Consequences of future climate for the building stock

Key words: Future climate, Urban Heat Island, Thermal comfort, Overheating, Cooling.

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In 2024 the Dutch meteorological institute published new climate scenarios, that fit the formats for building design. The impact of climate change on the built environment can so be assessed better. This article discusses the consequences for the Netherlands, but is applicable to other European regions with a moderate sea-climate.

The changing climate [1] should have consequences for buildings that are built or renovated nowadays. Users of these buildings will be confronted with very different indoor and outdoor climatic conditions than was anticipated during the design and realisation process. This makes climate adaptation an urgent topic for architects, consultants and HVAC professionals.

Analyses climate scenarios

The Royal Netherlands Meteorological Institute KNMI published realistic scenarios for the future climate [2] and derived datafiles for use in building simulation calculations, according to the NEN 5060 format [3] (based on EN-ISO 15972 [4,5]). At the time of this study, data was available for five locations, which together provide a good picture of the differences within the Netherlands.

Increase in outside temperature

The summer situation according to the climate scenarios have been compared with six recent years. and a newly constructed reference of the current climate; shown in **Tables 1 and 2**. In this analysis a summer season (from April 30th to September 28th) has been used, in accordance with building simulation models. **Table 1** shows the number of hours above a certain outdoor temperature. The colour-criteria are explained in **Table 3**.

Table 2 discusses the night situation; using Rmot as indicator. The Rmot (Running Mean Outdoor Temperature – θ_{rm} – EN16798-1/B-2) is a weighted average of the outside average daily air-temperature, of 'today' and the past seven days. It indicates how long it is continuously above an average outside temperature. The 16 °C corresponds to a summer period and the 22 °C to a warm summer period [7]. Additionally, the number of night hours is shown that the outside temperature remains above the given limit value in a summer period.

Interpretation of these data leads to the following observations:

- On both short (2033) and medium term (2050) an increase in outside temperature is shown.
- For the forecast year 2050 a clear difference can be seen between the 'Medium' and 'High' scenarios, with a middle scenario showing a certain stabilisation compared to 2033.
- All scenarios result in more and longer periods with higher outside temperatures and longer periods of heat waves. The warming at night is particularly worrying because of the effect on people's health.

Criteria

In the underlying research, multiple calculation methods and indicators were used to evaluate the risk of overheating. The main criteria are shown in Table 3.

Table 1. Outside temperature in past years and future forecast years.

	Past years – KNMI De Bilt						Future forecast years – KNMI De Bilt				
T (°C)	2018	2019	2020	2021	2022	2023	New reference current climate	2033L[1]	2050Md	2100Md	2150Md
24°C	428	257	304	140	321	317	297	471	550	874	532
26°C	201	168	203	47	174	160	168	284	349	551	344
28°C	100	112	122	12	99	74	90	159	202	294	204
30°C	40	67	62	1	44	17	38	78	101	175	93
32°C	23	27	22	0	9	0	5	22	43	80	24
34°C	11	16	0	0	6	0	0	3	9	49	4
36°C	0	10	0	0	0	0	0	0	7	24	2

1 Indicator L, M, D refer to climate scenario with low, medium and high rise on CO_2; the indicator 'd' and 'w' refer to a dry and wet variant. All scenarios are developed by KNMI [2] specific for Dutch conditions, based on IPCC studies [1]

Table 2. Rmot (θrm) and tropical nights in past years and future forecast years.

	Past years – KNMI De Bilt						Future forecast years – KNMI De Bilt					
T (°C)	2018	2019	2020	2021	2022	2023	Refer	2033L	2050Md	2050Mw	2050Hd	2050Hw
Number of days θrm > 16°C en 22°C												
16°C	101	75	78	101	94	94	72	123	108	118	116	106
22°C	7	6	9	0	1	1	14	19	32	11	37	20
Number of night-hours > 20 °C ('tropical nights' in the Netherlands)												
20°C	55	46	74	4	8	42	84	157	188	147	242	205

Table 3. Classification of the risk of overheating in existing buildings.

GTO -hours	Hours of NDH> 26°C	Risks for thermal IEQ
<300	< 29	very low
<450		low
450-900	29-88	moderate
900-1.800		high
> 1.800	>88	extremely

The Dutch building regulations uses the criterion 'weighted temperature exceedance' (GTO). The GTO is a weighting factor on the PMV 0.5 according to ISO 7730 [8].

For the assessment of the night-situation, especially in bedrooms, the Amsterdam University of applied sciences uses the indicator NDH (Night Degree Hour) [9]. This provides insight into the hours with an indoor operative temperature of 26 °C or higher during the night period (between 22:00 and 06:00). This indicator is calculated to evaluate the thermal situation in a bedroom.

Application to a reference house

For advice, standardisation and the building code it is important to investigate the consequences of the changing climate on buildings and dwellings. The consequences for homes are particularly relevant, given the linked risk to the health of inhabitants [10]. Currently, the application of passive measures (such as sun blinds and ventilated cooling) and cooling installations (such as air conditioning) is not yet a standard measure for new construction and renovation in Dutch homes.

Reference

The consequences are illustrated using a common type of house from the existing housing stock in the Netherlands: a terraced house from 1967 that is moderately insulated due to some improvement measures over the years. Initially, the house was assessed for the risk of overheating with the existing reference (NEN 5060 T05*). Even in the current reference climate, without further measures, there is already an unacceptable risk of overheating

* T05 refers to the climate dataset in accordance to NEN 5060/EN-ISO 15927 that has a calculated probability of 5% exceedance (once every 20 years); this dataset based on the period 1996-2015 is current standard for the calculation of the risks on overheating in the Netherlands

(GTO = 2601h, where <450h is the accepted standard). Which can however be easily limited by the application of sun screens or blinds (GTO = 75h).

GTO hours in living rooms with external blinds

For the next step, we take the situation with external sun blinds as the starting point for assessing the risk of overheating. Initially, we assess the living room on GTO; see **Figure 1**. Because the scenarios are available for five locations, the differences within the Netherlands are also made visible. Note that even in the current situation, the differences per region are already considerable, although that until now has been ignored, using a nationally uniform climate file.

Number of hours >26 °C at night in bedrooms

Figure 2 shows the outcome of the calculation with the criterion NDH for the bedrooms. It is striking that these, even more than the living rooms, are coloured 'red'. This is partly due to the threshold value, which qualifies from the value 88 as 'high risk'. The question is whether the calibration of the NDH criterion is correct, but that is beyond the scope of this study.

It must be noted that overheating at night is quite a new phenomenon, related to the changing climate. In past years, in temperate climate zones such as NW Europe, it was quite easy to counteract night-time overheating, by using ventilated cooling through natural ventilation. This possibility decreases sharply in the changing climate, because night-time temperatures do not drop sufficiently during growing periods of time. Note that this conclusion has already been drawn, while urban heating (UHI) has not yet been taken into account.

Urban heat island

In an urban environment it is often much warmer than in a green rural area or near open water: the urban heat island-effect (UHI). Depending on the meteorological situation, the UHI can vary from less than 1°C to (in extreme cases) more than 10°C difference between city and rural area. The UHI is usually at a maximum in the early evening (after sunset) because buildings are then maximally heated and the rural area cools down much faster. In contrast, the UHI is smallest and sometimes even negative in the morning (just after sunrise) [11, 12, 13].

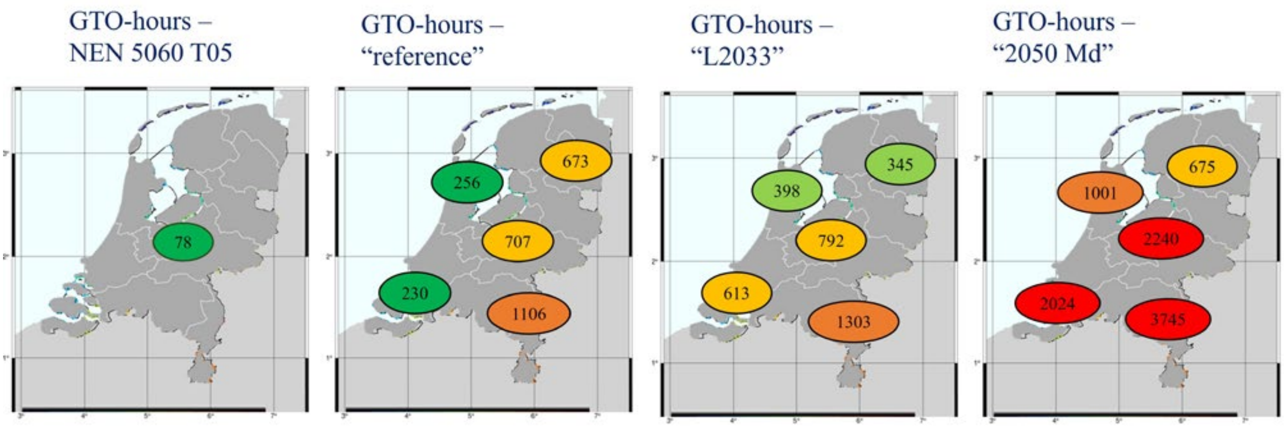

Figure 1. Number of GTO hours for reference home-type with sun blinds according to current standard (NEN 5060-T05) and climate scenarios.

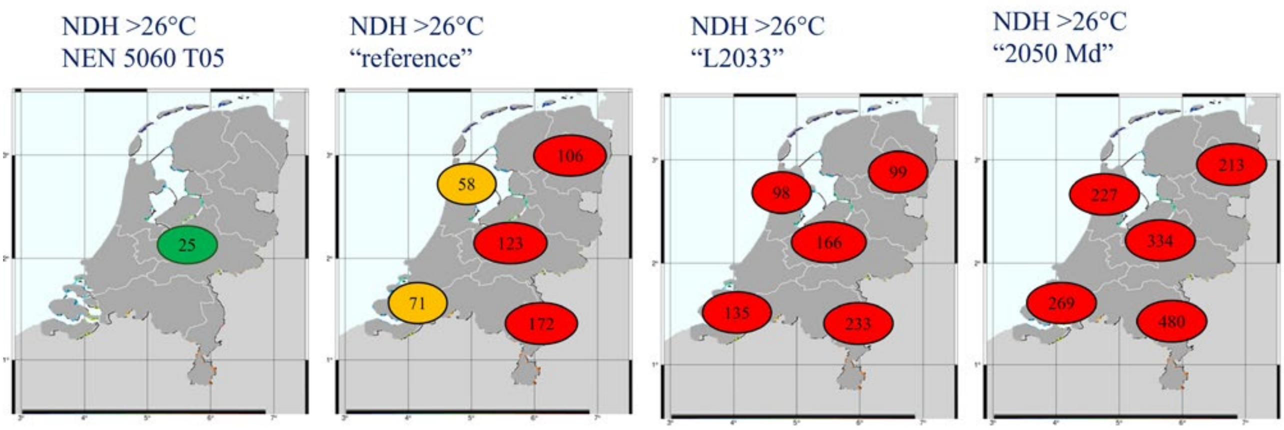

Figure 2. Number of hours NDH > 26 °C for the reference house with sunblinds according to current standard (NEN 5060-T05) and climate scenarios.

Although it is called the 'urban' heat island, it is not limited to city-centres. Also in villages and suburban area's the effect is notable, especially in places with stone walls and pavements, with the lack of bushes and trees. In the underlying study [14], an example has been developed for the location De Bilt and the centre of the nearby city of Utrecht. Conclusion is that the UHI delivers a substantial contribution to the warming of the built environment in cities and other populated areas.

Discussion

This exploratory study provides many insights. However, it is knowledge in development for countries with a traditionally mild summer climate, like in NW Europe. Further research is therefore required. A number of issues require attention:

- To what extent is the adaptation of the human body to the changing climate sufficiently taken into account? Special attention for the elderly and vulnerable people seems necessary. This also requires input from health science.
- The criteria used are partly insufficiently validated, due to a lack of practical data at high temperatures at night.
- To what extent are the criteria for new builds also applicable to existing buildings? Is an adapted assessment-framework necessary?
- The parameters that contribute to UHI must be further elaborated to make them applicable in a design process. This requires an assessment-framework for the contribution of area influences, such as urbanisation and the presence of greenery and water.
- Special attention is required for critical situations, such as apartments with a one-sided orientation.

Conclusion

From the analysis of this research, we draw the following conclusions:

- The calculated simulation results based on the future climate scenarios give such high summer temperatures, that it must be addressed in standards and via the building codes.
- The current assessment methodology for determining thermal comfort no longer matches future climate scenarios; a revision of the used data is eminent at short notice.
- External sun shading is essential for both thermal comfort and reducing the electricity demand of active cooling systems.
- The assessment of thermal comfort in summer should be site and project specific. Heat risks from the environment such as the urban heat island effect (UHI) must be evaluated.
- Attention should not only be paid to thermal comfort during daytime, but also during the night period, because of the impact on well-being and health of poor sleep.

Accountability

This article is based on a paper for Clima '25. The research on which the paper and the article are based was commissioned by TKI Urban Energy and the Netherlands Enterprise Agency (RVO) and carried out by the authors [14].

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