CHAPTER 2.3

Simulating and mapping future energy demands

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1. INTRODUCTION

Due to the climate change debate, a lot of research and maps of external climate parameters are available. However, there is still a lack of maps of indoor climate performance parameters. This chapter presents a methodology for obtaining maps of performances of similar buildings that are virtually spread all over Europe.

Figure 1: *Visualisation of the proposed methodology*

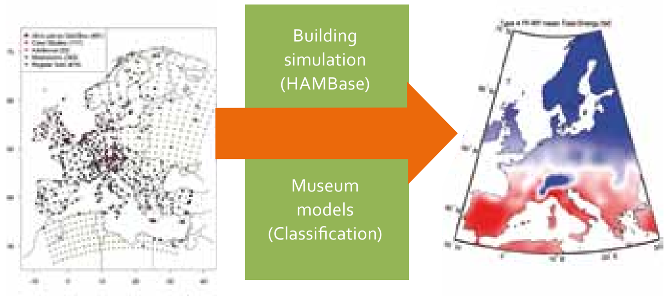

Figure 1

The produced maps are useful for analysing the regional climate influence on building performance indicators such as energy use and indoor climate. Our approach is a new combination of three recent developments. Each development is introduced in a separate section: firstly, the simulation and mapping of building performance indicators based on European weather stations; secondly, a multi-zone energy model, representing a wide range of buildings; and thirdly, the availability of hourly based, EU wide, external future A1B climate files from the Climate for Culture project.

1.1 The simulation and mapping of building performance indicators based on European weather stations (Schijndel, A. W. M. van & Schellen, H. L., 2013)

This chapter presents a methodology and results for obtaining maps of performances of similar buildings that are virtually spread over the whole of Europe. The whole-building model used for the simulations originates from the thermal indoor climate model ELAN which was already published in 1987 (de Wit et al., 1988). The current hourly-based model HAMBase, is part of the Heat, Air and Moisture Laboratory (HAMLab 2014), and is capable of simulating the indoor temperature, the indoor air humidity and energy use for heating and cooling a multi-zone building. The physics of this model is extensively described by de Wit (2006). An overview of the validation results of the whole building model HAMBase are recently presented in van Schijndel (2014).

1.2 A multi-zone indoor climate and energy model, representing a wide range of museums (Martens, M. H. J., 2012)

Marco Martens describes in his PhD thesis the input for the existing simulation model HAMBase that allows studying all 16 combinations of quality of envelope (QoE) and level of control (LoC) of a typical exhibition room layout. To be able to assess the influence of Quality of Envelope (QoE) and Level of Control (LoC), this room layout is put into the simulation model. The layout is based on common museum exhibition room specifications as encountered in several of the researched museums; this room is located in the corner of a building. The room consists of a single zone, 10 m long, 10 m wide and 3.5 m high. The ceiling, floor, north and east walls are adiabatic, which means that the zone is connected to other zones which are identical in behaviour but not part of the simulation. The south and west walls are external walls and each have a window of 5 m² each. Martens provides a full description of the input for the model (Martens 2012). This single zone is put into the model 16 times; for each zone some parameters are changed according to the QoE and LoC. These parameters are displayed in Tables I and II .

Table I: *Definition of Quality of Envelope (QoE) by different building parameters*

	QoE 1	QoE 2	QoE 3	QoE 4
Exterior wall	Solid brick wall 400 mm, plastered	Solid brick wall 400 mm, plastered	Solid brick wall 400 mm, insulation on the inside 100 mm, plastered	Brick wall 100 mm, cavity, insulation 150 mm, brick 100 mm, plastered
Glazing	Single	Double	Double low-e	Double low-e
Infiltration rate	1 h-1	0.4 h-1	0.2 h-1	0.1 h-1

Table II: *Definition of Level of Control (LoC) by different systems' parameters*

	LoC 1	LoC 2	LoC 3	LoC 4
Temperature set point [°C]	-	20 (heating)	20 (heating)	20 (heating); 22 (cooling)
Humidity set point [%]	-	-	40 (humidification); 60 (dehumidification)	48 (humidification); 52 (dehumidification)

The construction of the building depends on QoE: walls, glazing and infiltration rate caused by leakages in the envelope, all change when improving the thermal quality of the envelope. Set-points depend on LoC. The available capacity for heating, cooling, humidification and dehumidification is set to an unrealistically high value to make sure set-points are actually achieved; this is deliberately chosen to stress the influence on energy use. All 16 types were implemented into one single multi-zone HAMBase model, thus providing a very efficient way of simulating all variants simultaneously. A year with hourly based external climate values takes less than 10 seconds to run on a 4 GB/2.6 GHz computer.

1.3 Hourly based, EU-wide, external future A1B climate files (Climate for Culture 2014)

During the Climate for Culture project, external climate files were developed especially for building simulation purposes using the REMO model (Jacob and Podzun 1997).

2. METHODOLOGY

A multi-zone energy model, representing a wide range of museums and monumental buildings was implemented into HAMBase. The latter consists of 16 different building zone types made up of 4 levels of envelopes (LoE 1-4) and 4 levels of climate control (Lo C 1-4) from Martens (20 12). 7 performance indicators were used: (1) mean indoor temperature; (2) mean indoor relative humidity; (3) mean heating demand; (4) mean cooling demand; (5) mean humidification demand; (6) mean dehumidification demand; (7) total energy demand to produce EU maps for 16 building types and five 30-year time slices: recent past (1960-1990; RP), near future (2020-2050; NF), far future (2070-2100; FF), NF-RP and FF-RP. This gives a total of 560 maps. Interpretation of mean demand is the mean power (W) over a period of 30 years (regardless of the seasons). 1 W (J/s) heat demand multiplied with 365 x 24 x 3600 s equals to annual heating energy of 31536000 J = 31.536 MJ. Please note that in all our models, the building volume is 350 m³. So 1W also represents 31.536 MJ/(year x 350 m³) = 90 kJ/(year x (m³ building volume)) = 2.2510^{-3} liter oil/(year x (m³ building volume)) (by using caloric value of 106 J/litres for oil).

$$1\ W \approx \frac{2\ mL\ oil}{year \times m^3\ building}$$

For example 100W and a building volume of 500 m³ equals about 100 litres/year.

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Furthermore, for all power calculations related with the indoor climate, we assumed perfectly (100 % efficiency) air-conditioned HVAC system. The reader should note that in practical HVAC systems a lot more energy may be required for cooling and de-humidification. For example for dehumidification most systems cool first below dew point and afterwards heat the air to a certain value. Therefore, it is clear, that a lot more energy may be required than just looking at the air-side part of the balance.

3. EXEMPLARY RESULT

In this section, we present simulated results for recent past (RP), near future 2020-2050 (NF) and far future 2070-2100 (FF) energy demands for European museums and monumental buildings. As already discussed, we produced 560 maps. These maps will become publicly available on the Climate for Culture (2014) website. Figure 2 presents one of the main results

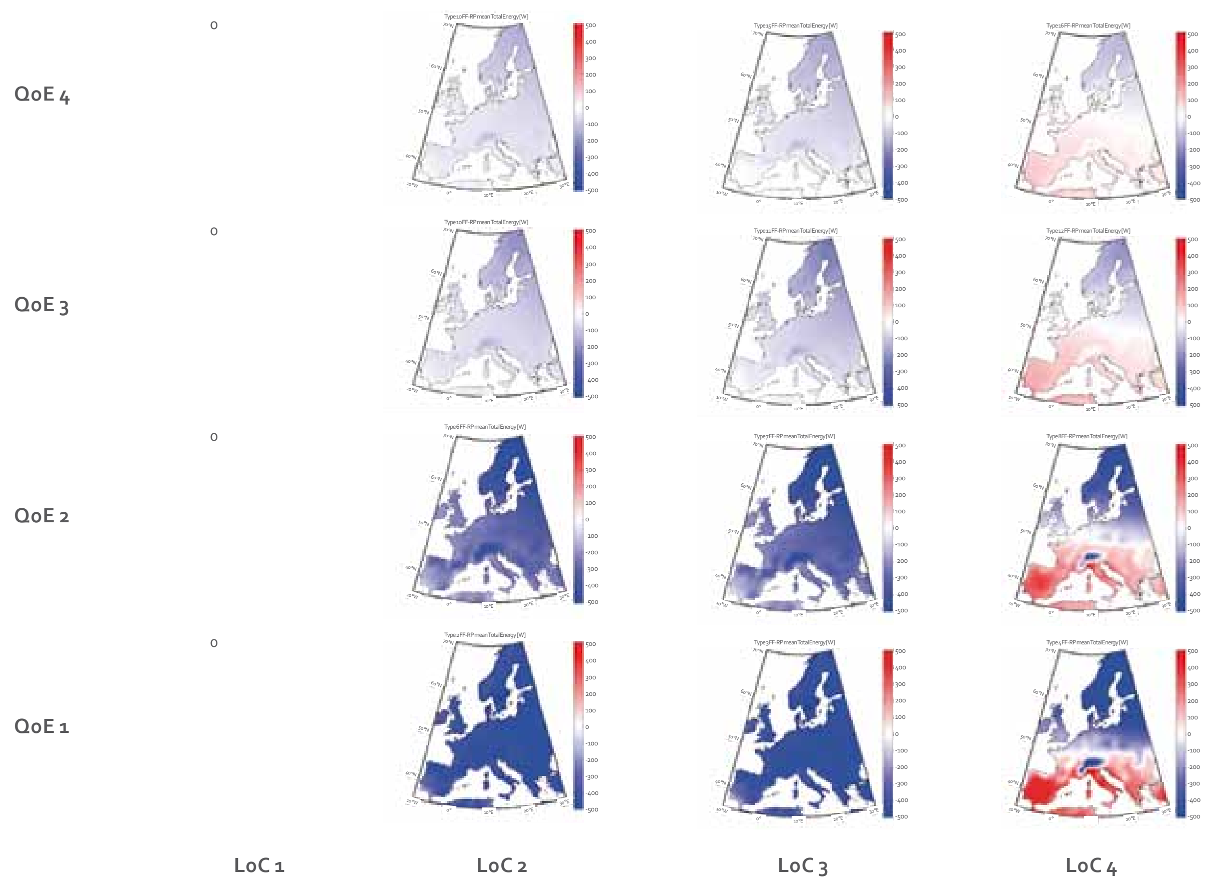

Figure 2

regarding the total energy use in far future (FF) minus the recent past (RP), i.e. FF-RP.

Figure 2: *The total energy use in far future (FF) minus the recent past (RP) using the corresponding Level of Control (LoC) and Level of Envelope (LoE). The colour blue represents less expected energy needed in the future, the colour red represents more expected energy needed in the future. The brighter the colour, the higher the value.*

It can be seen from Figure 2 that the first column is zero because LoC1 corresponds to a free floating building without any systems. The second column LoC2 corresponds to heated buildings systems. In LoC4, QoE1 represents a poor insulated building with a high performance system. Here the highest differences between expected energy gains and losses can be observed. We refer to Tables I and II for the meaning of all different combinations of LoC and QoE.

4. CONCLUSIONS

We presented a new method for simulating and mapping energy demands for European buildings for the recent past (RP), near future 2020-2050 (NF) and far future 2070-2100 (FF). It is a new combination of three recent developments: firstly, the simulation and mapping of building performance indicators based on European weather stations; secondly, a multi-zone energy model, representing a wide range of buildings which consists of 16 different building zone types equal to all combinations of 4 levels of buildings construction and 4 levels of climate control; and thirdly, the availability of hourly based, EU wide, external future A1B climate files from the EU FP7 Climate for Culture project. 7 performance indicators were used: (1) mean indoor temperature; (2) mean indoor relative humidity; (3) mean heating demand; (4) mean cooling demand; (5) mean humidification demand; (6) mean dehumidification demand; (7) total energy demand to produce EU maps for 16 building types and five 30 year time periods: RP, NF, FF, NF-RP and FF-RP. This gives a total of total 560 maps. By using a classification of monumental buildings and museums, the influence of level of control and level of envelope on the performance indicators can be visualised.

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