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## Climate adaptation of buildings through MOM- and upgrading - State of the art and research needs

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### Abstract

This study presents an overview of research initiatives and projects addressing climate adaption in management operation and maintenance (MOM) and upgrade of existing buildings. The aim was to identify knowledge needs and research demand necessary for decision makers to address climate adaptation in their MOM and upgrade plans. Climate adaptation of buildings in the Norwegian climate very much concerns increased moisture robustness and risk reduction of moisture damages. Thus, a strong focus on and development of strategies addressing building physical issues are needed in the coming future. In spite of this, very few projects focusing on climate adaptation and building physical challenges were found.

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### 1. Introduction and the need for climate adaptation of buildings

Climate change is described as one of the greatest challenges of our century [1]. The built environment is particularly vulnerable to climate change. If climate adaptation in this sector is not addressed now, the predicted effects of climate change will have a profound negative impact on society.

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 and changes over decades and there is an urgent need for planning and implementation now [2]. In order to maximize the operational lifetimes of the buildings, proper and climate adapted management, operation and maintenance (MOM) and upgrade-plans are crucial.

The Norwegian Climate Service Center predicts that Norway has to prepare for more rain, more intense precipitation and an increase in temperature [3]. This is the most prominent evidences concerning the climate change scenarios. Climate adaptation of buildings in the Norwegian climate therefore very much concerns increased moisture

robustness and risk reduction of moisture damages. Thus, a strong focus on and development of strategies addressing building physical issues are needed in the coming future.

This paper presents an overview of research-based initiatives relevant for climate adaptation of buildings through MOM and upgrade. A literature review and project portfolio overview of projects with Norwegian partners and relevant for Nordic climate have been carried out. The aim has been to identify knowledge needs and research demands which is needed for decision makers to address climate adaptation in their MOM and upgrade plans. Special emphasis has been put on unveiling research demands related to building physical issues and challenges.

## 2. Method

Following an initial literature study, the main methodological approach in this paper consisted in mapping of research projects with Norwegian partners within the field of management, operation and maintenance (MOM) and upgrade. The identified projects were sorted in a matrix, categorized according to main research theme and to which type of decision-maker for which it is relevant. The proposed levels and structure of the matrix are as follows:

Table 1. Proposed levels and sorting of research projects associated to climate adaptation of buildings through maintenance and upgrading strategies.

Level	Main actor of interest	Research theme		
		1. Climate adaptation	2. Energy efficiency	3. Economy
A. Law and legislative	Ministry/Directorate			
B. Legislative / planning / strategy	Municipality/Local authority			
C. Strategy / system	Managers/MOM operators	Relevant projects and their main research topics		
D. System / solution	Consultant/Contractor			
E. Solution / component	Product manufacturer			

The project mapping was based on queries among experts and representatives from major research projects within the field in order to arrive at a premier comprehension of the state-of-the-art of contemporary research. A draft of the project overview was also discussed with three mayor Norwegian building owners/managers and one of the largest consultant companies in Norway.

## 3. Results

The following tables show the identified research projects and their belonging according to vertical and horizontal category as described in the methods chapter. 28 projects was identified, of which 10 addressed climate adaption issues. Documentation from these ten projects has been scrutinized in order to identify main knowledge gaps within the Norwegian context.

The literature review and mapping of research projects relevant to climate adaptation of buildings through maintenance, operations and management (MOM) and upgrade revealed research needs and provided an identification of thematic areas where the research needs are present. It was a general finding, that the research projects relevant to MOM and upgrade are mainly related to energy-savings topics.

Table 2. Research projects associated to management, operation and maintenance (MOM) and upgrade of existing buildings for the Law/Legislative and Legislative/planning/strategy level.

Level	Main actor	Climate adaptation (project name)	Topic	Energy (project name)	Topic	Economy (project name)	Topic
Law/ legislative	Ministry/ Directorate	Climate and vulnerability assessment for Adaptation Committee [4-8]	Climate and vulnerability assessment for the built environment	ZEB [9-12]	Zero Emission Buildings – new and existing buildings	Green Conserve [13]	Green service innovation
		Climate change and the consequences for local and regional authorities [14]	Climate change and the consequences for the built environment and organisations/authorities	Green Conserve [13]	Green service innovation	Konsensus [15, 16]	LCA/LCC
		BIVUAC [17-22]	Climate vulnerability of buildings and infrastructure				
		SURE I and II [23] and [24]	Sustainable upgrade-processes, pre-normative R&D for a new EN-standard				
		Testing of data from the insurance sector [25]	How to use insurance databases for climate-related damages and adaptation of buildings and infrastructure				
Legislative / planning / strategy	Municipality/ Local authority	Climate and vulnerability assessment for Adaptation Committee [4-8]	Climate and vulnerability assessment for the built environment	ZEB [9-12]	New and existing buildings	Oscar [26]	Value of property and implementation process
		Climate change and the consequences for local and regional authorities [14]	Climate change and the consequences for the built environment and organisations/authorities	Rebo [27]	Upgrade of residential buildings; comfort and users		
		BIVUAC [17-22]	Climate vulnerability of buildings and infrastructure	CulClim [28, 29]	Upgrade of cultural-heritage protected buildings		
		CulClim [28, 29]	Upgrade of cultural-heritage protected buildings	SURE II [24]	Sustainable refurbishment of existing buildings.		
		NORADAPT [30]	Development of adaptation strategies for municipalities				

Table 3. Research projects associated to management, operation and maintenance (MOM) and upgrade of existing buildings for the Strategy/system level.

Level	Main actor	Climate adaptation (project name)	Topic	Energy (project name)	Topic	Economy (project name)	Topic
Strategy / system	Managers	BIVUAC [17-22]	Very little on technical solutions	ZEB [9-12]	Zero Emission Buildings new and existing buildings	Oscar [26]	Property value & implementation
		ACRP [31]	climate-related damages on airports	RetroKit [32, 33]	Systemic energy upgrade of buildings	Glitne [34, 35]	Economy & environmental effects
		Testing of data from the insurance sector [24]	Climate-related damages using insurance databases (infrastructure)	TES Energy Façade [36]	Prefabricated timber based building system for improving the energy efficiency	Cillecta [37]	LCA and LCC
				SmartTES [38, 39]	Continuation of TES Energy Façade		
				SeOPP [40, 41]	Upgrading of dwellings		
				Upgrade [42-45]	Energy-upgrade solutions		
				Cohereno [46, 47]	Energy upgrade of dwellings		
				EMROB [48]	Sustainable building upgrade		
			Rebo [27]	Residential; comfort & users			

Table 4. Research projects associated to management, operation and maintenance (MOM) and upgrade of existing buildings for the System/solution and Solution/component levels.

Level	Main actor	Climate adaptation (project name)	Topic	Energy (project name)	Topic	Economy (project name)	Topic
System / solution	Consultant/ Contractor	TallFacades [49]	Climate robustness for tall wooden facades.	ZEB [9-12]	New and existing buildings	Oscar [26]	Value of property & implementation process
		Robust [7, 50]	Climate robustness of buildings; climate exposure and building physics	Robust [7, 50]	Climate robustness of buildings, focus on climate exposure and building physics	Building upgrading for Overhalla municipality [51, 52]	Residential buildings with good comfort at affordable price
				SeOPP [40, 41]	Upgrading of single family dwellings		
				SUSref [53-55]	Mapping of upgrading needs in the EU		
				Upgrade [42-45]	Energy-upgrade solutions		
				RetroKit [32, 33]	Energy upgrade of buildings		
				SmartTES [38, 39]	Continuation of TES Energy Façade-project		
				Cohereno [46, 47]	Energy upgrade of single family dwellings		
				EMROB [48]	Guidelines for sustainable upgrading of buildings		
				EffeSuS [56]	Upgrade of protected buildings		
Solution / component	Product Manufacturer			ZEB [9-12]	new and existing buildings		
				Robust [7, 50]	Climate robustness of buildings, focus on climate exposure and building physics		

#### 4. Discussion and conclusion

For Norway and the Nordic countries, climate adaptation of buildings relates to; better resilience to moisture and potential moisture problems due to an expected increase in precipitation and a slight temperature raise. This means that typical building physical issues must be addressed. In MOM-planning and upgrade of existing buildings, there is a need to understand and better interpret actions for climate adaptation. However, a climate-adapted building is still not a clearly defined concept.

The identified projects in this study related to climate adaptation were rather few and they are mostly related to the overall levels of legislation, planning and strategies. The findings in these projects are to a certain extent superficial and overly generic, thus making them inapplicable for development of more concrete MOM and upgrade-strategies and -solutions. Few findings related to MOM and upgrade implementation for systems, technical solutions and components were done. Hence, it can be concluded that there is a large demand for research related to MOM and upgrade planning with the aim to improve technical systems and solutions for building owners.

#### 5. Further work

Based on the overview of the research projects and literature review, the authors recommend that future research activities should address the following three topics:

Firstly, strategies ensuring climate adaptation through MOM and upgrade plans should be further developed. As part of the research presented in this paper, work have been started by conducting a study of MOM routines and planning tools amongst three mayor Norwegian public building owners. The aim will be to identify systems, solutions and components that are critical to ensure climate adaptation of buildings with focus on building physical issues and challenges. This will be coupled with risk assessment of different climate change scenarios.

Secondly, checklists with key climate adaptation factors should be developed based on the systems, solution and component review as mentioned. Both the building as well as adjacent terrain and infrastructure should be included as part of such checklists.

Thirdly, systems, solutions and components that are key factors in ensuring climate adaptation should be refined and further developed. This must be done in close collaboration with the building industry to ensure that new developments are market-ready, useable and applicable for the entire building sector.

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