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Hopfe, C.J., Augenbroe, G., Hensen, J.L.M., Wijsman, A.J.T.M. & Plokker, W. (2009).
The impact of future climate scenarios on decision making in building performance simulation: a case study.
In Dado, E, Beheshti, R & Zreik, K (Eds.), Proc. EuropIA 12th Int. Conf. - Innovations for Building and Construction, Towards a better, stronger and sustainable future using advanced ICT, pp. 1-14. Paris: EuropIA.

The Impact of Future Climate Scenarios on Decision Making in Building Performance Simulation- a Case Study

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1. Abstract

Expected climate change may turn into a key challenge for building designers in the 21st century [Holmes et al., 2007]. In response to this challenge simulation packages have started to provide future climate scenarios to predict the energy demands and thermal comfort in buildings. The need to make predictions for climate change scenarios is becoming increasingly important.

This paper describes the integration of climate change scenarios in one of the building performance simulation tools, i.e. VA114, which is used extensively in the Netherlands.

Based on the existing traditional reference year “De Bilt 64/65”, NEN 5060:2008 released a new norm that introduces four new climate files for different types of climate adjustments. KNMI on the other hand assembled four different future scenarios for the expected climate change. The climate files from the NEN and the KNMI future scenarios have been combined in a future climate data analysis for usage within the targeted simulation software VA114.

The paper describes a case study focusing on the impact that a climate scenario may have on a concrete design decision. The case study involves two HVAC system designs: (1) a conventional cooling/heating system and (2) a heating/ cooling storage system. Both options are simulated and compared. The impact of climate change is shown on energy use and thermal comfort. It is then shown how the climate scenarios (and their inherent uncertainties) impact the uncertainty in the outcomes and how these outcomes influence the choice between the design options..

The conclusions of the paper highlight the relevance of different (uncertain) climate scenarios and the role they play in design decision making.

Keywords: global warming, energy consumption, thermal comfort, climate change, decision making

2. Introduction

For the last 40 years, building performance simulations (BPS) in the Netherlands, are done with the De Built weather for 1964/65- because it represents an average climate year with sufficient peak values.

However, it is evidentially that temperatures are increasing, and climate is changing. This causes a certain challenges in building design as no one knows what the influence of rising temperatures may be on the design. So far no climate change responsive weather files can be loaded directly into BPS.

A NEN- commission therefore started working on a new reference climate files based on the last 20 years, 1986-2005 [ontwerp NEN]. The results of this work are summarized in NEN 5060:2008; it provides four different reference years for different adaptations (energy and comfort). But one needs to acknowledge that the four reference years represent (at best) the current climate. As buildings are planned for a service life of 50-100 years or even longer, it must be assumed that conditions will change over time.

For that reason, Vabi bv in correlation with the TU Eindhoven, developed future climate scenarios for usage in the BPS tool Va114 that are based on the NEN norm but include different scenarios in order to predict future climate conditions that can impact energy demand and realized comfort. Another case study with a demonstration of all scenarios and a more extensive discussion of the climate files used can be found in [Evers at al., 2008].

Our research focuses on the prediction of performances in energy consumption and thermal comfort in a climate study. In particular the research tried to answer the question how climate sensitive the choice between different design options is to climate change. This was done in a case study studying its influence on decision making between two discrete options. A case study with two options was simulated with regards to energy demand and comfort. Results will show how future climate scenarios can influence not only the outcome of the building in terms of energy and comfort performance but also the sensitivity of design parameters on the outcome; and therefore ultimately influence the designer's choice of a preferred design option.

3. Case Study

3.1 Climate files

In the following paragraph a brief summary is given to provide some background information. A more extensive summary can be found in [Evers et al., 2008].

NEN 5060:2008 (ontw) was published beginning 2008; it is based on the historical weather situation between the years 1986-2005 from the measurement station de Bilt in the middle of the Netherlands. It distinguishes four different types of reference years, one for the average yearly calculation of the energy demand based on part 4 of NEN-EN-ISO 15927, which represents the routine use of the weather files. The other three reference years cover more extreme values designed specifically for comfort calculation. The three different comfort files represent a 1%, 2% and 5% chance that comfort is exceeded/ fallen below.

The KNMI (Koninklijk Nederlands Meteorologisch Instituut) is the national institute for weather, climate and seismology in the Netherlands. They offer four different scenarios on their webpage: G, G+, W and W+.
For scenario 'G' the worldwide increase of the external temperature is estimated to 1 ^{o}C in the period 1990-2050; for scenario 'W', the increase is estimated to 2 ^{o}C; for both scenarios no change in wind speed is assumed.
The scenarios 'G+' en 'W+' are identical to 'G' en 'W', with the difference that changes in wind speed are considered. On the KNMI webpage the average temperature for 30 years (1976-2005) and scenarios can be viewed to get an impression about the difference. It is interesting to note that one can design one's own scenarios to be calculated based on the 30 years; in this way the average temperature and precipitation can be generated up to the year 2100.

NEN is based on the period 1986-2005; KNMI uses the period 1976-2005; in addition KNMI offers 30 years of daily average values whilst in typical BPS one uses hourly values. This implies that our simulations require a combination of the reference files from NEN (ontw.) with hourly values and the transformed time. For simplification, only the future temperature change is considered; other parameters such as radiation are used without modification.
The entire new climate "package" offers 36 new climate scenarios: the four different scenarios of KNMI, the four different NEN climate files and all of them in 3 different time steps, reference year (called climate), 15 years and 30 years ahead.

In the following study we considered four different weather files: (1) the climate files for energy as used today and (2) looking 30 years ahead, and (3) the comfort files as used today and (4) looking 30 years ahead. The 'W+' scenario was chosen for energy; along with a 1% exceeding chance for the comfort simulation.

The chosen climate files were selected for demonstration purposes because they provide extreme values that are most interesting to test the sensitivity on the decision making process.

3.2 Case study "het bouwhuis"

"Het bouwhuis" is a building located in Zoetermeer/ The Netherlands between The Hague and Gouda (figure 1). It is the headquarters of Bouwend Nederland, the Dutch organisation of construction companies. The building consists of 11 stories designed in a T-shape. The two levels in the basement are designed for underground parking (7000m2).

[[insert Figure 1]]

Two options were considered in the design process- both of them ready-to-build:

- Option 1: a conventional heating/ cooling system; central heating and mechanical cooling and
- Option 2: heating/ cooling storage in combination with a double façade.

For a more detailed description of the systems we refer to [Hopfe et al.] Material properties are identical for both options and are also summarized in [Hopfe et al.].

4. Results

4.1 Results of energy demand and thermal comfort due to the expected change in climate

Results are divided into annual heating and cooling demand and the weighted average of the number of over heating and under heating hours.

Option 1 refers to conventional heating and cooling, whilst option 2 defines the solution with heating/ cooling storage.

Climate files I/II are for the energy demand: Climate file I stands for reference year, whilst climate file II provides the results for the simulation outcome in 30 years.

[[insert Figure 2]]

For the thermal comfort: Climate file I is the reference year; file II looks 30 years into the future.

Note: the files used in the comfort study are different files from the ones used in the energy study.

[[insert Figure 3]]

What the figures 2 and 3 show is the result for a base case (rectangular dot) and the range of possible outcomes (the vertical bar). The base case can be interpreted as the value that a deterministic calculation would have produced (under reasonable assumptions), whereas the bar reveals the effect of all the uncertainties on this outcome after these uncertainties are propagated through the simulation, for instance using a Monte-Carlo method. It must be noted that in this study not only the uncertainties in the different climate files have been used in the propagation but also other uncertainties, e.g. in property values.

4.2 Results Uncertainty/ Sensitivity Study

The studie shows the variation in the output of the simulation, as the result of different sources of variations in the input. In this case study approximately 80 parameters have been introduced in the analysis with certain assumptions about their uncertainty range and probability distribution. Among the parameters considered are design parameters (properties), scenario conditions and physical properties.. The detailed table with information about case study parameters and their ranges of uncertainty can be found in [Hopfe et al.].

Figure 4 shows some of the outcome in their full histogram and normality plot form. It is seen that the histogram strongly resemble a normal distribution.

[[insert Figure 4]]

A sensitivity analysis is used to determine the contribution of individual input variable to the uncertainty in model prediction. There exist different techniques to show the sensitivity of the parameters. The chosen one for demonstrating the results is the partial correlation coefficient (PCC). The PCC provides a measure of the linear relation between any given input X and the output, cleaned of any effect due to correlation between X and any other input [Saltelli et al., 2005]. The following figures show some results of the analysis. In interpreting the plots, it should be kept in mind that the higher the coefficient, the more sensitive the variable.

The results in Figure 5 show the most sensitive parameters for option 1 (the conventional heating/ cooling system). The unknown level of infiltration proves to be the dominant uncertainty with regards to annual cooling, as demonstrated by the large PCC coefficient.

[[insert Figure 5]]

Figure 6 shows another interesting result which is really what we are looking for. It shows the difference for different climate files, of the sensitivity of parameters on option 1. In other words, it shows the ranking of importance of parameters on the difference that may occur in a simulation with the two different climate files.

[[insert Figure 6]]

Figure 7 shows results similar to Figure 5, but now for design option 2. Again the ranking in sensitivity is not influenced much by the use of climate year I or II.

[[insert Figure 7]]

Figure 8 shows the difference for the two climate files, of the sensitivity of parameters on annual cooling in option 2. In other words, it shows the ranking of importance of parameters on the difference that may occur in a simulation with the two different climate files.

[[insert Figure 8]]

5. Decision making

Group decision making is influenced by different sorts of aspects, from measurable, with a tool calculable numbers to non- measurable, subjective aspects as aesthetics etc.

Previous studies have shown the implications of the two different design options on building performance with many uncertain parameters. The same approach can be extended to consider the effect of different climate scenarios.

It was shown in other studies that minimizing the risk of one option related to one performance aspect can increase the risk of another aspect. (Shown for weighted over and under-heating hours.)

The case study in this paper demonstrates that the range and the peaks for those performance aspects are strongly related to the uncertainty in climate change scenarios. Therefore uncertainty in future climate scenarios should play a major part in decision process.

This means that a conditional range/deviation due to expected climate needs to be added and the decision maker needs to be made aware of the fact what can happen to the one particular design option in lets say 20 years.

6. Conclusions

The aim of this paper was to show the impact of climate change on building design. Therefore a case study was conducted, showing an office building with two different options.

The following conclusions can be drawn based on the simulation outcome, the uncertainty and the sensitivity study:

1. Energy and thermal comfort performance due to climate change

It can be seen for both options that the annual heating demand is decreasing, whilst the energy consumption for annual cooling is increasing. The same can be said for the weighted over and under-heating hours: Whilst the amount of weighted overheating hours gets bigger, the amount of weighted under heating hours diminishes.

The uncertainty range in the results increases.

2. Sensitivity analysis

The rank of the uncertain parameters is different for both options and for the different weather scenarios chosen. Although only an small cross section of all results is shown above, it can be stated generally that it depends noticeable on the design option and chosen climate file what parameters are more sensitive than others.

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Figure1."Het Bouwhuis" [2]

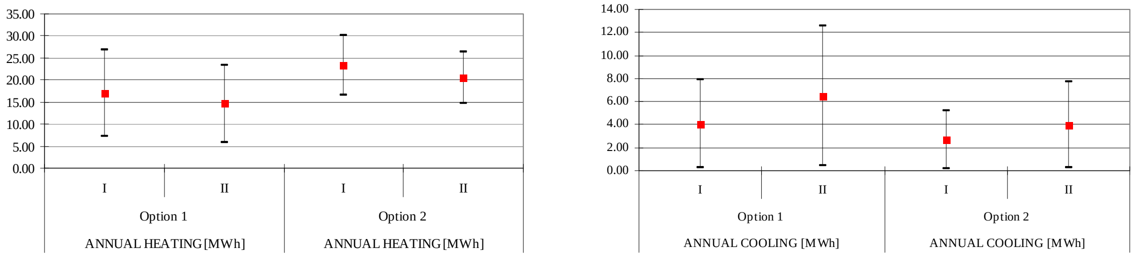

Figure2. Annual Heating and Annual Cooling

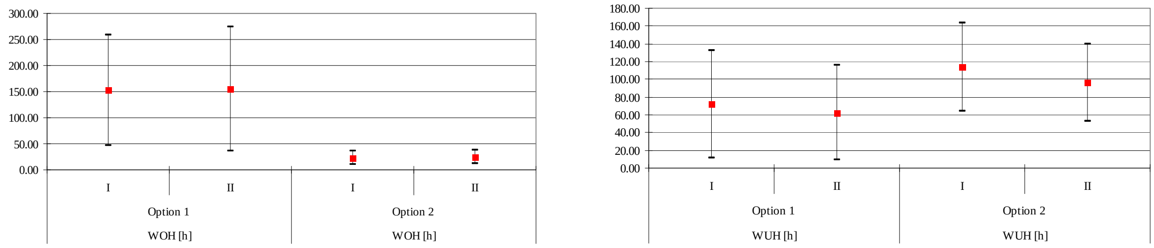

Figure3. Weighted Over-heating Hours (WOH) and Weighted Under-heating Hours (WUH)

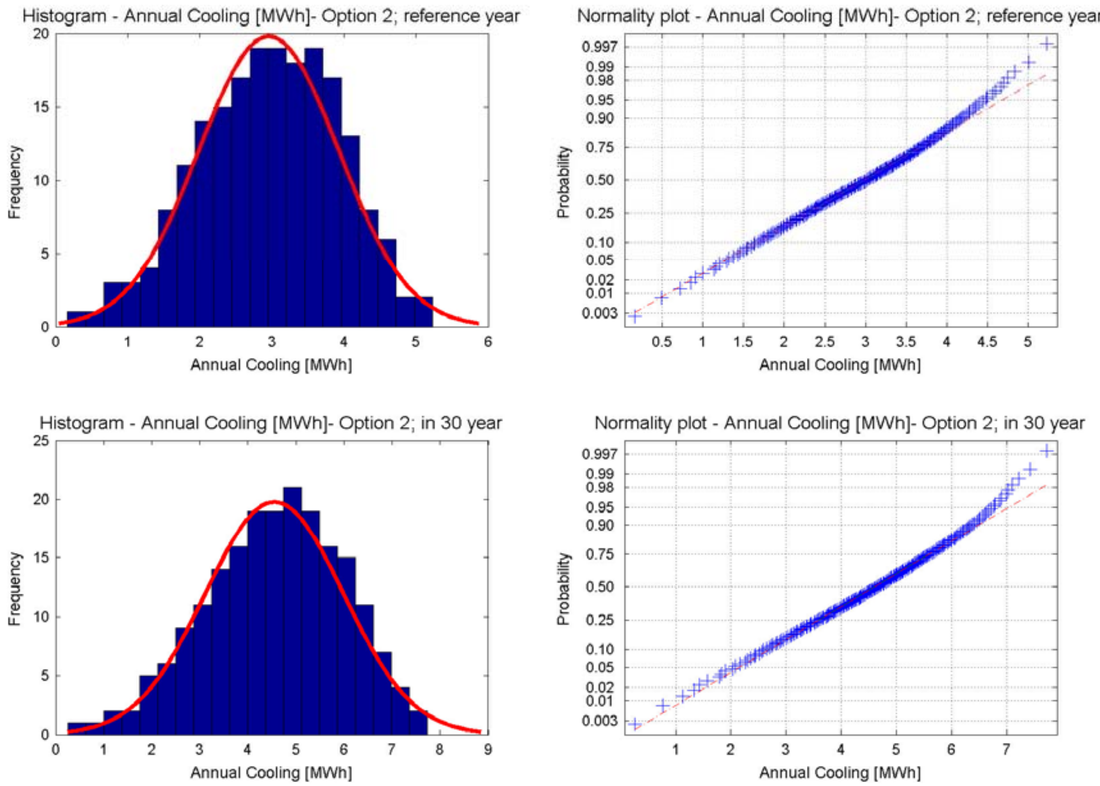

Figure4. Uncertainty Analysis; option 2

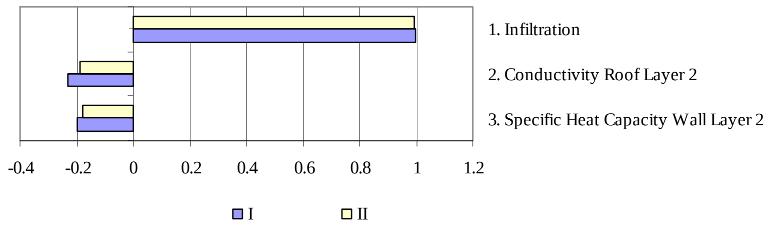

Figure5. Extract Sensitivity results; option 1

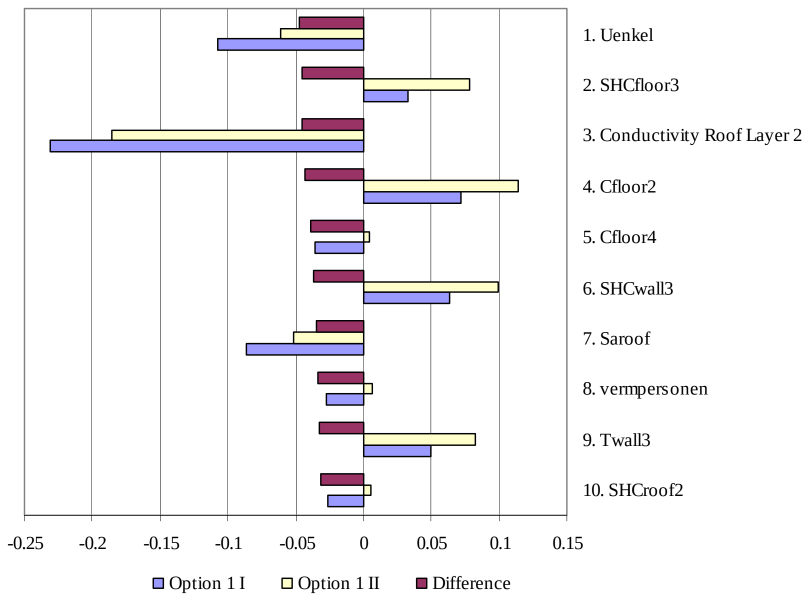

Figure6. Extract Sensitivity results; comparison and difference option 1 and 2

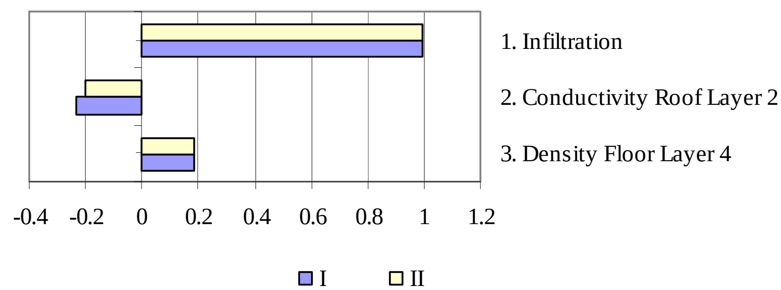

Figure7. Extract Sensitivity results; option 2

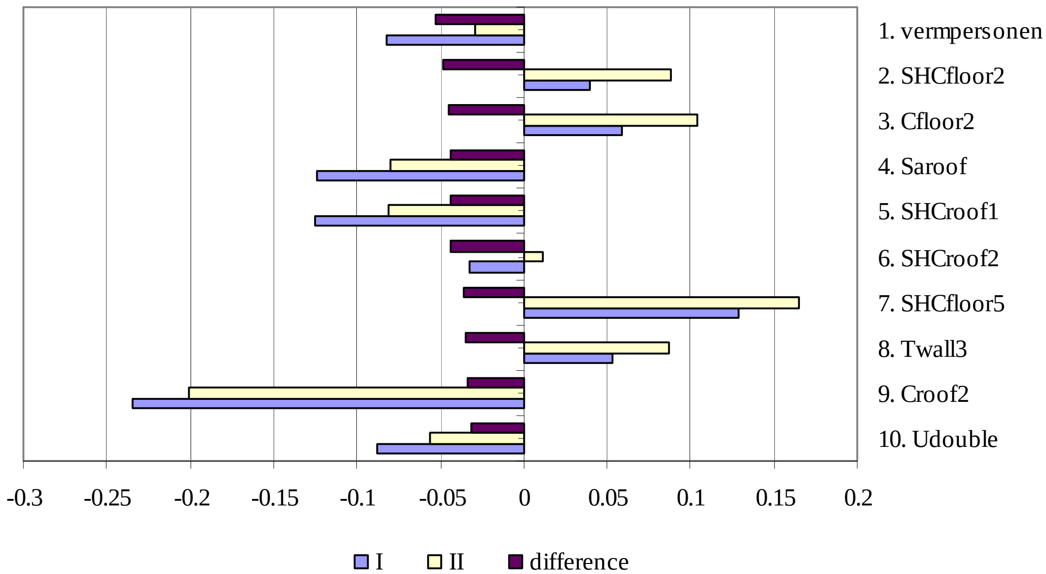

Figure8. Extract Sensitivity results for annual cooling; comparison and difference climate file I and II