxin and plastic based outdoor structures and surfaces		Low	+	Major	Long	€€€	***
31	Provide an outdoor emergency meeting point		High	+	Major	short	€	***

Nr.	Adaptation Solutions	Addressed Risk	Implementation: Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Extreme Precipitation								
Heatwave and warming trend								
Structure Sector								
32	Retrofit the windows to reduce solar gains		Moderate	+	Major	Long	€€€	***
33	Install exterior shutters with shading control		High	+	Major	Mid	€€€	***
35	Install UV-blocking window film		Low	+	Major	Short	€	***
Energy Sector								
38	Install power backup systems		Moderate	0	Moderate	Short	€€	*
40	Install Cooling and ventilation system		Low	-	Major	Long	€€€	***
42	Install PV panels to generate local electricity and reduce summer peak load and cover cooling demand		High	+	Major	Mid	€€€	***
Wellbeing and Organization								
45	Introduce response training for users and behavior rules during heatwaves events in regular time interval		High	+	Major	Short	€	***
46	Maintain cooling and ventilation systems in regular time interval		High	+	Low	Short	€	***
47	Reduce occupancy and internal loads during summer		High	+	Low	Short	€	***
48	Provide users with means to adjust the temperature and avoid overheating		Low	0	Major	Long	€€€	***
49	Fit rooms with temperature monitoring		Moderate	0	Major	Short	€	**
Communication systems								
50	Install smart window and shutters system with predictive functions		High	+	Major	Long	€€€	***
Urban and spatial environment								
54	Improve the Albedo paving surfaces to reduce overheating and UHI effect		High	0	Moderate	Long	€€€	***
57	Provide shaded outdoor areas		High	0	Major	Mid	€€	***
Drought and water scarcity								
Nr.	Adaptation Solutions	Addressed Risk	Implementation: Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Water and wastewater sector								
58	Retrofit sinks and toilets with water saving fixture		Moderate	+	Major	Mid	€€	***
59	Install systems for Rain and Gray water re-use		High	+	Major	Mid	€€€	***
Wellbeing and Organization								
64	Introduce training and information to reduce water use		High	+	Major	short	€	***
65	Introduce solution to track the building's water consumption in real time and inform the end users		Moderate	+	Major	Short	€€	***
Urban and spatial environment								
Storm and wind hazard								

Nr.	Adaptation Solutions	Addressed Risk	Implementation					
			Synergy effect	Mitigation effect	Exposure	Time	Estimated Cost	Priority
Extreme Precipitation								
Wellbeing and Organization								
67	Conducting emergency response training for users including behavior rules during storm events		High	0	Moderate	short	€	***
68	Installing an emergency alarm for storm events		High	0	Moderate	short	€	***
69	Conducting periodic maintenance of building structure to prepare against a storm event		High	0	Moderate	short	€	***
70	Conducting periodic maintenance of building technical systems to prepare against a storm event		High	+	Low	short	€	***

10.18 Annex 18: Updated Climate Change Risk Assessment for The Three Case Study Sites Based On the Implementation of The Adaptation solutions .

Left click on the Excel icon to open the chose object and open the corresponding file.

10.18.1 GAUstark Centre Updated Climate Change Risk Assessment.

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.1 Structure sector

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.2 Water, wastewater, and sanitation systems (KG 370-410)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.3 Energy systems (KG 420 to 440)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.4 Wellbeing and Organization

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.5 Communication systems (KG 450, 480, 630)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.1.6 Urban and spatial environment (KG 510 to 560)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.2 Jo Centre Updated Climate Change Risk Assessment

iQRe_Tool
v1.3_BS_Risk score_(

10.18.2.1 Structure sector

iQRe_Tool
v1.3_BS_Risk score_(

10.18.2.2 Water, wastewater, and sanitation systems (KG 370-410)

n/a

10.18.2.3 Energy systems (KG 420 to 440)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.2.4 Wellbeing and Organization

iQRe_Tool
v1.3_BS_Risk score_(

10.18.2.5 Communication systems (KG 450, 480, 630)

n/a

10.18.2.6 Urban and spatial environment (KG 510 to 560)

iQRe_Tool
v1.3_BS_Risk score_(

10.18.3 JUZ Centre Updated Climate Change Risk Assessment.

iQRe_Tool
v1.3_BS_Risk score_(

10.18.3.1 Structure sector

iQRe_Tool
v1.3_BS_Risk score_(

10.18.3.2 Water, wastewater, and sanitation systems (KG 370-410)

iQRe Tool
v1.3_bldg_Risk score

10.18.3.3 Energy systems (KG 420 to 440)

iQRe Tool
v1.3_bldg_Risk score

10.18.3.4 Wellbeing and Organization

iQRe Tool
v1.3_bldg_Risk score

10.18.3.5 Communication systems (KG 450, 480, 630)

iQRe Tool
v1.3_bldg_Risk score

10.18.3.6 Urban and spatial environment (KG 510 to 560)

iQRe Tool
v1.3_bldg_Risk score