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Climate Adaptation Framework for Moisture-resilient Buildings in Norway

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Abstract

In the next decades, buildings and infrastructure will be exposed to significantly different climatic strains than they are today. Still, building standards and design guidelines presuppose use of historic weather data. Thus, we need a point of departure for the support of decision-making aimed at reducing risk and climate vulnerability in the built environment. We therefore propose a new climate adaptation framework in compliance with the Norwegian Planning and Building Act; A general framework for climate adaptation and moisture-resilient buildings, tailor-made for implementation in both national and international standards, certification schemes and design guidelines.

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Keywords: Climate change; Climate adaptation; Risk management; Moisture-resilience

1. Introduction

Karl and Trenberth [1] stated more than ten years ago "We are venturing into the unknown with climate, and its associated impacts could be quite disruptive". Norway's vulnerability will be influenced by impacts from global scale climate change, even though the country is considered to have a high adaptive capacity, based on macro-level indicators such as wealth, technology, information, skills, infrastructure, institutions, equity, empowerment, and ability to spread risk [2], [3], [4]. Historically, location-specific climate data have only to a very limited extent been applied

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systematically for design purposes, life cycle assessments, and climate differentiation of the suitability of a given technical solution in a given climate.

Still, building standards and design guidelines presuppose use of historic weather data - 10 years after the finalization of the Norwegian R&D-programme Climate 2000 (2000-2007) which clearly emphasized the strong need for climate adaptation in light of the future risks of climate change (i.e. the use of future climate scenarios to support or replace guidelines based on historical climate data). Geographically dependent design and guidelines on the appropriateness of different solutions in different climates are needed; see e.g. [5], [6], [7], [8], [9], [10], [11] and [12]. The programme resulted in a stronger focus on climate adaptation in the Norwegian Planning and Building Act, but there is still a long way to go before we have a full understanding of climate adaptation of buildings and necessary methods and measures needed to handle the risks of a changing climate.

The Norwegian Meteorological Institute states that Norway has to prepare for even more rain, more intense precipitation and an increase in temperatures over the next decades [13]. We are entering an era with a need for a much stronger focus on building physics, moisture-resilience and risk reduction measures related to potential moisture damage.

This paper presents a first approach for a climate adaptation framework, to comply with the Norwegian Planning and Building act and funded on the Norwegian set of rules, regulations, standards and design guidelines. The principal objective is to establish a national framework for climate adaptation to be implemented within the Norwegian construction industry, and tailor-made for the existing system of performance-based regulations.

2. National instruments and policies

A successful implementation of adaptation policies at the national level is dependent on a few key institutions' ability to initiate both government regulatory measures and local-level collective efforts to reduce climate vulnerability. In Norway, this would be the Directorate for Civil Protection and Emergency Planning and the Directorate for Building Quality. SINTEF, as an independent institution developing technical design guidelines that reaches out to almost all actors in the construction industry, and academic institutions like NTNU also have an important role to play in the development of strategies aiming at building awareness of the future risks of climate change and in the development of precautionary and cost beneficial adaptation measures.

The building regulations should obviously be a central instrument in Norwegian climate adaptation policy. All 426 municipalities of Norway must contribute to long-term adaptation measures. The Ministry of Local Government and Regional Development, being responsible for Norwegian building regulation enforcement, should have a leading position in these efforts, together with the Norwegian Ministry of Justice and the Police.

The Directorate for Building Quality is responsible for administering and interpreting Norwegian building regulations, and has the authority to administer a centralized system of Approval of designers, constructors or controllers in the construction industry. The Directorate for Civil Protection and Emergency Planning and the Directorate for Building Quality have a common responsibility to initiate collective efforts by institutions to reduce climate vulnerability in the built environment. The development of increasingly Europeanized construction and construction products industries, and the continued development of Norwegian and international standards (especially the preparation of additional national appendices associated with the various types of climatic impact) are important factors to be considered.

3. A Norwegian perspective on the need for climate adaptation

Norway's weather is extremely varied, the rugged topography being one of the main reasons for large local differences over short distances. The seasonal variations are also extreme. The climate is putting great demands on our buildings and infrastructure, and climate change will enhance the exposure in the years to come. Scenarios for climate change in Norway indicate an increased occurrence of extreme weather [13]. Together with a warmer climate, precipitation over parts of coastal Norway will also be more intense. The costs of increased annual maintenance of buildings due to climate change are estimated to amount to NOK 4.5 to 10 billion in the period 2070 to 2100 [14]. The increase in annual insurance payments due to water damage is estimated to exceed NOK 0.5 billion for the same period. By comparison, insurance payments related to water intrusion into buildings in 2015 alone were approximately

NOK 2 billion (calculated by Finance Norway). As buildings and infrastructure assets have lifetimes from 40 to more than 100 years, they are exposed not only to the climate at the time of their construction, but also to climate variations over decades. There is thus an urgent need for implementation of more sophisticated adaptive measures [6].

Almås et al. [15] presented an approach to assess the overall impacts of a changing climate on the Norwegian building stock. The results showed that approximately 615 000 buildings today are situated in areas with a high potential risk of rot-decay for (exposed) wood-based components in buildings. In 2100, this number will increase to roughly 2.4 million buildings [16]. The current large number of wooden buildings and a high number of building defects indicate that future new and refurbished buildings must be far more robust to meet a changing climate. This also implies the need for enhanced maintenance of existing buildings. Building trends with enlarged user flexibilities of roofs and future incorporation of blue-green roofs in stormwater systems indicate new challenges in maintaining a robust and moisture-resilient building envelope.

The frequency of, and damage caused by, pluvial floods is expected to increase because of climate change and urban development. Increases and changes in precipitation patterns, unknown changes in land use within the catchment combined with dynamic erosion and transport of particles lead to severe flooding and water defining new floodways. There still exist a number of limitations in the understanding of precipitation patterns in a changing climate, and this impairs the design, maintenance, operation and renewal of critical infrastructure and stormwater systems. In the past, engineers, urban planners and contractors have treated "green solutions" (gardens, roofs, terraces, parking spots and other green areas) and "blue solutions" (drainage systems, ponds, sewer systems) as separate infrastructure assets. An integrated approach to the planning and operation of "green" and "blue" solutions is important for the optimization of the built environment. This also implies that buildings and its close surrounding will interact with, and be a part of, the stormwater management system.

4. The need for a holistic strategy on climate adaptation

The society's capacity to handle the impacts of climate change are closely related to societal organization, available resources, tools, cooperation and information, and to the level of knowledge and competence in relation to climate change. Climate change adaptation is therefore as much about basic societal processes of institutional and socio-economic nature, as it is about technical concepts and solutions [17], [21]. For example, municipal risk- and vulnerability analyses are decreed by law in Norway today - but are not implemented in a large number of municipalities, i.e. leading to a lack of public and individual attention to climate related risks.

Analyses of empirical data from process induced building defect assignments clearly illustrate the vulnerability of building envelopes under varying climatic exposure [18], [19]. Lisø [6] presented a first step towards methods and approaches allowing geographically dependent climate considerations to be made in the development of design guidelines for high-performance building envelopes, and approaches to assess the risks associated with the future performance of building envelopes due to climate change. The dissertation focused on methods for assessing impacts of external climatic parameters on a local scale, but with the use of daily and monthly averages of climate data. The reliability of climate indices is strongly dependent on the geographical spreading of the meteorological observing station network. The Norwegian network is not optimally distributed to fully embrace local variations, but provides a solid platform for the development of methods for geographically dependent design and guidelines on the appropriateness of different solutions in different climates.

The most influential government regulatory measure to ensure adherence to building codes and standards is the Technical Regulations (TEK10) under the Norwegian Planning and Building Act (PBA), which since 1997 have been performance-based. The principal motive for a transition from a prescriptive-based code to a performance-based code in Norway has been to stimulate to an increase in the quality of buildings and a reduction of the amount of building defects. The transition has been a gradual process, and the performance-based way of thinking was introduced in Norwegian building regulations as early as 1969.

The transition from a prescriptive to a performance-based code has strengthened the demand for supporting standards and design guidelines. Byggforskserien (the SINTEF Building Research Design Guides) comply with the performance-based requirements in the building code, and are an important reference to documented solutions in the technical regulations. The principal objective of the design guides are to adapt experience and results from practice and research in such a way that they can be of practical benefit to the construction industry. The series consists of more than 800 design guides, the first guides being published for the first time in 1958. It is the most used planning and design tool amongst Norwegian architects and engineers, is found on nearly all construction sites – and could thus be instrumental as a tool for fast and effective climate adaptation of buildings in Norway.

The technical solutions presented in Byggforskserien are in general meant to have a reliability level suitable for all parts of the country. Standard technical solutions for all types of climate are in some cases appropriate (e.g. weather-protective flashings). However, in most cases, climate differentiated performance requirements and solutions provide the highest level of reliability. In a great many incidents it is necessary to advise against the use of a given technical solution or material combination, simply because the local climate conditions are too harsh for the particular solution to obtain its expected lifetime or too harsh to avoid defects within a reasonable level of reliability.

An analysis of climate differentiated design recommendations in Byggforskserien and SINTEF Technical Approvals illustrates the challenge at hand [20]. The analysis clearly revealed the need for climate indices allowing for geographically dependent building envelope design guidelines. All the guidelines in Byggforskserien and the 241 Technical Approvals issued by the institute at the time of investigation (2005) were examined. Rough qualitative descriptions of the climate, such as “wind exposed areas”, “cold areas”, “harsh climates”, “areas with high driving rain impact” or “exposed areas along the coast” were widely used. Such descriptions are not appropriate or precise enough as a foundation for climate adaptation with a necessary level of reliability. Instead, limit values with respect to the climatic loads that have to be accounted for, must be clarified and expressed as a function of climate properties and material- or performance properties, together with national maps of climate zones for different purposes.

Norway has come far in the assessment and understanding of the need for climate adaptation of the built environment in light of the risks of climate change. This is deeply rooted in our long and proud traditions of climate adaptation in general, in a country with an extremely varied climate. There is now a growing awareness within the construction industry that a changing climate needs to be addressed, both with mitigation and adaptation measures. Still, we have not developed a holistic framework or improved the methods to meet the new risk. The governmental regulations are in large performance based, and thus «future-proof». The challenge then begins when it comes to the implementation and use of international and national standards, guidelines and certification schemes, which still are based on historical weather data 1961-90 climate normal), and thus implies a significant security risk. This is also still true when it comes to Byggforskserien, and the well-established National Approval System. The relationship between materials, structures, building envelopes and climatic impact is highly complex, but as long as these guidelines and certification schemes do not apply climate normals representing the present and future climate they are only designed to withstand the climate exposure loads of the past.

Climate indices (using geographic information system technology) allowing for quantitative and qualitative assessment of building envelope performance or decay potential will be an important element in the development of methodologies for adaptation measures to meet the future risks of climate change. We thus need a new point of departure for the support of decision-making aimed at reducing climate vulnerability in the built environment.

5. The Klima 2050 Framework for climate adaptation

We suggest the development of a climate adaptation framework for building design (the Klima 2050 Framework for climate adaptation), in compliance with the Norwegian Planning and Building Act and the governmental regulatory measures. See Fig. 1. The figure illustrate our ambition of establishing a revised national framework for climate adaptation of buildings, introducing the Klima 2050 Framework as a tool for risk reduction through climate adaptation. The framework should consist of three pillars; 1) An overall definition of climate-adapted buildings, 2) A revised set of agreed upon climate data and scenarios for building design and 3) A holistic methodology for assessment and management that provides the necessary level of risk reduction and safety for the building and its owners and users.

The hierarchy of the Governmental regulatory measures as presented in Fig. 1 is based on The Norwegian Planning and Building Act (performance-based). Level 2 are the regulations on technical requirements for building works (TEK10) and The regulations relating to building applications (SAK10). These are in part performance-based. Level 3 consist of guidelines, circulars and official reports from the Ministry of Local Government and Modernisation that the Norwegian construction industry consider as “Pre-accepted solutions”.

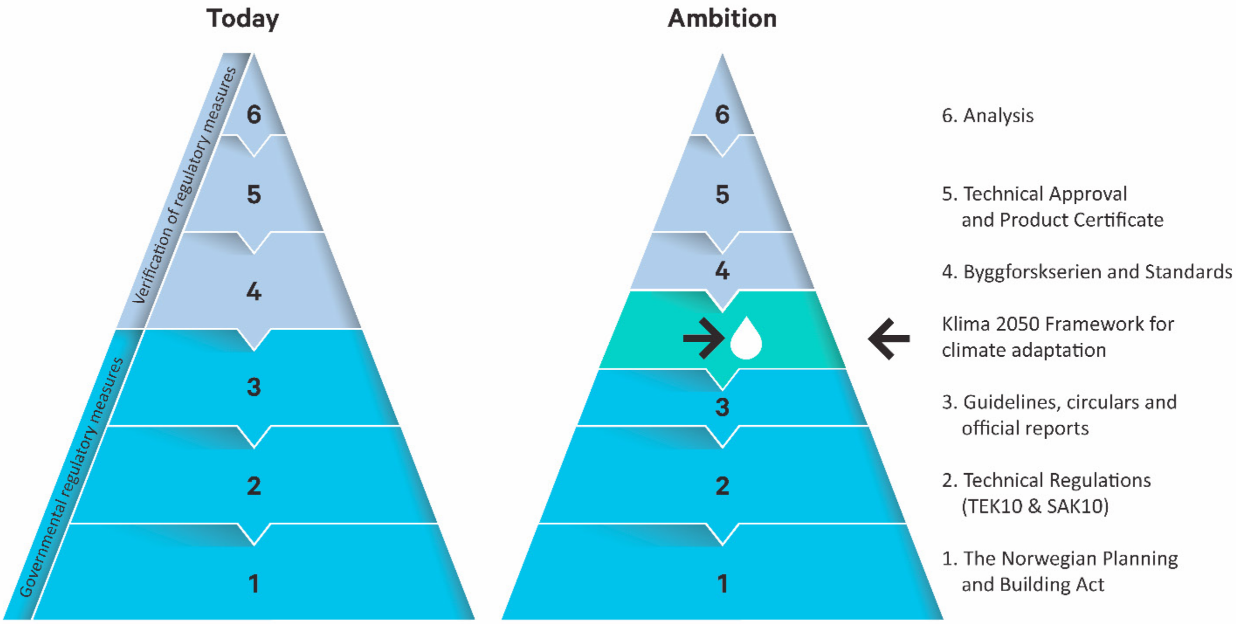

Fig. 1. The proposed Klima 2050 Framework for climate adaptation and moisture-resilient buildings, to be implemented in full compliance with the Norwegian system and the Planning and Building Act.

The Norwegian Planning and Building Act, the foundation of the governmental regulatory system, acts as a basis for climate adaptation strategies. The Klima 2050 Framework will be a significant contribution in the development of risk mapping and adaptation measures to meet the future risks of climate change – enabling us to assess the suitability of a given technical solution or material in a given climate, and to enhance our understanding of building envelope performance in relation to externally imposed climatic strains. The new framework will provide the existing system for verification with reliable climate scenarios and climate indices that will reduce the risks of climate related damage under changing climate conditions.

Country distinctive knowledge is necessary when developing national frameworks for climate adaptation. The Klima 2050 Centre will develop the framework and work with other relevant partners to agree upon appropriate climate data (new climate normals), a set of climate scenarios, tools and methods (e.g. climate indices for geographically dependent design), tailor-made for implementation in both national and international standards, certification schemes and design guidelines.

6. Conclusions

Nordic buildings of the future needs new and improved methods for vulnerability assessment of moisture-resilience in relation to externally imposed climatic strains. In light of the future risks of climate change, an agreed upon definition of climate adapted buildings is also needed. Climate change renders existing climate normals less useful. More representative climate indicators needs to be developed, representing the current and future climate in a more reliable way.

The Klima 2050 Centre will develop the framework, based on the presented conceptual point of departure. The suggested climate adaptation framework for buildings could be an important first step towards a national strategy for climate adaptation in general. Regional- and local-level climate scenarios, methods for risk assessment of climate related strains and geographically dependent climate indices allowing for qualitative and quantitative assessment of building envelope performance would be significant components in the proposed framework.

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