

# Mitigation and adaptation : energy efficient climate control in historic building

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## CHAPTER 3

### Mitigation and adaptation strategies

Tomás Vyhliđal

One of the key objectives of the Climate for Culture project was to perform an assessment of existing microclimate control strategies with respect to their energy consumption as well as their applicability to a wide spectrum of cultural heritage sites preserved in historic buildings of different structure, utilisation and climatic region in Europe. This was done with the help of building simulation models and is based on the analysis of an extensive number of project case studies spread over Europe. By coupling the building simulation models with results of high resolution climate change predictions, an outlook to the near (2020-2050) and to the far (2070-2100) future could be performed to assess energy demand predictions of selected control strategies. Along with the sustainability objectives concerning the expected rise of energy needs and costs, a lot of attention was also paid to the applicability of renewable energies to historic buildings. The above mentioned aspects are addressed in more detail in section 3.1.

The next key objective of the project was to develop indoor climate control strategies for the optimal control of relative humidity and temperature in typical historic buildings and exhibitions. In this research field, several new concepts have been proposed utilising the mathematical models and damage functions. The key objective of the methods was to achieve a risk-free environment under minimised energy consumption. These methods, as well as classical approaches have been implemented on a low cost controller, which can be applied to switching on and off the indoor climate control devices (dehumidifiers, humidifiers, heaters, coolers, ventilators), both portable and permanent. In addition to the classical building simulation softwares such as WUFI®Plus and HAMBBase-MatLab, Fluent software has been used to model and analyse airflows in selected spacious historic interiors. The simulation based analysis was also supplemented by the analysis of existing implementations of a wide range of control methods. The results are summed up in the implemented Decision Support System for indoor climate risk assessment and control. More detailed information on the topics mentioned here can be found in section 3.2.

Section 3.3 deals with revitalisation and enhancement of historic climatisation systems. This part of research consisted of both the detailed analysis of existing solutions as well as of concept studies supported by the simulation tools. Altogether, twelve key case studies have been addressed in the project. Section 3.4 then deals with “Temperierung”, i.e. wall heating systems, which mainly distribute heat via radiation from heating pipes inside or in front of the walls. On the one hand these systems have advantages in reducing cold wall effects and mould risk. On the other hand, in combination with reducing the infiltration rate of buildings, they can be used to improve climate stability when used in properly. A study on the Brezice castle “Temperierung” project in Slovenia and about the conservation heating control system to stabilise relative humidity at St. Renatus Chapel in Germany are presented. The last

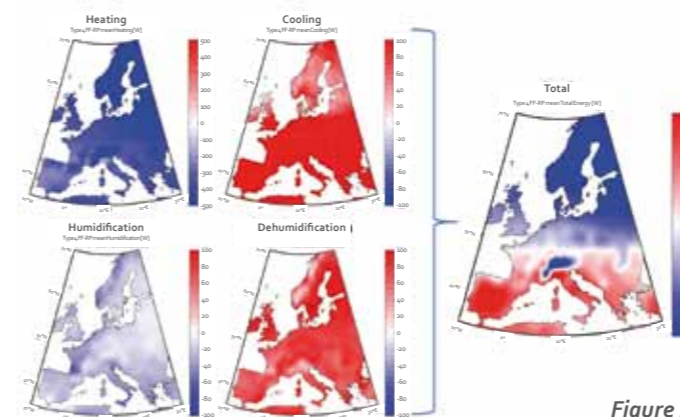
section 3.5 presents further contributions to promoting the radiative heating in historic buildings. Following on from the research of earlier EU project Friendly Heating on designing optimal heating strategy in historic churches, a series of experiments have been performed to study the efficiency of various heating

elements regarding the heating source and the elements shape. Besides, energy efficiency and various environmental aspects of the friendly heating system have been studied by modelling the indoor climate of the church in Rocca Pietore in Italy.

## CHAPTER 3.1

### Energy efficient climate control in historic buildings

Tor Brostrom, Jos van Schijndel, Magnus Wessberg, Poul Klenz Larsen et al.



An overarching goal of the Climate for Culture project is to promote efficient energy use in historic buildings. We firstly assessed how indoor climate and energy demand is affected by climate change. We then developed new strategies and technical solutions for energy-efficient climate control and compared them with state of the art solutions. Historic buildings without any climate control are vulnerable to climate change because indoor climate is strongly influenced by outdoor climate and the properties of the building envelope. In these buildings, however, climate change may require active climate control which causes a new energy demand. Normally the indoor climate of historic buildings with proper climate control will not be strongly affected by climate change but the energy demand for climate control will be affected: it may either increase or decrease.

Energy demand for climate control can be due to

- Temperature control: heating or cooling
- Humidity control: humidification or dehumidification

Figure 1: Change in average energy demand for heating, cooling, dehumidification and humidification for a case study building. The change is between the far future (2071-2100) and the recent past (1961-1990).

Based on building simulations, the project has shown how the energy demand for a type of building with a high level of climate control is affected by climate change (see Figure 1). We can see that energy demand for heating is expected to decrease all over Europe, however the energy demand for cooling and dehumidification is expected to increase. The overall energy demand, shown in the map on the right, shows a distinct geographic pattern where overall energy demands are expected to increase in Northern Europe and decrease south of the Alps. This is only one example; the results will be different for other types of buildings.

### 3.1.1 Assessment of control strategies

Having shown that climate change will have a rather complex effect on the energy demand for indoor climate control, we have investigated ways to control the indoor climate while minimising the energy demand.

**Passive strategies.** The basic strategy for stabilising the indoor climate in a historic building should be to minimise the influence from the outdoor climate through the passive function of the building envelope. Passive control is determined by the insulation, air tightness and hygrothermal buffering of the building envelope. Case studies within the project and simulations show how the indoor climate can be stabilised by reducing the air exchange and by reducing solar heat gain from windows.

**Active strategies.** If active climate control is needed, it should aim to control the indoor climate as energy-efficient as possible regarding given climate requirements. We assessed these using building simulations based on the case study experience and have made a cross comparison of their energy consumption using the building simulation software (Brostrom et al., 2012, Antretter et al., 2013). There was particular focus on controlling relative humidity while only intermittent heating (ie. keeping temperature just above a set-point of 5-10 °C in the winter season) was considered.

**Humidity control.** Humidity control is performed by releasing water vapour into the air. If the RH is too low, humidification is achieved by either injecting steam into the air or evaporating water or water mist. If the RH is too high, dehumidification is achieved by removing water vapour from the air via either condensation or adsorption, see e.g. Larsen and Brostrom (2014). The applicability of dehumidification in historic buildings depends on whether the technical installations are acceptable with

respect to both visual and physical impact. Portable dehumidifiers allow for flexible and cost effective solutions but often the machinery is not well suited to a historic environment. A system of central dehumidification can be better integrated but it requires air ducts. Unless the building already has air ducts, the installation tends to be expensive and intrusive. Simulation experiments show that humidity control is a very energy-efficient mitigation measure. However, the overall energy consumption depends on the assigned ranges of relative humidity. In addition to considering the fixed relative humidity set-point (possibly with seasonal adjustment), we studied the possibility of considering floating set-points to minimise energy consumption whilst still having risk-free indoor climate conditions. This will be addressed in the section 3.2.

**Humidistatic heating.** Humidistatic heating, or conservation heating, is the concept of heating a building in order to keep the relative humidity below given limits. The temperature is continuously adjusted and not controlled to a constant set-point. Humidistatic heating has been used for many years to maintain a moderate relative humidity in historic houses in winter (Staniforth et al., 1994). A peculiar aspect of humidistatic heating is that it is sometimes required to heat in summer in order to keep the RH at an acceptable medium level. This may cause uncomfortably high temperatures and high energy consumption (Larsen, 2007). An increased temperature will generally increase the absolute humidity in the building causing an unwanted positive feedback. Degradation of organic materials due to hydrolysis will increase with rising temperature and RH. The energy consumption for humidistatic heating is relatively high, due to poor thermal insulation and a high infiltration rate, as confirmed by a simulation-based comparison conducted by Brostrom et al. in 2012, where the overall energy consumption was several times higher compared to the direct humidity control method. Generally, dehumidification is more energy-efficient unless heat pumps are used; an air-to-air heat pump will typically reduce energy demand by two thirds. For large buildings, humidistatic heating with heat pump technology seems to be the most energy efficient measure, unless the thermal insulation is very poor. For small buildings dehumidification is more efficient unless the building is very leaky.



Skokloster Castle from the frozen lake Mälaren  
(Figure 2a)



Figure 2b

### 3.1.2 Renewable energy

Having addressed strategies and technical solutions, the final question is energy supply. One report of the project presents an assessment of the applicability of renewable energy sources, such as solar energy, heat pumps, wind power etc. in historic buildings. Renewable energy is becoming an increasingly important consideration in all types of buildings whether historic or modern. In the context of the Climate for Culture project, the introduction of renewable energy can be both a preventive and mitigative measure. The introduction of renewable energy will obviously reduce greenhouse gas emissions. Furthermore, the results from the Climate for Culture project show how climate change will have an effect on the energy demand for climate control in historic buildings and how they can be a sustainable and cost-effective solution for climate control aiming to mitigate the effects of climate change.

### 3.1.3 Conclusions

No single strategy or solution exists that can be used to mitigate the effects of climate change on all buildings. It depends on the type and use of the building as well as geographic location. This part of the project has provided new knowledge that will allow end users to better select appropriate solutions for a specific building in a specific region.

**A case study example.** In the next 50 years the outdoor climate in most of Scandinavia is expected to be warmer and more humid. Timber buildings that so far have done well without any climate control will face new threats. Insects such as woodworm will migrate north. Unheated or intermittently heated stone buildings such as churches and castles will be exposed to higher risks of mould growth.

*Figure 2: At Skokloster Castle in Sweden, different climate control strategies have been tested and compared.*

