MASTER

Evaluation of the TOJuly indicator in relation to current and future challenges of overheating in the residential building stock

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Master thesis

Evaluation of the TOJuly indicator in relation to current and future challenges of overheating in the residential building stock

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Abstract

In an effort to reduce the energy consumption of the building stock, the barrier between the indoor and outdoor space gets larger. A combination of improved insulation, properties increased airtightness, and global warming increases the risk of overheating in the Dutch residential building stock. Moreover, this risk is expected to increase in the upcoming decades. Using dynamic simulations, insight can be provided into the potential overheating risk, using Weighted Overheating Hours (WOHs). As defining the simulation models for the dynamic simulations is a labor-intensive task, executing these simulations for every new individual dwelling and apartment in the Netherlands is an unrealistic expectation. To solve this problem, the TOJuly (Temperature Overshoot July) indicator was designed, allowing an indication of the risk of overheating for newly built (e.g., not yet constructed) residential buildings, without the need for dynamic simulations. This study aims to evaluate the TOJuly indicator, answering the following question: How robust is the TOJuly indicator in relation to various building typologies of the Dutch residential building stock, occupant behavior, and climate change?

To answer this main research question, variant compositions for seven building typologies were designed, related to building characteristics, occupant behavior, and future climate. By means of a comparative analysis between TOJuly and WOHs, the assessment of the risk of overheating for different situations was analyzed. 1610 variants were designed for different variant categories and building typologies. To determine the WOHs, dynamic simulations were performed in EnergyPlus. The TOJuly values were calculated using the NTA 8800 calculation tool. Based on the results collected in this research, the TOJuly is assessed as a robust method for determining the risk for overheating in the Dutch residential building stock. Nonetheless, among the variants for which the TOJuly method was implemented as intended (e.g., not adapted for internal heat load or future climate), for 6.0% of the variants in the building characteristics category, TOJuly indicated an acceptable risk of overheating (≤ 1.2) whereas the threshold for WOHs (450 WOHs) was exceeded. Overall, the robustness of the apartments is lower compared to the dwellings. The least robust variants relate to the studio. The highest level of cohesion between the assessment for the risk of overheating in the two methods is attributed to the small terraced dwelling. Concerning building characteristics, the addition of an overhang is the most underestimated parameter in TOJuly. Results related to occupant behavior indicate that both the internal heat load and purge ventilation have a significant effect on the amount of WOHs in all building typologies. For the apartments, none of the measures applied in the included variants for the future climate scenario reduced the WOHs to 450 hours or less. When the internal heat capacity is reduced (e.g., timber-based building structures), the amount of WOHs may exceed the limit of 450 WOHs in a future climate scenario, whereas this threshold is not exceeded in the prescribed climate scenario for dynamic simulations. The conclusions of this research indicate that the TOJuly indicator is a useful tool for gaining insight into the risk of overheating in newly built residential buildings.

Acknowledgements

The execution of this master research project has been an enjoyable journey. Starting with just an idea for research in the field of overheating, towards writing this master thesis. During this graduation period, many people helped and inspired me, whom I would like to thank.

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Although he is not part of my official graduation committee, I want to thank my supervisor Pieter Nuiten from *W/E adviseurs* for guiding me through this project, answering my questions, and sharing all the previous work he and Cees put into the TOJuly. Due to Cees and Pieter, I had access to the best source of information regarding this topic. This brings me to the other members of *W/E adviseurs* in general, thank you for showing your interest in my project and making me feel welcome among the colleagues.

A few months into the project, I nearly got stuck in the methodology for generating the results. I would like to thank BZK and RVO for providing me with the tools I needed to continue this research. Additionally, I express my gratitude to the other students and staff in the Building Performance group, for providing their feedback and support during, and beyond, the monthly progress meetings.

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Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ATG	Adaptive Temperature Limit (*Adaptieve Temperatuur Grenswaarde*)
BENG	Nearly Zero Energy Building (*Bijna Energieneutraal Gebouw*)
BPS	Building Performance Simulation
BZK	Ministry of the Interior and Kingdom Relations (*Ministerie van Binnenlandse Zaken en Koninkrijksrelaties*)
CIBSE	Chartered Institution of Building Services Engineers
CLT	Cross Laminated Timber
CO2	carbon dioxide
DHW	Domestic Hot Water
DSM	Dynamic Simulation Model
GFA	Gross Floor Area
HVAC	Heating, Ventilation, and Air Conditioning
KNMI	Royal Dutch Meteorological Insitute (*Koninklijk Nederlands Meteorologisch Instituut*)
KPI	Key Performance Indicator
KPP	Key Performance Predictor
NEN	Netherlands Standadization Institute (*Nederlands Normalisatie Instituut*)
NFA	Net Floor Area
NTA 8800	Dutch Technical Agreement 8800 'Energy Performance of Buildings) (*Nederlandse Technische Afspaak 8800 'Energieprestatie van Gebouwen)*
OAT	One-at-a-time
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
RVO	Netherlands Enterprise Agency (*Rijksdienst voor Ondermend Nederland*)
TOJuly	Temperature Overshoot July (*Temperatuur Overschrijding Juli)*
W+	KNMI Climate Scenario with high-temperature increase with changed air circulation patterns
WHO	World Health Organization
WHO	Weighted Overheating Hour
WWR	Window to Wall ratio

1. Introduction

1.1. Background information

In the past decades, the built environment has been challenged to reduce the energy consumption of the building stock. One of the means to achieve (part of) the desired reduction, is to increase the insulation properties of buildings. As a result, a larger barrier between the indoor and outdoor space is generated, improving heat retention in winter. However, last years have shown that the increased energy performance requirements can result in a negative aspect as well. Recently built houses show to be more prone to overheating in summer and increased incidences of overheating are reported (Lomas & Porritt, 2017). In moderate climates, where winter-oriented design had been a common focus concerning thermal comfort and energy demand, the summer situation was often neglected, or less evident in the design phase of residential buildings.

Although increased awareness is generated in the field of overheating in buildings and the term 'overheating' is widely used, no internationally accepted definition is (yet) defined. The main cause for this absence is suggested to be the consequence of the relation between overheating and local and regional climate conditions (Dengel et al., 2016). According to the Chartered Institution of Building Serves Engineers (CIBSE), overheating could be defined as: conditions when the comfortable internal operative temperature threshold of 28°C is surpassed for over 1% of the annual occupied hours (CIBSE, 2006). However, this definition has been withdrawn as it did not take into account the extent of overheating (CIBSE, 2013). The World Health Organization (WHO) guidance on thermal comfort does not provide a direct definition of overheating but states that indoor temperatures above 24°C cause discomfort and can cause harm to more fragile and susceptible populations (Ormandy & Ezratty, 2012).

High indoor temperatures can be related to adverse health effects for the residents, ranging from decreased productivity and reduced quality of sleep to heat stress or mortality in extreme scenarios (Bundle et al., 2018; Holmes et al., 2016; Mücke & Litvinovitch, 2020; Okamoto-Mizuno & Mizuno, 2012; Seppanen et al., 2006). Reducing the risk and degree of overheating may therefore be beneficial to both perceived thermal comfort and human health. By adaptation of building designs and the application of physical measures, overheating can be reduced or mitigated. Typical passive adaptions include the application of solar shading devices, solar control glazing, and summer night ventilation (Grussa et al., 2019; Hamdy et al., 2017; Lomas & Porritt, 2017; Porritt et al., 2012; Salem et al., 2019; Tian & Hrynyszyn, 2020).

To provide an understanding of the positive effect of the passive measures mentioned above, the cause for the increased risk of overheating is examined. A main source for potential overheating is provided by windows (Dengel et al., 2016). Short-wave solar energy enters a room through the glazing, is absorbed by the building interior, and subsequentially radiated as long-wave thermal energy. This long-wave radiation is not able to transmit through glazing. By means of convection and conduction, the thermal energy is transported through the building envelope to the outside. However, insulation properties of residential buildings have increased in the past decades to reduce the energy demand. As a result, thermal energy transportation from the interior of the building to the exterior climate is reduced. Additionally, improved building quality increased the airtightness of residential buildings, decreasing the thermal heat reduction as well (Tian & Hrynyszyn, 2020). Moreover, the occupants themselves impact the level of overheating (Jones et al., 2016; Porritt et al., 2012; Zhang et al., 2018). Besides changing building requirements and characteristics, global warming introduces a negative effect on the overheating risk of residential buildings. It is expected that the risk of overheating will increase in the upcoming decades (Taleghani et al., 2014), which underlines the importance of gaining insight into this risk and reducing the potential and degree of overheating in the built environment.

Insight into the level of overheating can be generated by means of measurements in existing or completed buildings. For buildings in the design stage, information on the level of overheating cannot be provided by performing measurements. Building Performance Simulations (BPS) can be used to predict or estimate the possible overheating for these designs, however, the outcome(s) cannot be validated by measurements directly. The BPSs in the field of overheating are performed based on dynamic simulations. These dynamic simulations determine the indoor climate and energy parameters for each timeframe, typically one hour. In the Netherlands, the level of overheating is generally expressed based on the Weighted Overheating Hours (WOHs) (LenteAkkoord, 2019). By means of providing a larger weight to hours with a lower level of thermal comfort, the extent of overheating is taken into account. Determining the WOHs for a building or design is a detailed and labor-intensive task, due to the large number of input parameters used to generate the building models for the BPS. To provide insight into the possible risk of overheating for residential building designs, the TOJuly (*Temperature Overshoot July*) indicator was initiated.

The TOJuly indicator is part of the Dutch energy performance requirements, the BENG standards (*'Bijna Energie Neutraal Gebouw'*), and was put into practice on January 1st, 2021. The methodology for calculating the TOJuly indicator is embedded in the NTA 8800 guidelines. This guideline encompasses the method to determine if the BENG standards are met, and similar input parameters used for determining the energy performance are used to calculate the TOJuly indicator value (NEN, 2020). This makes the practical application of the indicator rather straightforward and does not require additional labor or effort. In July 2020, the threshold value for the TOJuly indicator was settled at 1.2 (RVO, 2020). If the TOJuly value is below 1.2, the risk of overheating is expected to be acceptable. If the threshold is exceeded, measures need to be applied to reduce the risk of overheating for a residential building design. The TOJuly is determined for newly built houses without active cooling (NEN, 2020). Using the TOJuly indicator, insight into the risk of overheating is generated, without the need for detailed dynamic simulations.

1.2. Research objective and research questions

In the previous section, the TOJuly was briefly introduced. Moreover, several important aspects in relation to the risk of overheating were discussed. This study aims to evaluate the robustness of the TOJuly indicator in relation to these aspects, by investigating the effect of building-, occupant behavior-, and climate characteristics. Additionally, this study aims to evaluate the current practical application as compared to detailed dynamic simulations.

The primary research question in this research reads as follows:

How robust is the TOJuly indicator in relation to various building typologies of the Dutch residential building stock, occupant behavior, and climate change?

In order to provide an answer to the main research question, the secondary research questions are defined. To answer these research questions, a comparative analysis is performed to evaluate the risk of overheating based on dynamic simulations and the TOJuly method. For different building typologies, building characteristics, and scenarios, the risk or level of overheating is determined. The variants are divided into three themes, relating to the objective of this research:

- *How are different building typologies and building characteristics assessed according to the TOJuly-method?*
- *What is the effect of occupant behavior on TOJuly?*
- *What is the effect of using different climate scenarios in the TOJuly-method, focusing on future climate change?*

Additionally, this research may lead to recommendations towards possible improvements for the TOJuly method, depending on the outcomes of the results and observations made during the execution of this study.

1.3. Thesis outline

Chapter 1 introduces the research objective and research questions. Background information is provided on the general cause of overheating, means to gain insight into the level of overheating in residential buildings are highlighted, and the TOJuly indicator is introduced.

Chapter 2 presents a brief overview of literature related to dynamic simulations on WOHs and explains the TOJuly indicator. Moreover, the relation between WOHs and TOJuly is established.

Chapter 3 illustrates the methodology used for the evaluation of the TOJuly indicator. The overall method is described, (simulation) model input parameters are presented, the design of variants is discussed and the performance indicators for determining the risk of overheating are described.

Chapter 4 presents the results of the first simulation and calculation phase: screening of building design parameters using an OAT analysis.

Chapter 5 presents the results of the second simulation and calculation phase: analysis of the TOJuly indicator for influential building variations.

Chapter 6 provides answers to the research questions related to the evaluation of the TOJuly indicator, discusses possible improvements for the TOJuly methodology, and provides an overview of the limitations for this research.

Chapter 7 concludes the research.

Chapter 8 provides possible directions for additional research on the topics researched in this study.

2. Weighted Overheating Hours and TOJuly

In Section 1.1, the weighted overheating hours (WOHs) and the TOJuly indicator were introduced. In this chapter, additional information regarding these assessment methods for determining the risk of overheating in residential buildings is presented. First, the general relation between the two methods is evaluated. In Section 2.2, a brief overview regarding WOHs in relation to overheating is given. Additionally, the TOJuly indicator is discussed in Section 2.3.

2.1. Relation Weighted Overheating Hours and TOJuly

As was mentioned, the TOJuly indicator provides insight into the risk of overheating, without the need for detailed dynamic simulations. However, comparing the methods establishes key differences between the two methods. These differences are based on the overall goal of the two methods. It must be acknowledged that the TOJuly method was designed keeping into account the time and effort needed to determine an indication of the risk of overheating. A direct comparison of the TOJuly to dynamically determined WOHs can therefore be misleading. Both in relation to the methods, as in the representativeness of results.

WOHs are determined by employing Dynamic Simulation Modelling (DSM). These models provide detailed insight into the performance of the modeled building, both related to energy and thermal aspects. The reporting interval of results is typically set to hours. The method used to determine the TOJuly indicator can be categorized as a quasi-stationary calculation (Loonen et al., 2019). These types of calculations are based on monthly averaged input parameters, resulting in generalized monthly outcomes. To implement the dynamic thermal and energy relation behavior of buildings and occupants, correction factors ('utilization factors') are implemented in the TOJuly method (e.g., NTA 8800). An overview of the main differences between dynamic simulations and quasi-stationary calculations is presented in Table 2.1. Although dynamic simulations can provide detailed insight into the performance of buildings, to a certain extent they remain a simplified representation of reality, depending on the input parameters and assumptions (Park, 2013). In this perspective, the quasi-stationary calculation can be categorized as a simplified representation of reality to a higher degree.

Table 2.1: Main differences between dynamic simulations and quasi-stationary calculations

	Dynamic simulation (WOHs)	**Quasi-stationary calculation (TOJuly)**
Input	Large amount of input data	Large/reduced amount of input data
	Hourly weather data (includes effect heatwaves)	Monthly means weather data
Modeling/calculations	Explicit calculations	Correction factors (‘utilization factors’)
Output	Hourly	Monthly
	Building, zone, room level	Building, façade level

2.2. Weighted Overheating Hours

Although WOHs are typically used to assess the risk and level of overheating in the Netherlands (LenteAkkoord, 2019), different methods are available or have been proposed (Hamdy et al., 2017; Ruae et al., 2006). In 2004, the Adaptive Temperature Limits guideline (ATG) was introduced in the Netherlands as an alternative to the WOH method. The WOH method was established in the 1970s and is based on the relation between Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) (Figure 2.1), by Fanger (Fanger, 1970). It was argued that the WOH method could not always provide clear communication between the different fields and parties involved in the built environment (Ruae et al., 2006). Moreover, the WOHs method predicted similar indoor climate perceptions for different building types, where research found that occupants had different perceptions in those buildings (Ruae et al., 2006). Nonetheless, the WOH method is still used in the Dutch built environment industry and provided the foundation for determining the threshold level for TOJuly.

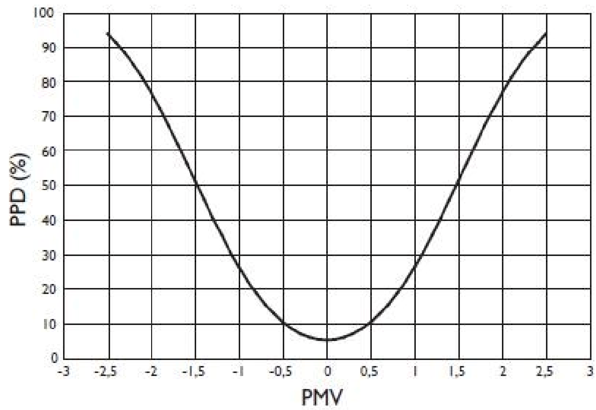

Figure 2.1: Relation between PMV and PPD (ISO 7730, 2005)

WOHs are used to quantify the sensation of thermal comfort, defined as 'the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation' (ANSI/ASHRAE, 2011). Based on a predetermined PMV-range, the weight factor for each hour is established. The PMV is determined based on the metabolic rate, effective mechanical power, sensitive heat loss, heat exchange through evaporation by the skin, respiratory heat exchange by convention, and respiratory heat exchange by evaporation (Gameiro da Silva, 2013). These parameters are affected by clothing insulation level, air temperature, radiant temperature, relative humidity, and air velocity. The total of WOHs is the sum of all hours multiplied with the respectively assigned weight factors. In the Netherlands, a maximum of 450 WOHs is regarded as an acceptable threshold for accepted thermal comfort limits (Leenaerts & Nuiten, 2019; Nuiten & Leenaerts, 2018).

Research indicates that the WOHs determined employing BPS may not be fully representative and coherent in all cases. Modeling airflow using the empirical equations in the dynamic simulation model may cause a 33% overestimation of the overheating hours in a passive house design, compared to a model with coupled detail airflow network model (Goncalves et al., 2021). Moreover, a performance gap in energy demand based on BPS is observed, compared to the actual energy demand (Cuerda et al., 2020). A similar performance gap may likely be present in relation to overheating as well. Furthermore, different dynamic simulation programs may generate different assessments of overheating risk, caused by both the user and the model itself (Roberts et al., 2019).

2.3. TOJuly

As was mentioned in Section 1.1, the risk of overheating has increased in the past decades due to improved building quality and global warming. Moreover, this risk is expected to increase in the upcoming decades. Using dynamic simulations, insight can be provided into the potential overheating risk and level. As performing these simulations (e.g., defining the simulation models) is a labor-intensive task, executing these simulations for every new individual dwelling and apartment in the Netherlands is an unrealistic expectation. To solve this problem, the TOJuly method has been designed, allowing an indication of the risk of overheating without the need for dynamic simulations.

The TOJuly expresses the risk of overheating for a residential building, without quantifying the level of that risk (LenteAkkoord, 2019; NEN, 2020). The results are only to be quantified in two categories: either the risk is acceptable, or the risk is too high. If a TOJuly value is twice as high compared to another TOJuly value, it cannot be assumed that the risk itself is also twice as large. Moreover, in assessing the risk for overheating, not just thermal comfort should be taken into account. The practical application, cost of measures, and energy demand impact the overall performance, cost, and usability of a house.

For residential buildings without active cooling, the TOJuly must be calculated to provide the building permit. Based on the building design, building characteristics, and installations in the building, the TOJuly indicator value is determined, according to the method described in the NTA 8800 guideline (NEN, 2020). For each external façade orientation, a TOJuly value is calculated. Building envelope surfaces are taken into account for their respective orientation. Figure 2.2 provides an indication which sections for the roof are taken into account for which TOJuly value.

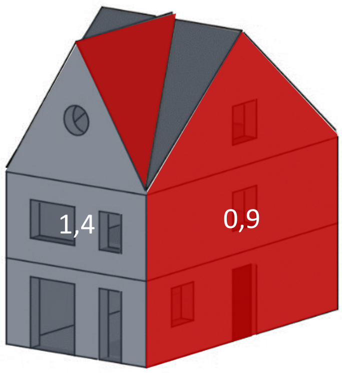

Figure 2.2: Sloped roof and external façade orientations in relation to TOJuly calculation. Grey surfaces are taken into account for the TOJuly value of 1.4, red surfaces are taken into account for the TOJuly value of 0.9. TOJuly values are indications. Image adapted from (DGMR, 2015).

The TOJuly indicator is automatically calculated in the attested software used to determine the other BENG requirements relating to the energy performance of buildings (LenteAkkoord, 2019). In short, the TOJuly is determined based on the cooling demand, and heat transmissions through the building envelope and ventilation. The month of July is used as a representative month for the summer. Formula 2.1 describes the TOJuly calculation as described in the NTA 8800 guideline (NEN, 2020).

$$TO_{July,or,zi} = \frac{(Q_{C;nd;July;or,zi} - Q_{C;HP;July;or,zi}) * 1000}{(H_{C;D;July;or,zi} + H_{gr;an;July;or,zi} + H_{C;ve;July;or,zi}) * t_{July}} \tag{2.1}$$

Where,

- $TO_{July;or,zi}$ is the indicator value for the risk of overheating, in the month July, for orientation *or* in calculation zone *zi* (e.g., individual dwelling or apartment), in *K;*
- $Q_{C;nd;July;or,zo}$ is the cooling demand, in July, for the specific orientation in the calculation zone, in *kWh,*
- $Q_{C;HP;July;or,zi}$ is the energy extracted from the cooling distribution system by the booster heat pump, in July, for the specific orientation in the calculation zone, in *kWh,*
- $H_{C;D;July;or,zi}$ is the direct heat transfer coefficient through transmission between de heated space and the outdoor air, excluding the ground floor, in July for the specific orientation in the calculation zone, in *W/K,*
- $H_{gr;an;July;or,zi}$ is the heat transfer coefficient through transmission building elements thermally connected to the ground, in July for the specific orientation in the calculation zone, in *W/K,*
- $H_{C;ve;July;or,zi}$ is the heat transfer coefficient through ventilation, in July for the specific orientation in the calculation zone, in *W/K,*
- t_{July} is the length of the month July, in *h.*

Although the TOJuly indicator is expressed in Kelvin, the unit is generally not expressed (LenteAkkoord, 2019; NEN, 2020). As most building designs have multiple external façade orientations, the maximum TOJuly value is regarded as the ultimate TOJuly value (NEN, 2020).

To determine the threshold value, dynamic simulations were performed for different building typologies (terraced dwelling, detached dwelling, and apartment) and variants (Leenaerts & Nuiten, 2019; Nuiten & Leenaerts, 2018). Besides the determined WOHs, the TOJuly values were calculated. Based on a threshold of 450 WOHs, the threshold for TOJuly was set to 1.2 (RVO, 2020). Additionally, the correlation between WOHs and TOJuly was determined and rated as high (Leenaerts & Nuiten, 2019; Nuiten & Leenaerts, 2018).

If the threshold value of 1,2 is exceeded, the building design will not be provided with a building permit. For these designs, measures need to be applied, or the design should be adapted. If measures are applied, they should be fixed to the building, internally or externally (e.g., interior fabric curtains are not allowed as a measure for reducing the risk of overheating) (NEN, 2020). Additionally, dynamically determined WOHs can be used to demonstrate that the risk for overheating is acceptable. Using this method, the WOHs may not exceed 450 hours for providing the building permit (LenteAkkoord, 2021; RVO, 2020).

The calculation method in the NTA 8800 (partially) comprises calculations based on correction factors and utilization factor (Table 2.1) (NEN, 2020). By means of these factors, dynamic behavior is taken into account to a certain degree. Nonetheless, the differences between dynamic simulations and the quasi-stationary NTA 8800 calculations are evident and existent.

3. Methodology

3.1. General explanation methodology

In this chapter, the methodology used for the evaluation of the TOJuly indicator is described. A general overview of this research process is illustrated in Figure 3.1. As was mentioned in Section 1.2, this study aims to evaluate the robustness of the TOJuly indicator, by investigating the effect of building-, occupant behavior-, and climate characteristics. Evaluation of the performance of the TOJuly indicator becomes more valuable and meaningful when a large set of different parameters is studied. On the other hand, a large set of parameters results in an even larger set of possible combinations for variants. To find a balance between studying a sufficiently large set of variants, while taking into account the time needed to produce, simulate and analyze the variants, the methodology is divided into two tracks. Within each of these two tracks, dynamic simulations and calculations of the TOJuly for different variants are performed. The outcomes of the TOJuly calculation and WOH determination are compared and analyzed. Based on these outcomes, conclusions are drawn and the research questions are answered.

Within the first track, an OAT sensitivity analysis is performed. Using this method, one variable at the time is applied on a base model and researched on its effect. Depending on the outcomes of the OAT sensitivity analysis, the variants for the analysis of the TOJuly indicator for influential building designs and characteristics are composed. In this second phase, multiple parameters are combined. For example, passive house envelope properties, with a timber frame-based design, simulated for the *NEN 5060 1%* weather data. The total of variants could potentially exceed 10 million variants per building if a brute-force approach is followed. By selecting possible combinations based on the results in the OAT sensitivity analysis, the number of variants can be drastically reduced.

Overall, the methodology involves multiple steps, partially distributed among the two different tracks. Moreover, these two tracks of the methodology are based on previous research on the applicability of the TOJuly indicator (Nuiten & Leenaerts, 2018), (RVO, 2019), (Leenaerts & Nuiten, 2019).

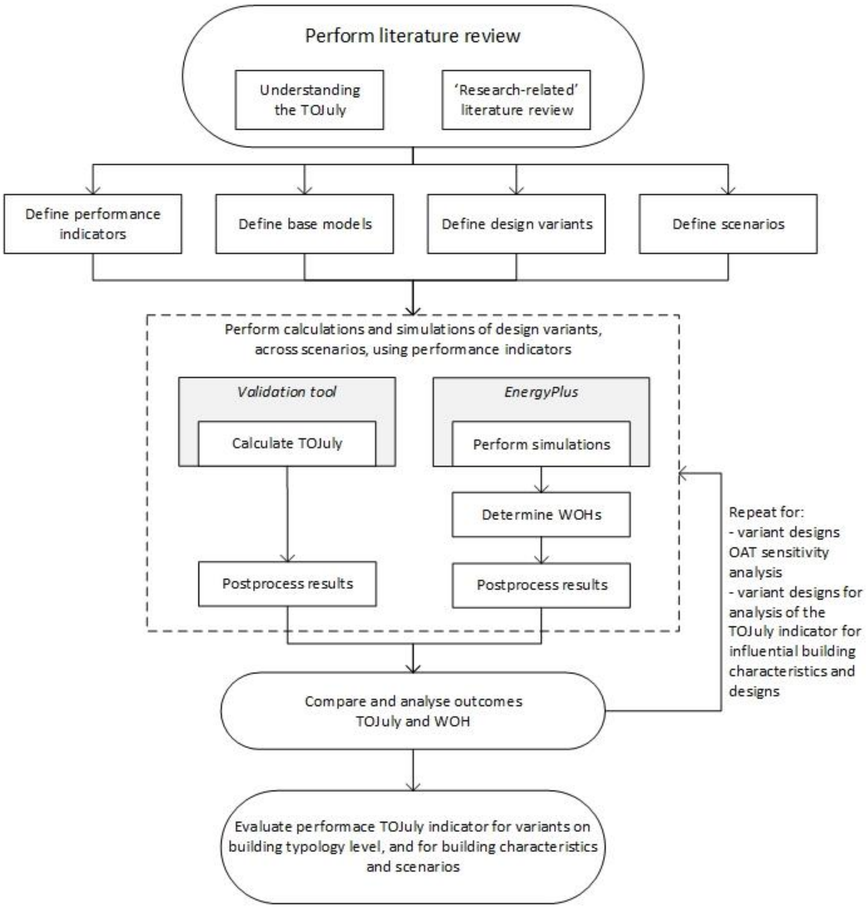

Figure 3.1: Research methodology flowchart

In the upcoming sections in this chapter, the steps are described in more detail. The performance indicators are defined in Section 3.2. In Section 3.3, the case study buildings and their building geometries and parameters are described in Section 3.3. The variants for the OAT sensitivity analysis and the analysis of the TOJuly method for influential building variations are defined in Sections 3.4 and 3.5, respectively. In Section 3.6 the Building Performance Simulation (BPS) models are explained, followed by the method for analyzing the results and answering the research question in Section 3.7.

3.2. Performance indicators

In order to answer the research questions, performance indicators are defined. These performance indicators directly relate to the research questions and contain the relevant information for answering the research objectives. Performance indicators, or Key Performance Indicators (KPIs), are quantifiable and measurable values used to gauge or compare the performance of an objective (Jahangirian et al., 2017). In this research, the KPIs are implemented for comparison and assessment of the performance of the building variants and scenarios, focusing on the field of thermal comfort. The following KPIs are used in this research:

- TOJuly
- Weighted overheating hours (WOHs)
- $T_{i,max}$ (maximum indoor air temperature)

Before describing the KPIs in more detail, a remark is made. The KPIs presented, do not strictly meet the definition of key performance indicators. As a KPI is known to be a measurable value, TOJuly, WOH, and $T_{i,max}$ should be categorized as a key performance predictor (KPP) for this research. As will be described in Section 3.3, the simulations and calculations are applied to fictive buildings, and physical measurements are not performed. Nonetheless, the notion of KPI will be used throughout this research, as this provides improved cohesion with existing and related research in this field.

3.2.1. TOJuly

The TOJuly indicator was introduced in Section 2.3. As was described, it expresses the risk of overheating for a building and is determined for all external façades in a residential building.

TOJuly is determined for each façade orientation and the highest of the resulting TOJuly's is considered as TOJuly indicator. The methodology and formula related to the calculation of the TOJuly indicator, have been explained in Section 2.3 and Formula 2.1. This method is used to determine the KPI TOJuly in this research.

3.2.2. Weighted overheating hours

Weighted overheating hours can be a misleading term. The number of hours exceeding a comfortable level is not the same as ordinary clock hours. In the WOH definition, the number of hours a threshold temperature is exceeded and the extent of that exceedance is taken into account (by assigning a weight). For example, a temperature of 31°C is paired with a larger weight factor than a temperature of 29°C, resulting in more WOHs.

The amount of WOH is calculated according to the following formula:

$$Weighted\ Overheating\ Hours = \sum_{i}^{h} h_i * wf \qquad (3.1)$$

Where *h* is the number of hours and *wf* is the weight factor for that hour.

The weight factor is determined using the following procedure:

$$wf = 0{,}47 + 0{,}22 * PMV + 1{,}3 * PMV^2 + 0{,}97 * PMV^3 - 0{,}39 * PMV^4 \qquad (3.2)$$

Where PMV is the Predicted Mean Vote, determined for each hour. Formula 3.2 is applied for hours with a $0.5 \leq PMV < 2.5$. For hours with a PMV larger than 2.5, a weight factor of 10 is assigned.

To determine the PMV the following formula is used:

$$PMV = (0.303\ e^{-0.036*M} + 2.028) * ((M - W) - H - E_c - C_{res} - E_{res}) \qquad (3.3)$$

Where,

- M is the metabolic rate in *W/m²*,
- W is the effective mechanical power in *W/m²*,
- H is the sensitive heat loss,
- E_c is the heat exchange through evaporation by the skin,
- C_{res} is the respiratory heat exchange by convection,
- E_{res} is the respiratory heat exchange by evaporation.

In Formula 3.3, H, E_c, C_{res}, and E_{res} are derived according to Formulas 3.4 – 3.7:

$$H = 3.96 * 10^{-8} * F_{cl} * ((T_{cl} + 273)^4 - (T_r + 273)^4) - F_{cl} * H_c * (T_{cl} - T_a) \tag{3.4}$$

$$E_c = 3.05 * 10^{-3} * (5733 - 6.99 * (M - W) - P_a) - 0.42 * ((M - W) - 58.15)) \tag{3.5}$$

$$C_{res} = 0.014 * M * (34 * T_a) \tag{3.6}$$

$$E_{res} = 1.7 * 10^{-5} * M * (5867 - P_a) \tag{3.7}$$

Where,

- F_{cl} is the clothing surface area factor,
- T_{cl} is the clothing surface temperature in *°C*,
- T_a is the air temperature in *°C*,
- T_r is the radiant temperature in *°C*,
- P_a is the water vapor pressure in *Pa*.

F_{cl} and T_{cl} are defined according to Formulas 3.8 and 3.9, respectively:

$$F_{cl} = 1.06 + 0.645 * 0.155 * I_{cl} \tag{3.8}$$

$$T_{cl} = (T_a + 1) - \frac{T_{cl} - 35.7 + 0.028 * (\mathrm{M} - \mathrm{W}) + 0.155 * I_{cl} * 3.96 * 10^{-8} * F_{cl} * (T_{cl} + 273)^4 - (T_r + 273)^4 + F_{cl} * 12.1 * V_{air} * (T_{cl} - T_a)}{1 + 0.155 * I_{cl} * (3.96 * 10 ** -8 * F_{cl} * 4 * (T_{cl} + 273)^3 + F_{cl} * 12.1 * V_{air})} \tag{3.9}$$

Where I_{cl} is the clothing insulation level in *clo* and V_{air} is the air velocity in *m/s.*

To conclude, in Formula 3.5 P_a is defined as:

$$P_a = \frac{RH}{100} * 288.68 * (1.098 + \frac{T_a}{100})^{8.02} \tag{3.10}$$

Where RH is the relative humidity.

To calculate the PMV according to Formula 3.3, Formulas 3.4 – 3.10 are applied. Although the formulas are extensive, only seven parameters need to be defined or implemented: metabolic rate (M), effective mechanical power (W), clothing insulation (I_{cl}), air velocity (V_{air}), air temperature (T_a), radiant temperature (Tr) and relative humidity (RH). The metabolic rate, effective mechanical power, clothing insulation, and air velocity are predefined constants and defined according to the Dutch Building Decree for performing dynamic simulations for determining WOHs (BZK, 2020) (Table 3.1). The air temperature, radiant temperature, and relative humidity are to be determined by dynamic simulations.

Table 3.1: Constant parameters for determining WOHs

Parameter	**Value**
M *[W/m²]*	64
W *[W/m²]*	0
Icl *[clo]*	0.5
Vair *[m/s]*	0.15

3.2.3. Maximum air temperature

The third performance indicator is determined in close connection with the dynamically simulated WOHs. A downside of WOHs is that it does not allow immediate insight of the temperatures in the room or zone it is calculated for. For example, a total of 500 WOHs can be achieved in a room with a maximum indoor air temperature of 31°C. However, 500 WOHs could also be a result of a lower maximum air temperature for a longer duration of hours. To provide additional insight into the level of overheating during this research, the maximum indoor air temperature ($T_{i,max}$) is determined for each zone or room for which the WOH is determined. This maximum indoor air temperature is the highest temperature in °C during the simulation period. Although $T_{i,max}$ is determined for each variant, it is not reported for all variants specifically in Sections 4 and 5.

3.3. Case study buildings

The methodology introduced in Section 3.1, is applied to a set of 7 residential buildings. The designs of these buildings are provided by the Dutch RVO as part of the BENG reference buildings. These reference buildings originate from 2016 and provide a good representation of the types of dwellings and unitary buildings at the same time (DGMR, 2015). The set of 7 reference buildings is composed of 4 types of dwellings and 3 types of apartments (Table 3.2). Among the apartments, an apartment on the top floor (e.g. 5th floor) and an apartment on the fourth floor are studied. These apartments are similar in geometry and building characteristics, except for the presence of a roof for the top-floor apartment. Figures 3.2 and 3.3 provide an overview of the dwellings and apartments, respectively. The set of 7 reference buildings is chosen to provide insight into the risk of overheating for a broad scope of buildings in the Netherlands.

Table 3.2: Reference building names and typologies

Reference building name (Dutch)	Building typology
Woning S tussen	Terraced house
Woning M hoek	Corner house, semidetached house
Woning L vrij	Detached house
Woning M tussen	Terraced house, 'Life-cycle proof 'house
Woongebouw M Woning	Apartment complex, 4th floor
Woongebouw M Woning	Apartment complex, top floor
Woongebouw XL Woning XS	Studio (student apartment)

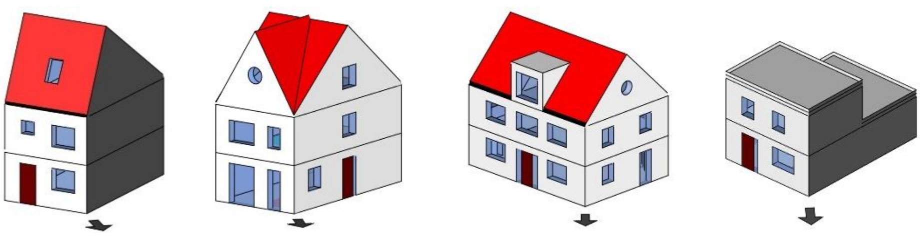

Figure 3.2: Visual impression dwellings (DGMR, 2015)

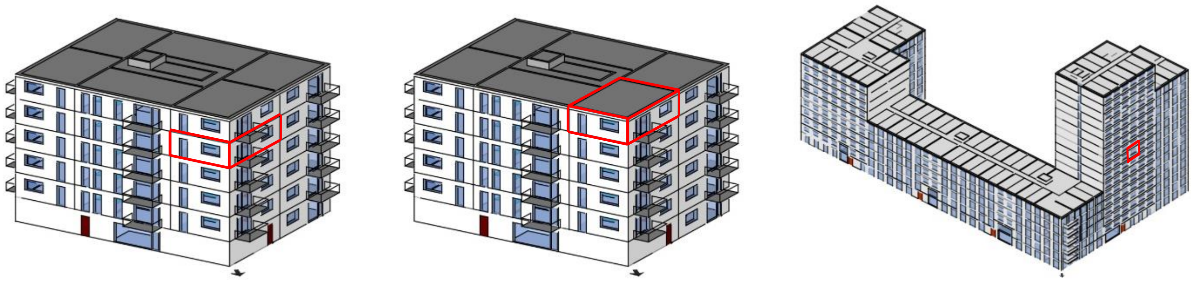

Figure 3.3: Visual impression apartment buildings (single apartments indicated in red) (DGMR, 2015)

3.3.1. Building geometry

The geometries of the residential buildings are derived from the SketchUp files provided with the BENG reference buildings. The reference buildings do not come with predetermined floorplans, although an indication for the kitchen and bathroom is given in the SketchUp files. Table 3.3 presents an overview of the Gross Floor Area (GFA), Net Floor Area (NFA), floor height and Window to Wall Ratio (WWR) for the seven houses. The GFA of the individual apartments is not shown in the table, as the apartments are part of a larger apartment complex. The WWR is calculated by dividing the total glazing area by the gross external wall area.

Table 3.3: Main building geometry parameters

Parameter	Value or description						
Building typology	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
GFA *[m²]*	146	180	264	105	-	-	-
NFA *[m²]*	110	133	181	87	76	76	30
Floor height *[m]*	2.6	2.6	2.6	2.6	2.6	2.6	2.6
WWR *[-]*	0.27	0.20	0.24	0.24	0.32	0.32	0.43

3.3.2. Building characteristics

Besides the building geometry, the reference buildings come with predefined building characteristics. In this section, a brief summary of the main building characteristics is given. As the reference buildings originate from 2015, they no longer fit the updated thermal insulation requirements implemented in 2021 and the new NTA 8800 guidelines. During the execution of this research, the currently active Dutch Building Decree is applied, in combination with (part of) the NTA 8800 requirements. This implies that the initial base model buildings also meet the TOJuly indicator threshold.

An overview of the main building characteristics is presented in Table 3.4. The building mass of the reference buildings relates to building structures with high mass materials (e.g. concrete, brick, sand-lime brick). All buildings consist of concrete floors and external brick walls. For dwellings, the inner layer of the external wall consists of sand-lime bricks, whereas this layer is modeled with concrete for the apartments. The pitched roof for the dwellings is based on a timber structure covered with roof tiles. The flat roofs consist of a concrete layer topped with bitumen. To meet the minimum thermal insulation requirements of the Dutch Building Decree, mineral wool is added to the wall, roofs, and ground floors. Moreover, the external walls are designed with an air cavity. The internal heat capacity is considered high, due to the combination of the density of the applied materials and their individual heat capacity. Overall, this building method is comparable with the design of a major part of the newly built houses in 2021.

The heating system is based on an air source heat pump, with a setpoint temperature of 20°C. This system also provides domestic hot water (DHW). For ventilation, a balanced ventilation system with centralized heat recovery is applied. This strategy is also known as type D2. Furthermore, no cooling is applied.

As the TOJuly requirement was not met for the original BENG reference building design, white external shade screens are applied on all seven buildings. Although the TOJuly is part of the BENG requirements, the other requirements on energy demand, primary energy demand, and generation of renewable energy are not considered in this research.

Table 3.4: Main building characteristic parameters

Parameter	**Value or description**
Building mass	Heavy
Internal heat capacity *[kJ/Km^2]*	500-700
Rc ground floor *[m^{2}K/W]*	3.7
Rc façade *[m^{2}K/W]*	4.7
Rc roof *[m^{2}K/W]*	6.3
Solar absorption coefficient of materials (external) *[-]*	0.6
U value windows *[W/m^{2}K]*	1.65
g-value glass *[-]*	0.6
U value door *[W/m^{2}K]*	1.65
Infiltration qv10 *[dm^3/m^{2}s]*	0.4
Ventilation type	D2
Heating	Air source heat pump
Cooling	none
Shading device	White screens, external
Summer night ventilation	none

3.4. Variants OAT sensitivity analysis

As was mentioned, screening of building design parameters by means of an OAT sensitivity analysis is applied for the base models and the design variants. The base models of the seven residential buildings fit the description in Table 3.3 and 3.4. Additionally, the orientation is based on the façade most prone to introducing potential overheating. For the studied dwellings and apartments, this results in a South-West orientation for the façade containing the most glazing area. The design variants are discussed in Sections 3.4.1 – 3.4.16. Section 3.4.17 provides an overview of all variants included for the OAT sensitivity analysis.

3.4.1. Weather data

Within the category of weather data, three climate conditions are studied: *NEN 5060 Energy*, *NEN 5060 5%*, and *NEN 5060 1%*. In this section, they are introduced and their respective implementation is discussed.

The climate data implemented in the TOJuly method is based on the NTA 8800 guidelines. This guideline prescribes the use of the *NEN 5060 Energy*, a climate data set designed for energy-related calculations in the Dutch built environment. For each month, a climate reference month from the past 20 years is determined and used (NEN, 2018). With a 5-year interval, the reference years are evaluated and potentially updated. The *NEN 5060 Energy* used in this research originates from 2018 and is based on the years 2000 to 2011. Within the TOJuly method, the mean outdoor air temperature, wind velocity, and solar radiation are used. Based on the *NEN 5060 Energy*, the monthly means have been determined for the outdoor air temperature and wind velocity. The solar radiation is implemented per month for different orientations and surface angles. The wind speed in the TOJuly method slightly differs from the *NEN 5060 Energy*, as peaks in wind velocity are excluded.

As the *NEN 5060 Energy* reference years are selected on their average nature, they are not suitable for performing calculations or simulations in the field of temperature exceedance studies (NEN, 2018). For these types of studies, multiple periods of high(er) outdoor summer temperatures are desired, to include the effect of warm or hot summer days. These missing phenomena are implemented in weather data sets specifically combined for performing temperature exceedance calculations or simulations. When performing simulations for determining WOHs, the *NEN 5060 5%* is prescribed. This climate reference data includes a 5% exceedance probability of the implemented weather data (e.g. the probability of outdoor air temperatures being higher in summer is 5%). Similar to the *NEN 5060 Energy,* 12 months from specific years (1996 to 2013) have been selected for being representative of this 5% exceedance probability. Figure 3.4 indicates the monthly mean outdoor air temperatures for *NEN 5060 Energy* and *NEN 5060 5%*.

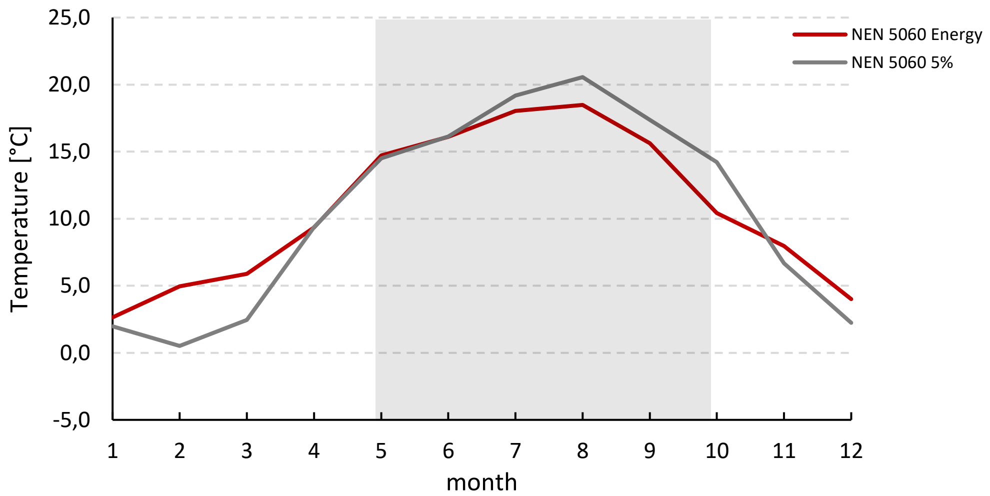

Figure 3.4: Comparison monthly mean outdoor air temperatures NEN 5060 Energy and NEN 5060 5%. Simulation period indicated in grey.

Besides the prescribed weather data for the calculations and simulations, an additional set of weather data is researched in this study. This part of the research directly relates to the third research question on the impact of future climate change on the overheating risk in residential buildings. Although the future climate is uncertain, the Dutch weather institute (KNMI) provides four scenarios from the climate in 2050 and 2085 in the Netherlands. These scenarios are based on moderate or higher temperature increase (referred to as 'G' and 'W'), with an unchanged or changed air circulation pattern (indicated with '+'). All four scenarios have in common that increased air temperatures in the respective years are inevitable (KNMI, 2015). In 2050, the air temperatures in the climate scenarios are expected to increase with 1.0 to 2.3°C, compared to the period of 1981-2010. Towards 2085, this increase in temperature is expected to continue, resulting in estimated temperatures of +1.3 to +3.7°C with respect to the same reference period of 30 years. Moreover, the number of warm summer days and heatwaves are expected to occur more often (KNMI, 2015).

The climate data provided with the four scenarios is not able to be used directly within this research. Although most of the relevant information is provided or can be determined, key information on direct- and normal solar radiation, wind velocity, and relative humidity is not reported or modeled in detail within the climate scenarios. Therefore, it is decided to compare the *NEN 5060 1%* climate data with the most extreme KNMI future climate scenario (W+). The *NEN 5060 1%* climate data is composed of weather data in a similar method compared to *NEN 5060 5%*, albeit with an exceedance probability of 1%. Moreover, all relevant and necessary information related to climate input for the models is present. Figure 3.5 shows the mean monthly air temperature for the *NEN 5060 1%* reference year, the 'W+' climate scenario (high-temperature increase with changed air circulation patterns) for 2050 and 2085. Additionally, the mean monthly temperature for 2019 and 2020 is averaged and shown in Figure 3.5. In this figure, it is observed that the *NEN 5060 1%* outdoor temperature is rather representative for the period of May to September. For the majority of these five months, the *NEN 5060 1%* is below the 2050 climate scenario, except for July. Compared to the average temperature of 2019-2020, it is observed that the N*EN 5060 1%* shows better cohesion in the W+ climate scenario. It is concluded that the *NEN 5060 1%* reference year can be used to research the impact of future climate change, although differences between this climate data and the future climate scenarios are observed.

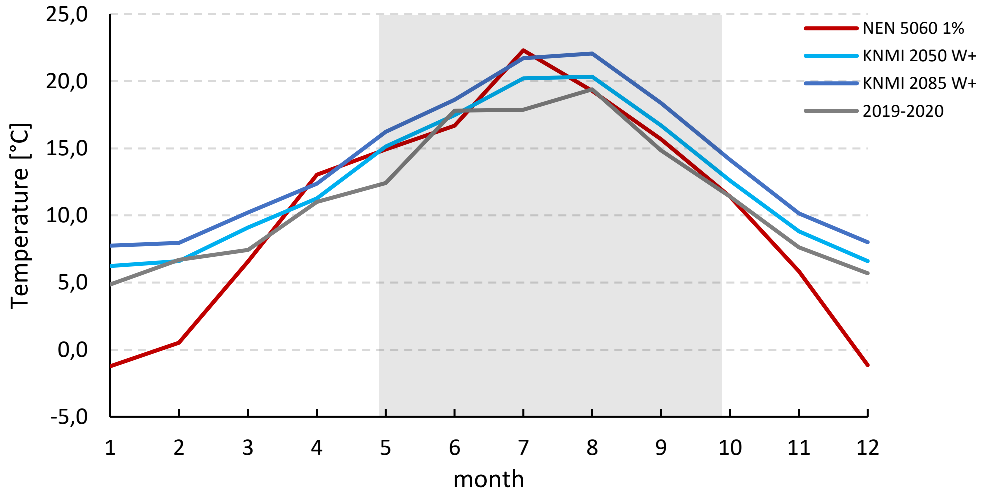

Figure 3.5: Comparison monthly mean outdoor air temperatures NEN 5060 1%, KNMI climate scenarios W+ for 2050 and W+ for 2085 and average of years 2019-2020. Simulation period indicated in grey.

3.4.2. Orientation

The orientation of the base models is referred to as South-West, as the façade most contributing to a potential overheating risk is facing towards that orientation. In addition, the following seven orientations are studied: West, North-West, North, North-East, East, South-East, and South. This provides a comparison of the effect of eight orientations for the seven reference buildings.

3.4.3. Internal heat capacity

As was explained in Section 3.3.2, the building mass for the base model buildings is considered heavy. As an effect, the internal heat capacity (e.g. heat storage within the materials) is relatively large. In practice, this results in heat buffering during warm days and reduces the peak indoor air temperatures. This results in more thermal energy stored in the building, and it takes more time and energy to cool the building down. For the set of seven base model buildings, the specific internal heat capacity ranges from 500-700 kJ/m^2K.

In an effort to reduce the carbon footprint of the built environment, a trend of timber-frame and CLT-structured (Cross Laminated Timber) buildings is evoking. For this reason, this research implements and studies the effect of those building methods in a dedicated calculation and simulation variant as well. For the dwelling, the external walls, internal floors, and roofs materialized on a timber-frame building design. The ground floor remains unchanged and is therefore similar to the base model. For the apartment buildings, CLT is used for the load-bearing structure of all floors, facades, and roofs. The specific internal heat capacity for these variants ranges from 200-300 kJ/m^2K.

3.4.4. Envelope properties

Besides the envelope quality for the base model, which meets the Dutch Building Decree (Table 3.4), two additional envelope quality variants are research in the OAT sensitivity analysis of this research. These envelope qualities are categorized as 'Building Decree Plus' and 'Passive House'. Within these envelope quality sets, the thermal insulation, window properties, and infiltration are implemented (Table 3.5).

Table 3.5: Envelope properties for the envelope variants

Parameter	Base model	Building Decree Plus	Passive House
Rc ground floor *[m^2K/W]*	3.7	6.0	8.0
Rc façade *[m^2K/W]*	4.7	6.5	8.0
Rc roof *[m^2K/W]*	6.3	8.0	10.0
U value windows *[W/m^2K]*	1.65	1.0	0.7
Glass panes *[-]*	2	3	3
g-value glass *[-]*	0.6	0.5	0.5
U value door *[W/m^2K]*	1.65	1.0	0.7
Infiltration qv10 *[dm^3/m^2s]*	0.40	0.15	0.15

3.4.5. Infiltration rate

The infiltration rate in the base model is set to 0.40 dm^3/m^2s. Within Section 3.4.4, the 'Building Decree Plus'- and 'Passive House' envelope quality sets the infiltration rate was decreased to 0.15 dm^3/m^2s. Besides studying the effect of infiltration combined with the other envelope quality parameters, the infiltration rate is studied on its effect as a single measure. Therefore, the infiltration rate in the base model is reduced to 0.15 dm^3/m^2s in an additional variant, while all other envelope quality parameters in the base model remain unchanged.

3.4.6. Glass surface

The base model designs are directly derived from the BENG reference buildings and come with predetermined window dimensions. As the effect of solar radiation on the risk of overheating is present (Moreno & Hernández, 2018), a variant devoted to an increased glass surface area is designed. Compared to the base model, the glass surface is increased to 125%. Increasing the glazing area is performed in both the x- and y-axis of the window. Table 3.6 presents the WWR of the base models and the variants with increased glass surface area for the seven residential buildings.

Table 3.6: Window to Wall ratios for the base models and the 125% variant

	WWR						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Base model	0.27	0.20	0.24	0.24	0.32	0.32	0.43
125%	0.33	0.24	0.30	0.30	0.40	0.40	0.53

3.4.7. Solar control glazing

One of the known effective measures to reduce solar radiation through windows is to apply solar control glazing. Two variants are devoted to this type of glazing. Where the glazing in the base model is set at a g-value of 0.6, the solar control glazing in the variants is set to a g-value of 0.3 and 0.4. The g-value indicates the solar transmittance through the total glass panes of the window. Note that reducing the g-value of the glazing also reduces the visible light transmittance of the windows.

3.4.8. Shading device

As was presented in Table 3.4, the base models include a white external shading screen. This screen is lowered automatically, based on predetermined settings. These settings are different in the TOJuly method as compared to the method used to determine the WOHs. In the TOJuly method, a percentage of time is used for which the shading device is lowered. In the simulations for the WOHs, a solar setpoint of 150 W/m^2 is used. When it comes to shading devices, four additional variants are studied: a dark external shading screen, no external shading screen, a white external screen that is activated at 300 W/m^2, and a dark external shading screen activated at 300 W/m^2. For the last two variants, no TOJuly can be determined, as is not possible to implement automatic activation of the shading device at a different solar radiation setting.

3.4.9. Overhang

In the previous two sections, methods for (partially) obstructing solar radiation from entering the building through windows were converted into variants. Another type of fixed building design feature that reduces incoming solar radiation are overhangs above windows. In this research, overhangs are designed as horizontal closed surfaces extending perpendicular to the façade. Two overhangs are implemented in the list of variants: an overhang of 0.40m and an overhang of 0.80m. The overhangs are located directly above the window and the width of the overhang is equal to the width of the window.

3.4.10. Ventilation strategy

In total, four ventilation strategies are included in the OAT phase of this research: D2 (base model), C4c, D5a, and D3. These abbreviations are derived from the NTA 8800 and indicate the type of system and its setup. Type D2 is described as mechanical balanced ventilation (e.g. mechanical supply and exhaust) with central heat recovery without zoning and without control (e.g., set to a minimum ventilation rate). Type C4c is mechanical exhaust ventilation with CO2-based control in the living room and at least one other bedroom, without zoning. D5a is classified as mechanical balanced ventilation with central heat recovery, CO_2 controlled in living spaces. Type D3 is described as mechanical balanced ventilation with central heat recovery and CO_2 controlled supply and exhaust (NEN, 2020).

3.4.11. Purge ventilation

Besides normal ventilation, both the TOJuly method and the method for determining WOHs apply a secondary ventilation strategy: natural ventilation by opening windows. This will be referred to as purge ventilation. Within the TOJuly method, purge ventilation is applied for 2 hours per day at a rate of 4.2 $dm^3/s.m^2$, combined with temperature limits and a predefined time schedule. As the TOJuly is based on a monthly calculation, these conditions are summarized and combined in time fractions (0.08 in the month July). The method used for determining the WOHs uses the same temperature and time limits (Section 3.6.2.1.) but is applied for 4 hours per day at a rate of 6 $dm^3/s.m^2$. Three additional variants are designed for this parameter. For TOJuly, purge ventilation for 4 hours per day at a rate of 4.2 $dm^3/s.m^2$ is researched. In the simulation for WOHs, purge ventilation is studied for 2 hours at a rate of $dm^3/s.m^2$ and 2 hours at 3 $dm^3/s.m^2$.

3.4.12. Internal heat load

The internal heat load is defined per person living in the house. The number of persons living in the house, depends on the gross floor area of the house, with a minimum of one resident. Table 3.7 indicates the number of people living in the case study dwellings and apartments. The internal heat load is calculated by multiplying the number of people by 180 Watt. 180 Watt is the average heat load per person, produced by the person and appliances, as described in the NTA 8800 (NEN, 2020).

Three variants are based on the internal heat load of the base model. Two of these variants relate to the heat load per person: 120W and 240W instead of 180W per person. This allows studying the effect of occupant behavior related to the production of internal heat. A thirds variant is devoted to the number of people living in the house. An additional resident is added to the house, with a heat load of 180W to research the effect of more residents and a resulting higher internal heat production.

Table 3.7: Number of residents per house, for base model and for the variant with one additional resident

	Number of residents						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Base model	2.38	2.41	3.09	2.04	1.84	1.84	1
+1 resident	3.38	3.41	4.09	3.04	2.84	2.84	2

3.4.13. Summer night ventilation

Summer night ventilation, or night ventilation, is a ventilation device that allows passive cooling with outdoor air, without opening windows. The device is outfitted with a rain, insect, and burglar-proof design, allowing it to be opened based on temperature and ventilation demand. In this research, the summer night ventilation is temperature-controlled, similar to the purge ventilation, and is time-restricted. Two variants are examined in this research: single summer night ventilation, and double summer night ventilation (e.g. on two different facades, and if possible, on different floors). The total opening area for summer night ventilation is 0,5 m^2. For the studio, only the single summer night ventilation can be applied, as there is one external façade.

3.4.14. Solar absorption coefficient

The solar absorption coefficient for external materials (e.g. bricks, roof tiles, and bitumen) in the base model is set at 0.6, following the NTA 8800 guideline. A variant is added in which the solar absorption coefficient is increased to values related to the materials themselves: 0.7, 0.7, and 0.9 for bricks, roof tiles, and bitumen, respectively.

3.4.15. Occupant presence in attic

Three of the reference buildings are designed with an attic: the small terraced house, the semi-detached house, and the detached house. When following the guidelines, the attic is not regarded as a living area. Consequently, no internal heat load, purge ventilation, or heating is applied on this floor. A variant is designed in which the attic is treated as a living area, by adding an internal heat load, purge ventilation, and heating. This variant can only be applied for the determination of WOHs. Moreover, the net internal heat load per square meter is reduced, due to the increased living area.

3.4.16. Natural ventilation during the day

The last variant is devoted to occupant behavior in which the windows are opened during the day. This can be regarded as purge ventilation from 8 A.M. to 10 P.M. Again, this variant is only used to determine WOHs and no TOJuly, as it is not possible to integrate such behavior in the TOJuly method in a straightforward manner.

3.4.17. Overview variants OAT sensitivity analysis

An overview of all variants per variant category is presented in Table 3.8. These variants are used in the OAT sensitivity analysis. Based on the results of the OAT sensitivity analysis, the variants for the analysis of the TOJuly indicator for influential building variants are composed. The selection of variants is based on the results of the performance indicators derived by the calculation of TOJuly and the determination of WOHs. Within each variant category, the effect of the variant compared to the other variants in the category is evaluated. Additionally, the level of cohesion between different variants in the variant categories is determined and compared to the base model (e.g., the difference among variants based on input parameters and design). In an effort to reduce the total number of variants for the analysis of the TOJuly indicator for influential building variants, the total number of variants is determined and, if needed, variants are removed based on the least differentiated outcomes of the OAT sensitivity analysis. As a result, variants could be emitted even though the parameter(s) related to the variant proves to be influential concerning the TOJuly indicator.

Table 3.8: Overview of variants and variant categories for the OAT sensitivity analysis

Variant category	**Individual variants**
Weather data	NEN 5060 Energy NEN 5060 5% NEN 5060 1%
Orientation	North North-East East South-East South South-West West North-West
Internal heat capacity	500-700 kJ/m^2K 200-300 kJ/m^2K
Envelope properties	Base model Dutch Building Decree Plus Passive house
Infiltration rate	0.40 dm^3/m^2s 0.15 dm^3/m^2s
Glazing surface area	100% 125%
Solar control glazing	g-value 0.4 g-value 0.3
Shading device	None White shade screen, 150 W/m^2 Dark shade screen, 150 W/m^2 White shade screen, 300 W/m^2 Dark shade screen, 300 W/m^2
Overhang	None 0.40m 0.80m
Ventilation type	D2 C4c D5a D3
Purge ventilation	4h, 6 $dm^3/s.m^2$ 2h, 6 $dm^3/s.m^2$ 2h, 3 $dm^3/s.m^2$ 4h, 4,2 $dm^3/s.m^2$
Internal heat load	180 W per person 120 W per person 240 W per person +1 resident
Summer night ventilation	None Single Double
Solar absorption coefficient	0.6 0.7-0.9 (according to material)
Occupant presence in attic	No Yes
Natural ventilation during the day	No Yes

3.5. Variants for analyzing the TOJuly indicator for influential building variations

Depending on the outcomes of the OAT sensitivity analysis, the variants for the analysis of the TOJuly indicator for influential building designs and characteristics are composed. The selection is based on the methodology described in the previous section. By selecting possible combinations based on the results in the OAT sensitivity analysis, the number of variants can be drastically reduced. Moreover, certain combinations are not likely to be applied in reality, such as a shading device, combined with an overhang and solar control windows. These combinations will also be left out of consideration in this research. The resulting variants are arranged according to the dedicated research question(s) they belong to.

3.6. Simulation models

Section 3.6.1 presents the calculation model for the TOJuly method, Section 3.6.2 describes the model and software used for determining the WOHs. Within these sections, information regarding the input parameters of the models is specified, and the postprocessing of data is described.

3.6.1. Model for TOJuly

To calculate the TOJuly indicator for the variants and buildings, specific software, input, and calculation methods are used. In this section, these tools and steps are presented and discussed. A majority of the input related to the seven residential buildings, and their variants, has already been described in Section 3.3. In Section 3.6.2, additional information regarding the calculation of TOJuly is explained.

The TOJuly indicator for the buildings and their variants is determined by means of the NTA 8800 calculation tool, version 1.50. This tool encompasses the calculations as described in the NTA 8800 in an elaborate excel file. The excel file allows changing certain fixed parameters, such as the internal heat load per person (180W), although they are not meant to be adapted. Within official NTA 8800 attested software (e.g., *Vabi* and *Unieq*), it is not possible to change these fixed parameters. For this research, the NTA 8800 calculation tool allows research freedom, as well as calculation of the TOJuly according to the guidelines in the NTA 8800.

3.6.1.1. Model input

In order to calculate the TOJuly, the following input parameters for each variant are needed for the NTA 8800 tool:

- Selection of climate (NEN 5060 weather data)
- Main building characteristics (GFA, specific internal heat load, building height, infiltration, thermal bridges)
- Floor, roof, façade and window properties (Rc-values, U-values, surface area, orientation)
- Installation properties (ventilation characteristics, heating system characteristics, DHW, etc.)

In total, several hundred parameters can be implemented in the tool. In addition, the tool has been extended to be able to select additional climates, such as the *NEN 5060 5%* and *NEN 5060 1%.* Moreover, the internal heat load per person, the number of occupants, time fraction for purge ventilation, and the solar absorption coefficients for roof and façade can be adapted after extending the tool. This allows all variant categories described in Sections 3.4 and 3.5 to be studied.

The specific input parameters for each variant depend on the characteristics and parameters belonging to the specific variant. These input values are derived from the BENG reference buildings, NTA 8800, the Dutch Building Decree, and reference details for building structures.

3.6.1.2. Generation of results

As a large set of TOJuly indicators is calculated for the different variants in this research, manual insertion of the input parameters for each variant would become a time-consuming and error-prone task. To improve the efficiency of the calculation of TOJuly for the variants, a batch tool is used. This tool allows automatic and sequential calculation of the complete NTA 8800 tool, after which the TOJuly values for the variants can be extracted among all results. Moreover, the batch tool reduces the manual labor and associated possibility for user error.

3.6.1.3. Postprocessing of results

When using the batch tool for the NTA 8800 calculations, all results are reported in the same excel file. These results include information on energy performances, energy demands, and the TOJuly for each orientation. As solely the TOJuly is of interest within this track of the calculations, this information is extracted. For each building, a minimum of one TOJuly value and a maximum of 4 TOJuly values are produced, depending on the number of external facades. As was explained in Section 3.2.3, the highest of these TOJuly values is considered as the ultimate TOJuly value for the dwelling or apartment. Before reporting this ultimate TOJuly indicator value, the orientation belonging to that value is reported and checked. This provides an additional step towards monitoring the legitimacy of the results.

Ultimately, all information regarding the NTA 8800 tool is reduced to one single TOJuly value for each variant. For a small set of variants, no TOJuly is determined. Either, it is not possible to implement those variants in the NTA 8800 tool (for example, presence in the attic), or relevant information was missing (time fractions for natural ventilation during the day, and adapted solar setpoints for shading devices).

3.6.2. Model for WOHs

The weighted overheating hours are determined using Building Performance Simulations (BPS). By means of dynamic simulations, hourly data on the air temperature, radiant temperature, and relative humidity is derived. The seven reference buildings, and their variants, are modeled according to the input parameters corresponding to the specific variant.

The buildings are modeled in DesignBuilder (version 6.1.6.011). For the apartments and studio, the height of the apartment in the building is taken into account by modeling the remaining building in a simplified manner. Moreover, the apartment on the top floor is modeled at the same height as the apartment vertically enclosed between two floors. This reduces the difference between the apartments to solely the presence of an externally-bounded roof. Dwelling division walls and apartment division walls (e.g. walls separating the houses from their neighbors) are defined as adiabatic.

After establishing the building geometry, envelope properties and materialization, occupant-related parameters, and HVAC systems, the dynamic simulation can be performed. To do so, EnergyPlus (version 8.9.0.001) is used. With a resolution of 15 minutes, the hourly simulations are performed.

The resulting data is used to determine the WOHs and $T_{i,max}$, according to the method described in Sections 3.2.2 and 3.2.3.

3.6.2.1. Model input

Similar to the input for the TOJuly model, most parameters are defined according to the NTA 8800 and the Dutch Building Decree. Additionally, the Dutch Building Decree contains a specific appendix devoted to simulations for WOHs (BZK, 2020). This information is used as a primary source for performing the dynamic simulations in this research.

The weather data used for the base models is based on the *NEN 5060 5%* climate data. To allow simulations with this data, Elements software (version 1.0.6) is used to convert the excel file weather file into a .epw file. The same procedure is executed for generating and .epw file for the *NEN 5060 1%* weather data, as input for the variants.

In order to simulate the case study buildings, zones are defined within each dwelling and apartment. The division of zones is derived from the guidelines in Appendix VII of the Dutch Building Decree (BZK, 2020). This resulting number of zones is presented in Table 3.9. Considering the dwellings, the first zone is dedicated towards the ground floor, two zones are located on the first floor (front and back) and a fourth zone covers the attic. As the design of the terraced medium dwelling is not provided with an attic, the fourth zone is not defined. For the apartments, the floorplan is divided into three zones: the first zone covers the living room and kitchen, the second zone defines the bedroom and the third zone describes the entrance and bathroom. The studio is modeled based on a single zone.

Table 3.9: Division of zones within the case study buildings

	Zones within building						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Zones	4	4	4	3	3	3	1

The envelope properties are implemented according to Sections 3.3.2 and 3.4.4. Special effort is put into making sure the windows in the TOJuly model and dynamic model are similar. This includes the ratio of glass surface area and window frame surface area. The internal heat load is similar to the internal heat load as described in Section 3.4.12 (e.g. 180W per person and the number of occupants depending on the GFA). When it comes to purge ventilation and summer night ventilation, temperature and time restrictions are applied. These restrictions are described in the Dutch Building Decree guidelines for dynamic simulations for WOHs (BZK, 2020). The purge ventilation is applied between 7 A.M. and 8 A.M. and 8 P.M. and 11 P.M. if the indoor air temperature exceeds 24°C and the outdoor air temperature exceeds 13°C. Moreover, the indoor air temperature must be higher than the outdoor air temperature. Summer night ventilation operates based on the same temperature condition as purge ventilation, although the indoor air temperature may be lower than the outdoor air temperature. In the models, this type of ventilation system is (potentially) operational between 10 P.M. and 6 A.M. The total opening area for summer night ventilation is 0,5 m^2. To conclude the description of the main input parameters for the dynamic simulations, the operation of shading devices is controlled by a solar energy setpoint set to 150 W/m^2 in the base model and 300 W/m^2 in part of the variants.

3.6.2.2. Generation of results

The EnergyPlus simulations are performed for the period of April 30th to September 28th. For each variant, a .idf file is generated by DesignBuilder, or the .idf file is adapted based on a previous variant. The .idf files contain all relevant building information to run the simulation in EnergyPlus. Running the simulations takes a maximum of 10 seconds per building and is executed in batches of multiple variants.

The output of the EnergyPlus simulations is stored in .csv files which will be used in the postprocessing phase.

3.6.2.3. Postprocessing of results

Each variant results in a single .csv file containing all simulation outcomes. From this data, three parameters are extracted to determine the WOHs: indoor air temperature, radiant temperature, and relative humidity. For each hour in the simulation period, this data is combined with the other constant parameters on metabolic rate, clothing insulation, and air velocity. According to the formulas described in Section 3.2.2, the performance indicator weighted overheating hours is calculated. This calculation is automated in Python, for improved ease and time consumption. The WOHs for each zone are determined for all hours in the simulation period and do not depend on occupant presence.

As the reference buildings consist of multiple zones, the zone with the most WOHs is referred to as the maximum amount of WOH for the dwelling (WOH_{max}). The zones covering an attic do not contribute to this maximum WOHs, as they are not considered a living area.

Besides the weighted overheating hours, the maximum indoor air temperate in each zone is reported. This allows additional information with regard to the thermal comfort properties in that zone. The $T_{i,max}$ can provide information on the potential overheating risk if zero WOHs are reported. However, the WOH remains the main performance indicator for the dynamic simulations.

3.7. Analysis of results

Following the methodology described in the previous sections, a TOJuly value and WOHs are determined for each variant. Direct comparison of the resulting values is not possible, as TOJuly must be regarded as a ‘traffic light’. There is no sliding scale, either the TOJuly is met (≤1.2) or not met (>1.2). For the WOH a threshold level of 450 hours is set as thermal comfort limit.

To quantify the results and the relation between TOJuly and WOHs, four quadrants are used (Figure 3.6). The first and fourth quadrants describe results that fit the reasoning behind the TOJuly method and indicate cohesion of the results within the variant (indicated with green). The second quadrant relates to a situation in which the WOH threshold of 450 hours is met, but TOJuly exceeds 1.2. Although not an ideal situation, this still fits within the NTA 8800 method, as was described in Section 2.3. The third quadrant categorizes variants that meet TOJuly but exceed the WOH threshold. According to the NTA 8800, these variants would be considered with an acceptable risk for overheating, whereas the WOHs indicate that this risk is larger than 450 hours.

Each variant is categorized within one of these four quadrants. As the calculations and simulations come with a certain level of uncertainty, the results entail a level of uncertainty as well. Therefore, the same categorization procedure is applied using the threshold levels with a 10% deviation margin.

TOJuly ≤ 1.2 WOH ≤ 450	TOJuly ≤ 1.2 WOH > 450
TOJuly > 1.2 WOH ≤ 450	TOJuly > 1.2 WOH > 450

Figure 3.6: Categorization of results in four quadrants

The research questions are divided into three main categories: building characteristics, occupant behavior, and future climate. Within these categories, a set of variants is established in Section 3.5. These variants are categorized according to the four quadrants, and the results are used to provide the information necessary for answering the research questions. Moreover, results will be discussed on a building typology level, and on a variants category level. For some variants, no TOJuly is established. When analyzing these variants, this will be based on the relative difference of WOHs.

The main research question asks to express the robustness of the TOJuly indicator. In this research, variants in the third quadrant express low robustness of the TOJuly indicator, as they do not fit the designed method and reasoning behind the TOJuly. However, a certain level of uncertainty must be taken into account. As no limit for the number of variants or buildings in the third quadrant was set during the design stage, it is not possible to provide an unambiguous maximum percentage during this study. Moreover, no thresholds for similar applications on estimating the risk of overheating are found in literature. To give an indication for an indication for a direction of a probable threshold, a percentage of 5% is defined. Note that this 5% is not a strict maximum percentage, but merely an indication. In this research, the composition of the variants in the third quadrant is of larger interest compared to the number of variants themselves. Based on the three secondary research questions, possible overrepresentation of dedicated variants or characteristics within the third quadrant is discussed.

4. Results OAT sensitivity analysis

This chapter presents the results of the variants researched in the OAT sensitivity analysis. According to the methodology described in Section 3.4, single measures are implemented onto the base model to evaluate the effect of the variants and variant categories. Based on these results, decisions are made towards the combination of variants for analyzing the TOJuly indicator for influential building designs and characteristics.

In an effort to present and discuss the results of the OAT phase in a concise manner, the most important results are summarized in this chapter. Section 4.1 provides a general overview of the relevance of the variants. In Section 4.2, the results of a selection of variants are discussed in more detail.

4.1. Relevancy of variants

As was mentioned earlier, the results of the variants in the OAT phase are used to determine the variants and variant combinations for analyzing the TOJuly indicator for influential building designs and characteristics. Before discussing the relevance of the variants, a general remark is made. As the models for the variants in the OAT phase are composed based on adding building parameters and features to the base models, some results become exaggerated. For example, when applying solar control glazing, this solar control glazing is added to the main building characteristics and parameters. Consequentially, the buildings in those variants are modeled with both solar control glazing and white shading devices.

The relevancy of the variants and variant categories is summarized in Table 4.1. In this table, the number of variants within a category is discussed as well. The relevance is based on the performance indicators derived by the calculation of TOJuly and the determination of WOHs. An overview of these results is given in Appendix I.

Table 4.1: Relevancy of variants and variant categories for analyzing the TOJuly indicator for influential building designs and characteristics

Variant category	Individual variants	Relevancy of variant(s)
Weather data	NEN 5060 Energy NEN 5060 5% NEN 5060 1%	Used climate file depends on simulation track, NEN 5060 5% is not relevant for TOJuly calculations. NEN 5060 1% is relevant for researching effect future climate.
Orientation	North North-East East South-East South South-West West North-West	Differences on the effect of orientation are limited (due to presence of shading device in base model). Nonetheless these are useful variants. Number of orientations can be limited to four orientations: North-East, South-East, South-West and North-West.
Internal heat capacity	500-700 kJ/m^{2}K 200-300 kJ/m^{2}K	Variants provide relevant information and may be further combined with envelope properties.
Envelope properties	Base model Dutch Building Decree Plus Passive house	Differences in effect of envelope properties on risk of overheating are present. Although deemed as relevant, the Dutch Building Decree Plus variant may be set aside for the second track.

Infiltration rate	0.40 dm^3/m^2s 0.15 dm^3/m^2s	The relevance is this variant category is low, as the two infiltration rates are already implemented in the envelope properties variants.
Glazing surface area	100% 125%	Both the results of TOJuly and WOHs indicate that these variants are relevant for further research in the second track.
Solar control glazing	g-value 0.4 g-value 0.3	Due to the combination of solar control glazing and external shading devices, the effect on TOJuly and WOH is limited. The effect of solar control glazing with a g-value of 0.4 is more limited compared to glazing with a g-value of 0.3. Solar control glazing with a g-value of 0.4 may be abundant within the combined variants for the second track.
Shading device	None White shade screen, 150 W/m^2 Dark shade screen, 150 W/m^2 White shade screen, 300 W/m^2 Dark shade screen, 300 W/m^2	The effect of removing the shading devices from the base model are large. Moreover, the differences between white and dark shading are evident. With regard to the solar setpoints, 300 W/m^2 can only be research on WOHs.
Overhang	None 0.40m 0.80m	The effect of overhang is not always expressed in the results for TOJuly. As an overhang of 0.4 generates a similar TOJuly compared to the base model, its relevance is reduced. An overhang of 0.80m is a relevant variant for further research within the second track.
Ventilation type	D2 C4c D5a D3	The results indicate that this variant category is relevant. Moreover, the differences between the variants are present in the results. Type D3 may be excluded when composing variants for the second track, as part of reducing the number of possible combinations.
Purge ventilation	4h, 6 $dm^3/s.m^2$ 2h, 6 $dm^3/s.m^2$ 2h, 3 $dm^3/s.m^2$ 4h, 4,2 $dm^3/s.m^2$	The time fraction and rate of purge ventilation differs per simulation track. With regard to the TOJuly method, the rate and time fractions for purge ventilation are fixed in NTA 8800. For WOHs, the differences in ventilation rates result in small deviations from the base model. The time fraction indicates a larger effect on the WOH. Variants in the second track may be reduced to 4h at 6 $dm^3/s.m^2$ and 2h at 3 $dm^3/s.m^2$ for dynamic simulations.
Internal heat load	180 W per person 120 W per person 240 W per person +1 resident	Based on the results, most internal heat load variants are found to be relevant. When adding an additional resident, the effects of this additional resident mainly depend on the number of residents in the base model building. For example, the amount of residents in the studio is increased with 100%, whereas this relative increase is 32% for the detached dwelling. This results in unequal relative differences between the models. Therefore, this variant will not be implemented in the second track.
Summer night ventilation	None Single Double	Due to the implementation of summer night ventilation in the models for WOH simulations, the effect of a single summer night ventilation system and double implementation of the system is limited. Therefore, the relevance of two setups for these systems is reduced.

Solar absorption coefficient	0.6 0.7-0.9 (according to material)	The NTA 8800 method prescribes the use of a solar absorption coefficient of 0.6. Increasing this coefficient, expresses an increase of TOJuly. For the dynamic simulations for WOHs, a solar absorption coefficient of 0.6 is not considered as highly relevant, as the model becomes less realistic. In the second track, the TOJuly may be calculated solely with a coefficient of 0.6, and for WOHs the coefficient depends on the materials themselves.
Occupant presence in attic	No Yes	The relevance of this variant category is low compared to the other variant categories. This relates to the amount of building typologies containing an attic, and the fact that these variants are only suitable for determining the WOHs.
Natural ventilation during the day	No Yes	Although the effects of opening windows during the day only are interesting with regard to the WOHs, the relevance of this variant is low for this research due to the missing TOJuly indicator values.

4.2. Discussion of the effect of variants

Based on the calculated TOJuly values and determined WOHs for the different variants and the relevance of the variants was discussed in Table 4.1. A selection of variants will be discussed in more detail. This selection of variants consists of the effect of the addition of an overhang and the effect of the solar absorption coefficient of external materials. These variants are discussed as they provide highly relevant information with regard to the TOJuly method itself, which is the core objective of this research. Moreover, the effect of building height on TOJuly and WOHs is discussed. Although not a dedicated variant in the OAT sensitivity analysis, it provides relevant information with regards to this research and the risk of overheating in general.

4.2.1. The effect of an overhang

As was described in Table 4.1, the addition of an overhang is not always represented in the resulting TOJuly. Figure 4.1 illustrates the TOJuly and WOHs for the seven residential buildings. For these houses, it is concluded that the risk of overheating is low, as both the TOJuly and the number of weighted overheating hours do not exceed the threshold levels of 1.2 and 450 respectively. Again, the remark is made that in addition to the overhang, the white external shading devices are present in the models. However, the results illustrated in Figure 4.1 ask for a different discussion based on the results. As can be seen, the TOJuly for an overhang of 0.40m is similar to the variant without an overhang. This observation is made for all building typologies within this variant category and all building typologies meet the threshold levels for TOJuly and WOHs.

The reduced, or missing, effect of an overhang of 0.40m in the TOJuly indicators, originates from the method used in the NTA 8800 to define the impact of an overhang. The overhang is defined based on the relative height ratio. This ratio is determined by the height of the glass area and the depth of the overhang (e.g., how much the overhang extends from the façade. Based on this ratio, a solar reduction factor is determined. These reduction factors are based on the relative height ratio and classified into three categories. One of these categories describes no effect of the overhang on reducing solar radiation on the window (NEN, 2020). According to this calculation method, the overhang of 0.40m does not have result in reduced solar radiation on the glass surface of the window. However, Figure 4.1 indicates a decrease in WOHs, indicated by the lines in the graph.

When it comes to the effect of an overhang of 0.80m, the same calculation method for relative height is implemented in the NTA 8800. The height of the window in the studio results in a solar reduction factor similar to the overhang of 0.40m. In other words, the overhang of 0.80m is neglected in the studio. For all three variants, the TOJuly for the studio is settled at 0.5. However, the WOHs indicate a decrease in the risk of overheating. For the other building typologies, an overall effect of the overhang of 0.80m is observed for WOHs and TOJuly. However, the impact on TOJuly is reduced as the designs contain both windows for which the overhang is neglected (similar to the studio) and windows for which the overhang of 0.80m provides a reduction of solar radiation of the glazing surface.

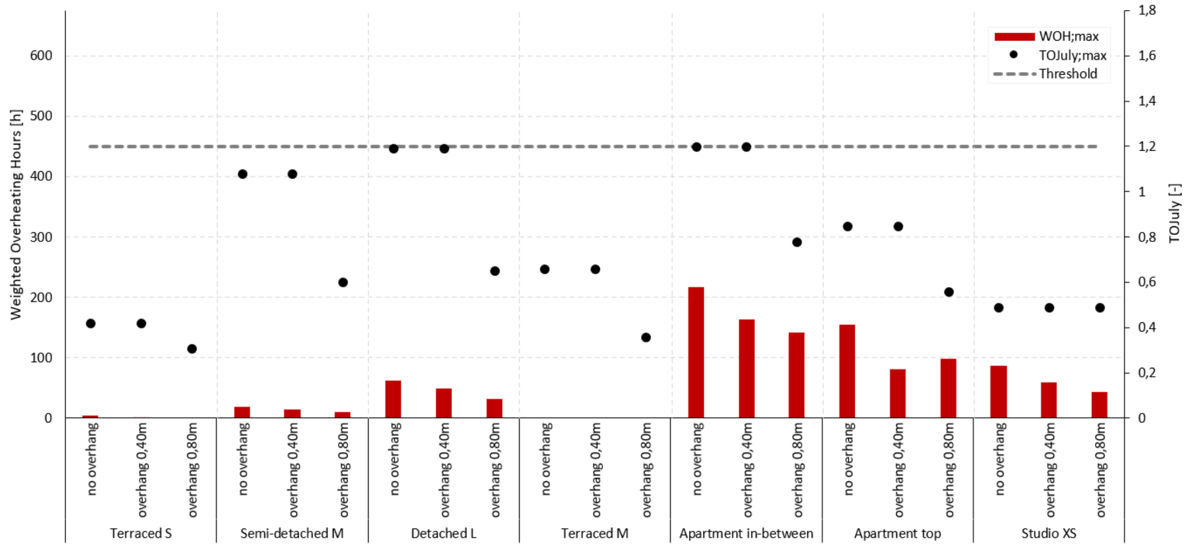

Figure 4.1: Effect of overhang on TOJuly and WOHs, for seven building typologies.
The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

4.2.2. The effect of solar absorption coefficients

In the NTA 8800, the solar absorption coefficient is set to 0.6 (NEN, 2020). As a result, the solar absorption coefficient for external materials (e.g. bricks, roof tiles, and bitumen) in the base model is set at 0.6. A variant was added in which the solar absorption coefficient is increased to values related to the materials themselves: 0.7, 0.7, and 0.9 for bricks, roof tiles, and bitumen, respectively.

Figure 4.2 presents the TOJuly and WOHs for the variant with the increased solar absorption coefficients and the base models. The difference between the design of these apartments is reduced to the presence of the roof for the top floor apartment. Among the presented building typologies, the difference between the base model and the variant is a maximum of 0.14 for TOJuly and 88 hours for WOHs. This largest impact on changing the absorptance coefficient is found in the apartment on the top floor, where the WOH increased by approximately 31%. For the remaining building typologies, the differences are smaller. Although the differences are relatively small, they may be of an impact for cases close to the threshold level.

For the continuation of this research, the solar absorptance coefficients for the calculation of TOJuly will remain set to 0.6. In the models for the dynamic simulations, the absorptance coefficient is set to the individual material characteristics. This way, the TOJuly is determined using the prescribed methodology in the NTA 8800, and the dynamic simulations are modeled closer to reality.

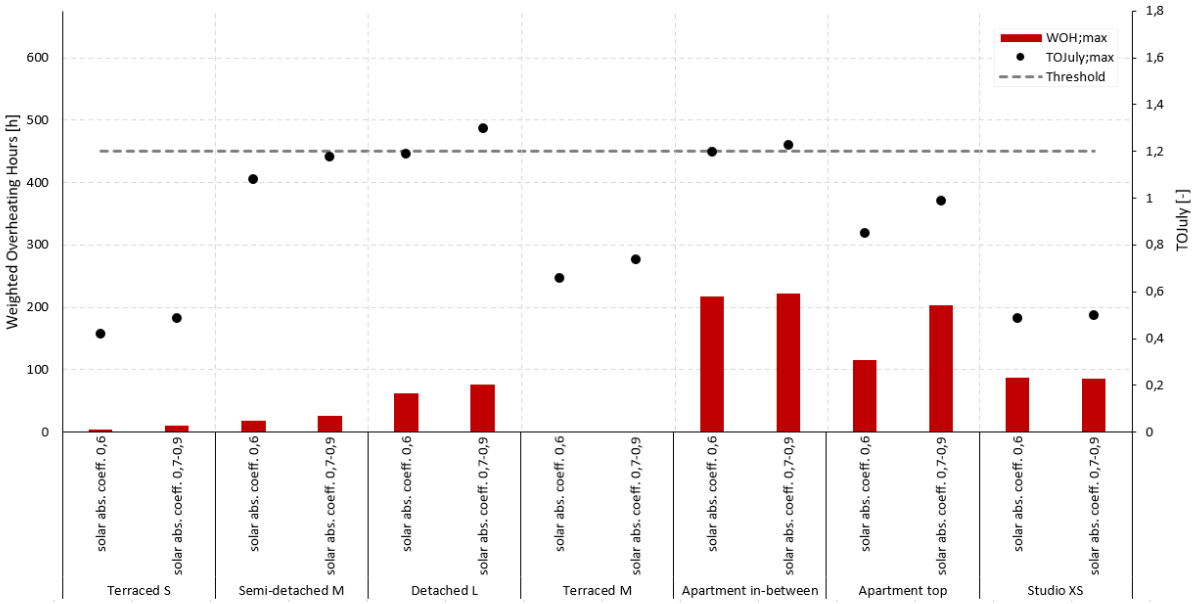

Figure 4.2: Effect of solar absorptance coefficient on TOJuly and WOHs, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

4.2.3. The effect of building height

During the design of the variants for the studio, a differentiating effect on TOJuly and WOHs in relation to the building height was observed. The following results and discussion of results do not belong to a specified variant category.

In Figure 4.3, the results of the base model with white external shading screens and without shading screens, for three apartment heights are presented. The overall height of the building remains set at 52 m, and the height in the figure represents the height of the apartment relative to the ground surface. For the two cases, with and without a shading device, the apartment height impacts the WOHs, where the highest amount of WOHs is observed for the lowest height. The effect of the apartment height is not represented in the TOJuly values for these cases. This can be related to the way the NTA 8800 calculation is defined: only the total building height is taken into account for determining the TOJuly. Within this total building height, the effect of external parameters (e.g., wind velocity and air pressure) are evenly distributed over the total building height by means of three airflow zones. Using this method, no distinction is made for different floors in a building in TOJuly.

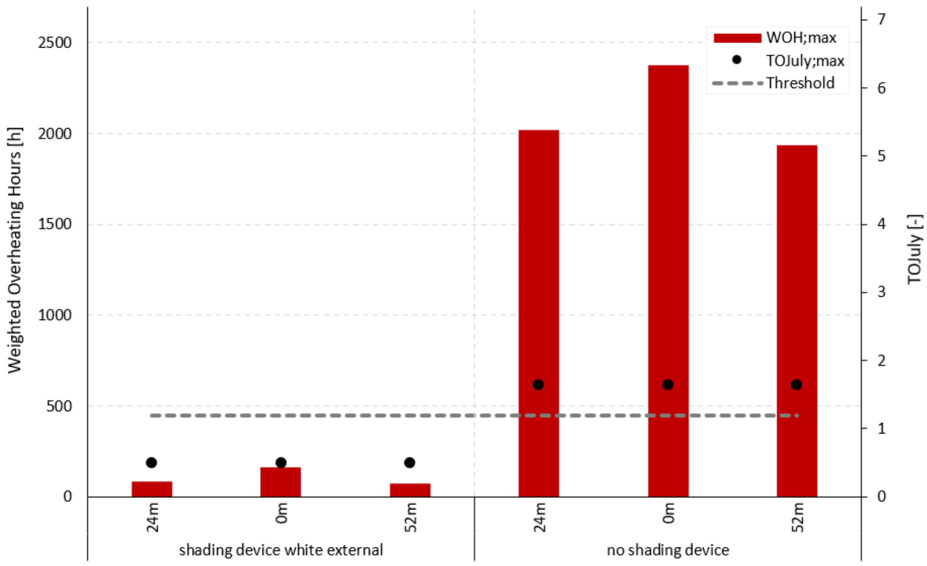

Figure 4.3: Effect of building height on TOJuly and WOHs, for the studio.
The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

4.2.4. Conclusions based on the OAT sensitivity analysis

In Sections 4.2.1 - 4.2.3 three variants and their results were discussed. Based on the information presented, three main conclusions are drawn:

- The effect of an overhang in the NTA 8800 method is underestimated for windows with a relatively large glass area height. As was found in the dynamic simulations, an effect on WOHs is present, whereas no effect was found in the calculated TOJuly, or this effect was limited.
- Depending on the exterior materials used for a building, the solar absorption coefficient related to these materials may be underestimated in the NTA 8800 method. The largest differences were introduced in the roof, where the NTA 8800 prescribed a solar absorptance coefficient of 0.6, whereas the material applied in this research (e.g. bitumen) is typically paired with an absorptance coefficient of 0.9.
- The effect of building of apartment height in a building is not individually taken into account in the NTA 8800 method. Although different classes of airflow zones are defined, the airflow zones characteristics are evenly distributed over the total building. When performing dynamic simulations, results imply that the effect of apartment height may have a significant effect on the risk of overheating.

4.3. Determining variants for analyzing the TOJuly indicator for influential building variations

Based on the relevance of the variants discussed in Table 4.1 and the additional discussion of results in Section 4.2, the variants for analyzing the TOJuly indicator for influential building designs and characteristics are defined. Table 4.2 presents the variants within each category and allows insight into which variants were discarded. The selection of relevant variant parameters for the main phase does not solely rely on the results themselves. The total number of possible combinations is also taken into account.

Table 4.2: Variant categories and variant parameters for the for analyzing the TOJuly indicator for influential building designs and characteristics

Variant category	Variants OAT phase	Variants main phase
Weather data	NEN 5060 Energy NEN 5060 5% NEN 5060 1%	NEN 5060 Energy (TOJuly) NEN 5060 5% (WOH) NEN 5060 1% (TOJuly and WOH)
Orientation	North North-East East South-East South South-West West North-West	North-East South-East South-West North-West
Internal heat capacity	500-700 kJ/m^{2}K 200-300 kJ/m^{2}K	500-700 kJ/m^{2}K 200-300 kJ/m^{2}K
Envelope properties	Base model Dutch Building Decree Plus Passive house	Base model Passive house
Infiltration rate	0.40 dm^3/m^{2}s 0.15 dm^3/m^{2}s	- (Included in envelope properties)
Glazing surface area	100% 125%	100% 125%
Solar control glazing	g-value 0.4 g-value 0.3	g-value 0.3
Shading device	None White shade screen, 150 W/m^2 Dark shade screen, 150 W/m^2 White shade screen, 300 W/m^2 Dark shade screen, 300 W/m^2	None White shade screen, 150 W/m^2 Dark shade screen, 150 W/m^2 Dark shade screen, 300 W/m^2 (WOH)
Overhang	None 0.40m 0.80m	None 0.80m
Ventilation type	D2 C4c D5a D3	D2 C4c D5a
Purge ventilation	4h, 6 dm^3/s.m^2 2h, 6 dm^3/s.m^2 2h, 3 dm^3/s.m^2 4h, 4,2 dm^3/s.m^2	2h, 4,2 dm^3/s.m^2 (TOJuly) 4h, 6 dm^3/s.m^2 (WOH) 2h, 6 dm^3/s.m^2 (WOH)
Internal heat load	180 W per person 120 W per person 240 W per person +1 resident	180 W per person 120 W per person 240 W per person

Summer night ventilation	None Single Double	None Single
Solar absorption coefficient	0.6 0.7-0.9 (according to material)	-
Occupant presence in attic	No Yes	-
Natural ventilation during the day	No Yes	-

The parameters presented in Table 4.2 are used to define the variants in which the individual measures are combines. These combined variants allow additional insight into the risk of overheating for different building characteristics, changing occupant behavior, and the effect of future climate change. In total, 58 variants are designed within the category of building characteristics and 57 variants relate to occupant behavior. Moreover, these 115 variants are used to research the effect of future climate change. All these variants result in a set of 230 variants for each of the seven building typologies, adding to a total of 1610 variants. The composition of the variants is described in Appendix II.

5. Analyzing the TOJuly for influential building variations

In this chapter, the results of the NTA 8800 calculations and EnergyPlus simulations are presented and discussed. Using the KPIs TOJuly and WOHs, the risk of overheating is determined, based on the threshold levels presented in Section 2. The presentation of results is divided into three sections, relating to the three secondary research questions:

- building characteristics and building typology (Section 5.1)
- occupant behavior (Section 5.2)
- future climate (Section 5.3).

Due to the large set of variants, not all results will be discussed in detail. Within each section, the most impactful aspects on estimating the risk of overheating are selected and presented. This does not implicate that all additional results have been discarded, nor are they classified as insignificant.

5.1. Building characteristics and building typology

In the following sections, the results of the TOJuly calculations and WOHs determinations in relation to building characteristics and building typology are discussed. First, a selection of variants is presented and illustrated, focusing on the effect of estimating the risk of overheating. This selection includes the effect of orientation, envelope properties, and internal heat capacity, solar reductive measures, and summer night ventilation. Although three KPIs were implemented in this research, $T_{i,max}$ will only be reported occasionally. For the results for the complete set of 58 variants related to building characteristics and building typology, please refer to Appendix III.

5.1.1. Orientation

Before looking into variants in more detail, the effect of orientation on the risk of overheating is discussed. Figure 5.1 illustrates the TOJuly and WOHs for the small terraced dwelling. The other dwellings and apartments are not discussed in detail, as the observations discussed for the terraced house are also made for the other houses unless indicated specifically.

In Figure 5.1, five overheating reducing measures are presented (e.g., white external shading screens, dark external shading screens, solar control glazing with g-value 0.3, 0.80m overhang, and summer night ventilation) for four orientations (e.g., South-West, North-East, South-East, and North-West) (the orientation relates to the façade with the largest glazing surface area). Additionally, the results of the design variants without any type of solar control or additional ventilative measure are presented. Focusing on the effect of orientation, the following observations are made. The South-East and South-West orientation introduce the highest risk for overheating for both TOJuly and WOHs. Between the two, the highest TOJuly value is generally reported for the South-West orientation for the variants illustrated in Figure 5.1. The highest number of WOHs is found for the South-East orientation. A similar trend is found among the other building typologies. The largest differences between the two orientations are present in the studio when applying an overhang of 0.80m or summer night ventilation (54.8% and 64.4%, respectively).

For all upcoming variants discussed in Sections 5.1.2 – 5.1.4, the dwellings and apartments are oriented South-West.

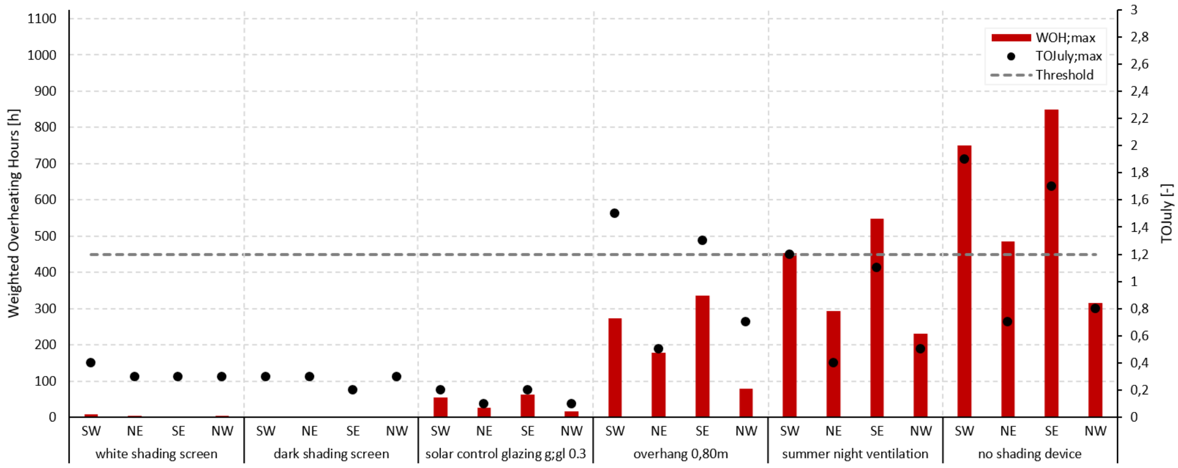

Figure 5.1: Effect of orientation on TOJuly and WOHs, for terraced small dwelling.
The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.1.2. Envelope properties and internal heat capacity

Figure 5.2 presents the TOJuly values and WOHs for the seven building typologies, for variants on envelope properties (Building Decree (BD) and Passive House (PH)), internal heat capacity (concrete/brick structure (heavy) and timber/CLT (light) building structure) and different glazing surface areas (100%, 125%). In Figure 5.2, three main observations are made. First, reducing the internal heat capacity has a clear effect on the WOHs for all seven typologies. The increase in WOHs remains below the threshold of 450 WOHs (except for the top apartment at 456 WOHs). Similar to the WOHs, an increase in TOJuly is observed. This increase results in TOJuly values above the threshold level for the semi-detached and detached dwelling, and the two apartments.

Increasing the thermal insulation properties (including the glazing properties and infiltration level) results in an increase for both WOHs and TOJuly for most building typologies. However, comparing the apartments with a CLT building structure, increasing the building envelope from Building Decree levels to Passive House levels, reduces the amount of WOHs and increases the TOJuly simultaneously. For the other dwellings, this observation is not present or is less strong.

When increasing the glazing surface area from 100% (e.g., base model design) to 125%, the observations made above still hold. Moreover, the relative differences become larger, as the increase in glazing surface area results in more WOHs and a higher TOJuly compared to the base model designs.

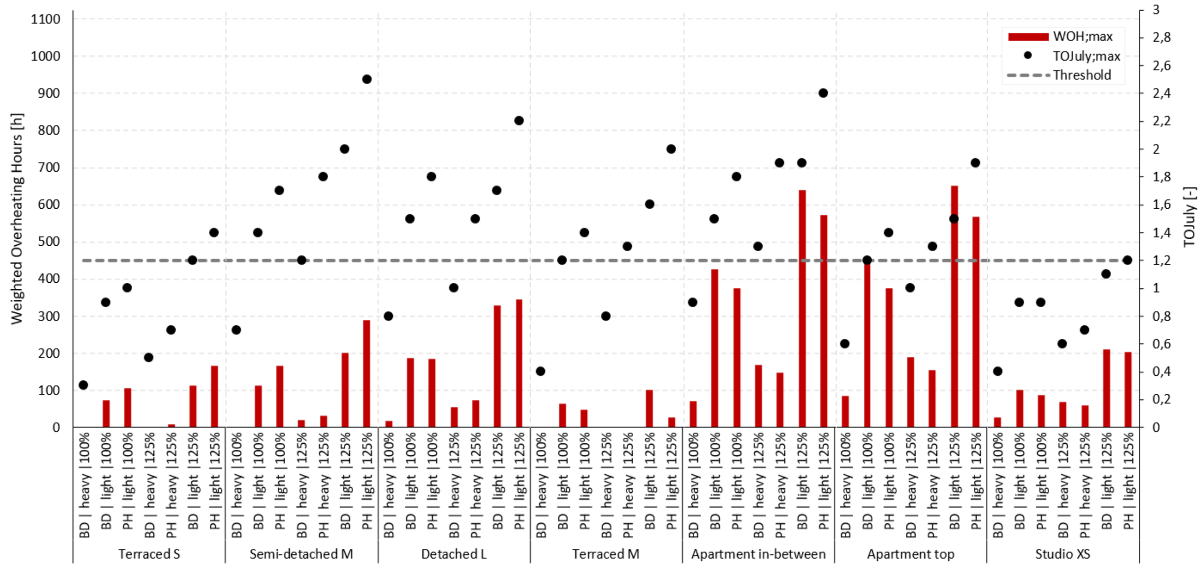

Figure 5.2: Effect of envelope properties and internal heat capacity on TOJuly and WOHs, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.1.3. Solar reductive measures

The effect of solar reductive measures is illustrated in Figure 5.3. The solar reductive measures include white and dark external shading devices, solar control glazing (g-value 0.3), and an overhang of 0.80m. For comparison, the results of the variants without solar reductive measures are integrated into the figure. As reducing the solar radiation through glazing is an effective measure in reducing the risk of overheating, some variants show 0 WOHs (white and dark external screens). For these variants, the $T_{i,max}$ ranges from 27.4 – 27.8°C.

For all typologies, implementing white or dark external shading screens reduces both TOJuly and WOHs to values below the threshold levels of 1.2 and 450 hours, respectively. For the dwellings and the studio, applying solar control glazing proves an effecting measure for lowering both WOHs and TOJuly. For the apartments, the variants with solar control glazing meet TOJuly but exceed the threshold of 450 WOHs by approximately 100 hours.

As was discussed in Section 4.2.1, the effect of an overhang is underestimated in the TOJuly method. The results in Figure 5.3 illustrate this statement, as the threshold for TOJuly is exceeded for all seven typologies, whereas the WOHs are exceeded for five of them.

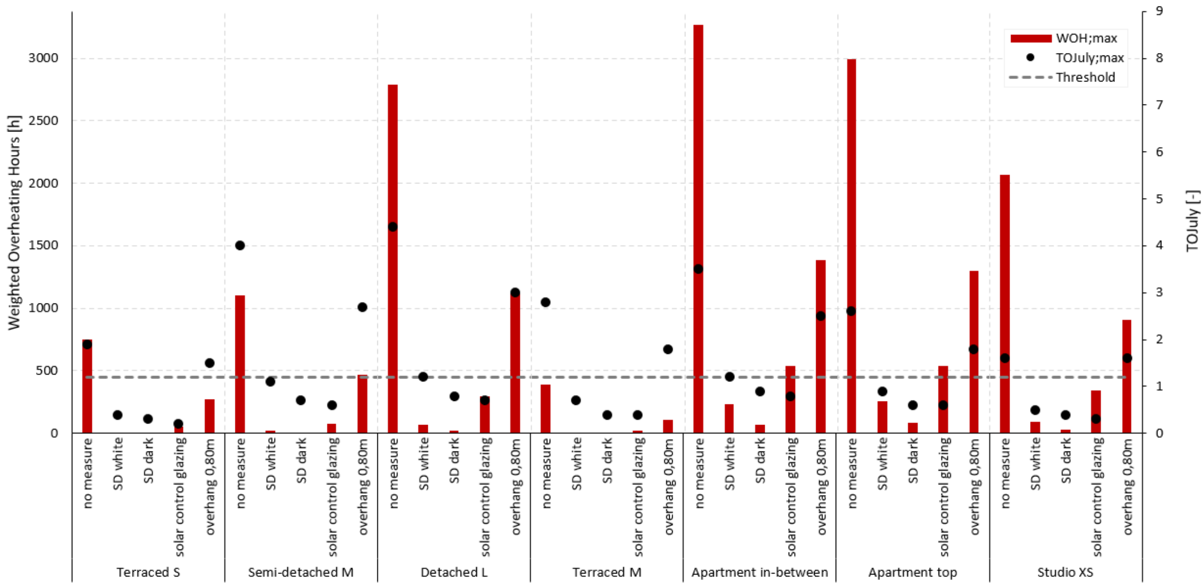

Figure 5.3: Effect solar reductive measures on TOJuly and WOHs, for seven building typologies.
The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.1.4. Summer night ventilation

The effect of summer night ventilation (SNV) on TOJuly and WOHs is presented in Figure 5.4. In this figure, the results of the following variants are visualized: no summer night ventilation with ventilation type D2, summer night ventilation (single, in living room) with ventilation types D2, C4c, or D5a, and summer night ventilation with ventilation type D2 in combination with solar control glazing (SCG g-value 0.3). For all typologies, the addition of a summer night ventilation system reduces both the TOJuly and WOHs. However, the combined effect with the ventilation type can diminish the positive effect on thermal comfort in the building variants. When combining summer night ventilation with an additional solar reducing measure, such as solar control glazing, the WOHs for all typologies get (well) below 450 hours. Moreover, the TOJuly threshold for those variants is met. Looking at the studio specifically, the addition of summer night ventilation proves a positive effect on meeting the TOJuly threshold of 1.2. However, the WOHs are 537 hours and higher for the variants with ventilation types D2, C4c, and D5a. Note that the effect of the summer night ventilation system depends on both the control type and the opening area of the modeled system. A larger opening area and activating the system during the day, instead of temperature-controlled night activation, may cause an additional beneficial effect on lowering the WOHs.

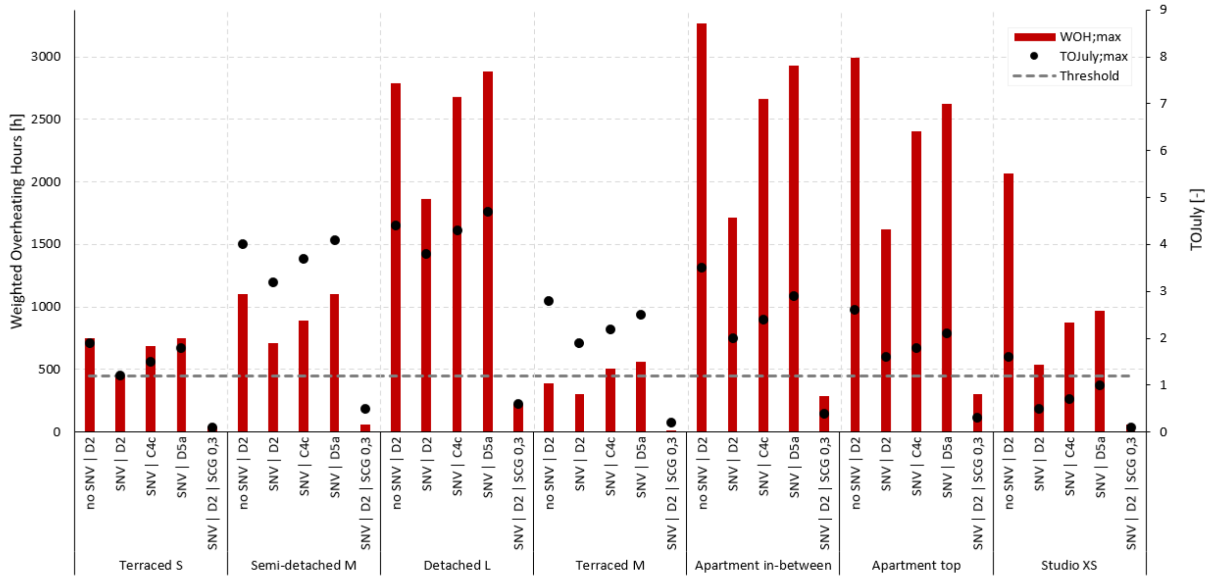

Figure 5.4: Effect of summer night ventilation on TOJuly and WOHs, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.1.5. Relation between TOJuly and WOHs

To quantify the assessment of the different variants, the four-quadrant method described in Section 3.7 is applied. In total, 58 variants for seven building typologies were researched. As not all variants resulted in a TOJuly, a set of 336 variants is distributed among the four quadrants. The results are summarized in Table 5.1 (in number of variants and percentage of 336). The first and fourth quadrants describe results that meet both TOJuly and WOH threshold and results that do not meet both TOJuly and WOH threshold, respectively (indicated with green). The second quadrant contains results for which the WOH threshold of 450 hours is met, but TOJuly exceeds 1.2 (indicated in orange). The third quadrant categorizes variants that meet TOJuly but exceed the WOH threshold (indicated in red). Table 5.2 presents the division among the quadrants, applying a margin of 10%. For the total set of variants within this category related to building characteristics, the TOJuly method in relation to WOHs functions as it has been designed (44.0% and 34.2%). Indicated by means of the second quadrant, 53 variants do not meet the TOJuly threshold, but the risk of overheating is determined to be within the limits based on the dynamic simulations. 6.0% of the variants are placed in the third quadrant, indicating that the TOJuly threshold is met, but the WOHs exceed the limit even though an additional margin is applied.

In Table 5.3, the results per quadrant are distributed among the building typologies. Generally, the risk for overheating in the terraced dwellings is smaller compared to the other two dwellings. Overall, the risk of overheating in the apartment between two floors is slightly higher compared to the top-floor apartment. This is both expressed in TOJuly values and WOHs (appendix III). The main cause for this differentiation between the two apartments, is the presence of the roof for the top floor apartment, allowing additional heat loss to occur. The difference in WOHs is generally marginal, whereas differences between TOJuly values are more evident between these two apartments. Moreover, exceptions among the variants are observed as well.

Table 5.1: Results classification of variants in quadrants (no margin)

42,6% 143	7,4% 25
14,9% 50	35,1% 118

Table 5.2: Results classification of variants in quadrants (margin 10%)

44,0% 148	6,0% 20
15,8% 53	34,2% 115

Table 5.3: Number of variants per quadrant, for the seven building typologies

	Number of variants per quadrant						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Q1	31	17	16	24	14	17	29
Q2	6	11	8	17	6	3	1
Q3	2	0	1	0	3	4	10
Q4	9	20	23	6	25	24	8

As the third quadrant is of the largest interest in this research, the variants within this quadrant are discussed in more detail. The 20 variants designs are listed in Table 5.4, indicating the building typology, variant composition, and KPI results. For 7 of the 20 variants in Table 5.4, the WOHs do not exceed 550 hours. Focusing on the variants with the largest deviation between the estimated risk for overheating for TOJuly and WOHs, the studio is the most prominent building typology, followed by the apartments. Moreover, 16 out of 20 variants include summer night ventilation. The largest deviation between TOJuly and WOHs is found for the studio with composition a.54 (CLT structure, Passive House envelope properties, summer night ventilation, and ventilation type C4c). The large deviation is explained by the added effect of differentiating assessments between the TOJuly method and WOHs, as was highlighted in Sections 5.1.2 – 5.1.4. In total, 10 of the 20 variants in the third quadrant are related to the studio, overrepresenting this building typology compared to the other building typologies.

Table 5.4: Variants in third quadrant (building typology, variant composition and KPIs), building characteristics variants

Building typology	**Variant composition**	**TOJuly**	**WOH**	**$T_{i,max}$ [°C]**
Apartment in-between	a.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|	0.8	540	30.8
Apartment top	a.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|	0.6	542	30.8
Studio	a.10 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|	0.7	1004	30.5
Studio	a.22 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|	0.7	707	30.1
Studio	a.25 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	0.5	735	30.5
Terraced small	a.27 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	1.1	548	30.6
Studio	a.27 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	0.5	883	30.7
Apartment in-between	a.42 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	1.2	1064	32.3

Apartment top	a.42 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	1.1	1021	32.3
Detached	a.43 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	0.9	520	31.7
Apartment in-between	a.43 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	0.6	511	30.8
Apartment top	a.43 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	0.5	504	30.8
Terraced small	a.44 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	1.2	829	32.6
Studio	a.44 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|	0.6	524	30.8
Apartment top	a.45 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|	1.0	692	31.2
Studio	a.47 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|	0.8	660	31.0
Studio	a.54 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|C4c|-|180W|	1.1	1370	31.8
Studio	a.55 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D5a|-|180W|	1.0	970	30.9
Studio	a.56 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D2|-|180W|	0.9	813	31.4
Studio	a.57 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|C4c|-|180W|	0.0	877	30.8

5.1.6. Summary observations related to building characteristics and building typologies

Based on the results discussed in Sections 5.1.1 – 5.1.5, the following observations were made:

- The highest TOJuly value is generally reported for the South-West orientation, whereas the highest number of WOHs is found for the South-East orientation.
- Reducing the internal heat capacity results in a higher risk for overheating, both in TOJuly and WOHs. For specific typologies, this may result in exceeding the TOJuly threshold, without exceeding the WOHs threshold.
- For the apartments, increasing the building envelope from Building Decree levels to Passive House levels reduces the amount of WOHs and increases the TOJuly simultaneously.
- Solar radiation measures, limiting the solar radiation through windows, are effective in lowering both TOJuly and WOHs. This does not hold for the application of an overhang, for which the effect on TOJuly is underestimated.
- The addition of a summer night ventilation system reduces both the TOJuly and WOHs. However, this measure indicates a more positive effect on TOJuly compared to WOHs.
- Based on the results of all variants related to building characteristics, 6.0% is placed in the third quadrant. For these variants, the TOJuly threshold is met, but the WOHs exceed the limit. Within this 6.0%, half of the variants relate to the studio and 80% includes summer night ventilation.
- Among the dwellings, the risk for overheating in the terraced houses is smaller compared to the semi-detached and detached dwelling.
- Generally, the risk of overheating in the top-floor apartment is slightly lower compared to the risk for the apartment between two floors.

5.2. Occupant behavior

In upcoming sections, the results related to the variants on occupant behavior are discussed. In contrast to the results in Section 5.1, the main focus will be on the determined WOHs. Two main categories of variants are researched in Sections 5.2.1 and 5.2.2: internal heat load, and purge ventilation. Additionally, the effect of increasing the solar setpoint for the external shading devices is presented in Section 5.2.3. Although the NTA 8800 method was used to determine the TOJuly values, an important remark is made in relation to the results in upcoming sections. In contrast to Sections 5.1, the TOJuly method has been adapted to allow calculations with different internal heat loads. According to NTA 8800, the internal heat load is set to 180 Watts per person, a constant value (NEN, 2020). In Section 5.2.1, this constant value is adapted to 120 W and 240 W, no longer following the NTA 8800 guidelines. The complete set of results related to the 57 variants on occupant behavior are presented in Appendix IV.

5.2.1. Internal heat load

The effect of the internal heat load is discussed in three parts. First, the effect is discussed per orientation, followed by discussing the effect of increased and decreased internal heat load in combination with building envelope properties. In the third part, the effect of the internal heat load is discussed in relation to the addition of a summer night ventilation system.

Figure 5.5 presents the TOJuly values and the WOHs for the small terraced dwelling and the apartment in-between two floors, in relation to internal heat load for different orientations. For both the dwelling and the apartment, reducing the internal heat load from 180 W per person to 120 W per person shows a clear effect on the KPIs in the figure. The amount of WOHs for the dwelling is reduced from 2 - 9 WOHs to 0 WOHs for all orientations. The $T_{i,max}$ is reduced from 28.1 – 28.3°C to 27.3 – 27.6°C for the four orientations. Similar to the dwelling, the WOHs for the apartment are reduced if the internal heat load is lowered to 120 W per person. In both cases, the threshold of 450 WOHs is not exceeded. If the internal heat load is increased to 240 W per person, a clear increase in WOHs is present in Figure 5.6. For the apartment, this increase results in a minimum of 546 WOHs, exceeding the threshold for thermal comfort. Similar to Figure 5.1 in Section 5.1.1, differences between orientations are observed.

If the TOJuly is determined for the increased and decreased internal heat loads, the following observations can be made. Similar to the WOHs, the internal heat load affects the TOJuly values. In relation to the dwellings, an internal heat load of 240 W results in a TOJuly exceeding 1.2, whereas the WOHs remain below 450 hours. For the two apartments and the studio, both TOJuly and WOHs exceed the threshold levels for thermal comfort if the internal heat load is set to 240 W per person.

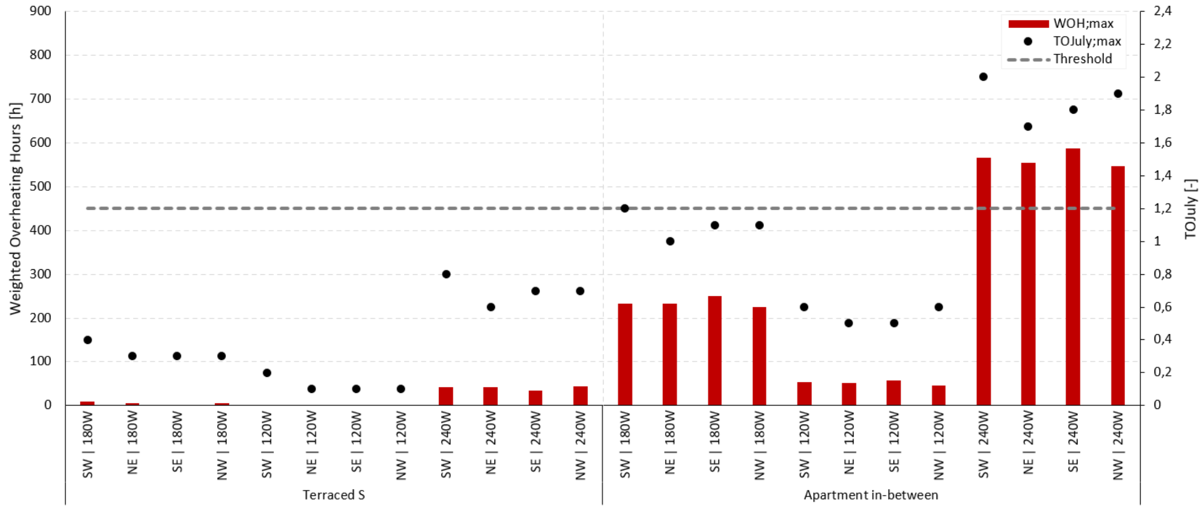

Figure 5.5: Effect of internal heat load on TOJuly and WOHs, for small terraced dwelling and apartment in-between two floors. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

The effect of differentiating the internal heat load in relation to building envelope properties is illustrated in Figure 5.6. As was mentioned in Section 5.1.2, the effect of the envelope properties may result in different assessments for the risk of overheating depending on the method used (e.g., NTA 8800 versus WOHs). Similar to the previous paragraph, a clear effect is observed when decreasing and increasing the internal heat load. Moreover, for timber and CLT (light) structures with Passive House (PH) properties, increasing the internal heat load to 240 W per person can cause WOHs above 450 hours. When looking at the TOJuly values in relation to WOHs, the added effect of the impact of the building envelope properties and internal heat load results in a mismatch between the assessment of the risk of overheating. This observation holds for the semi-detached and detached dwelling, as well as the two apartments. Note that for determining the TOJuly values in Figure 5.6, the NTA 8800 method has been adapted to accommodate the differentiation in internal heat load.

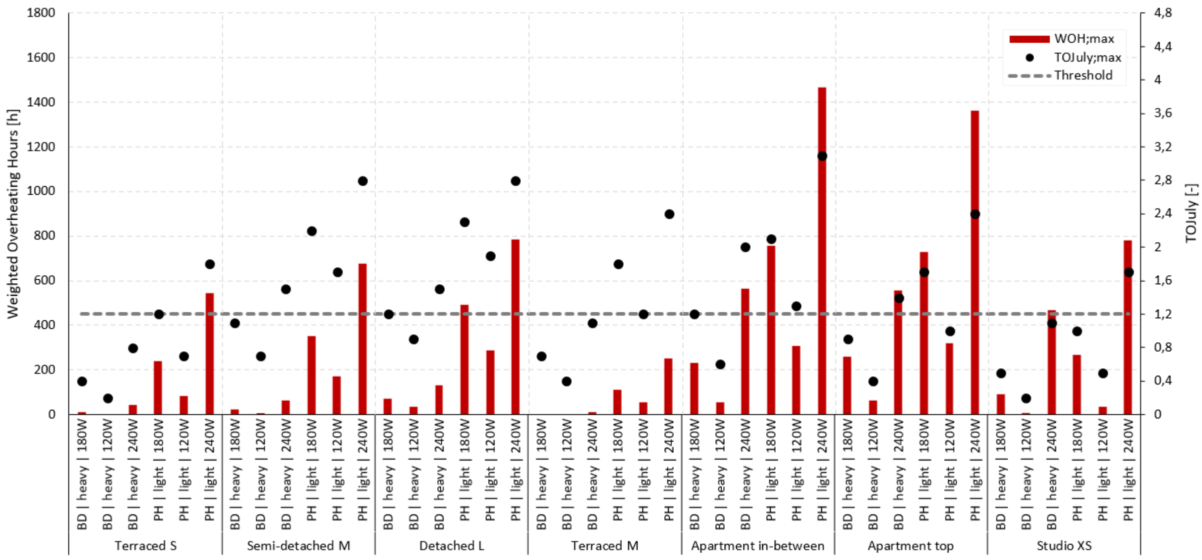

Figure 5.6: Effect of internal heat load and envelope properties on TOJuly and WOHs, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

Figure 5.7 presents the effect of removing the external shading devices and integrating summer night ventilation. For the variants where summer night ventilation is included and the internal heat load is set to 180 W per person, the overall amount of WOHs is high. Except for the medium terraced dwelling, all typologies exceed the 450 WOHs threshold. If the internal heat load is lowered to 120 W per person, the amount of WOHs is reduced and for several typologies the threshold is no longer exceeded. On the other hand, an internal heat load of 240 W per person drastically decreases thermal comfort levels. Again, observations made earlier in relation to summer night ventilation need to be taken into account in the results related to this section.

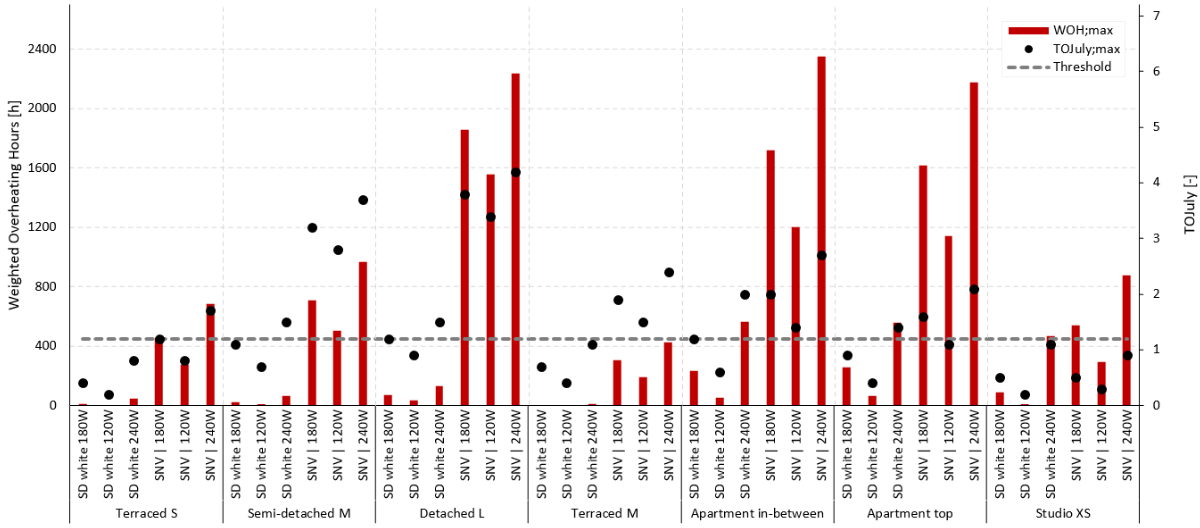

Figure 5.7: Effect of internal heat load and summer night ventilation on TOJuly and WOHs, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.2.2. Purge ventilation

A second variant category devoted to occupant behavior was designed by means of reducing the timeframe and rate of purge ventilation. All results discussed above include 4 hours of purge ventilation at a rate of 6 $dm^3/s.m^2$. The purge ventilation is applied between 7 A.M. and 8 A.M. and 8 P.M. and 11 P.M. if the indoor air temperature exceeds 24°C and the outdoor air temperature exceeds 13°C. In Figure 5.8, the effect of reducing the time for which purge ventilation is applied to 2 hours. For all typologies, reducing the timeframe for purge ventilation results in a (small) increase in WOHs. For the dwellings, the impact of reduced purge ventilation is small, as the amount of WOHs was already limited. The largest increase in WOHs can be found in the studio. Additionally, this studio is more sensitive to internal heat load in combination with reduced purge ventilation. This is caused by the relatively high internal heat load per m2 in comparison to the other typologies. Moreover, the temperature restrictions for purge ventilation result in an increased positive effect for purge ventilation if more WOHs are reported.

The reduced purge ventilation in the dynamic simulations still meets the guidelines in the Building Decree for determining the risk of overheating. In the Building Decree, only a maximum rate for purge ventilation rate and time is given (BZK, 2020).

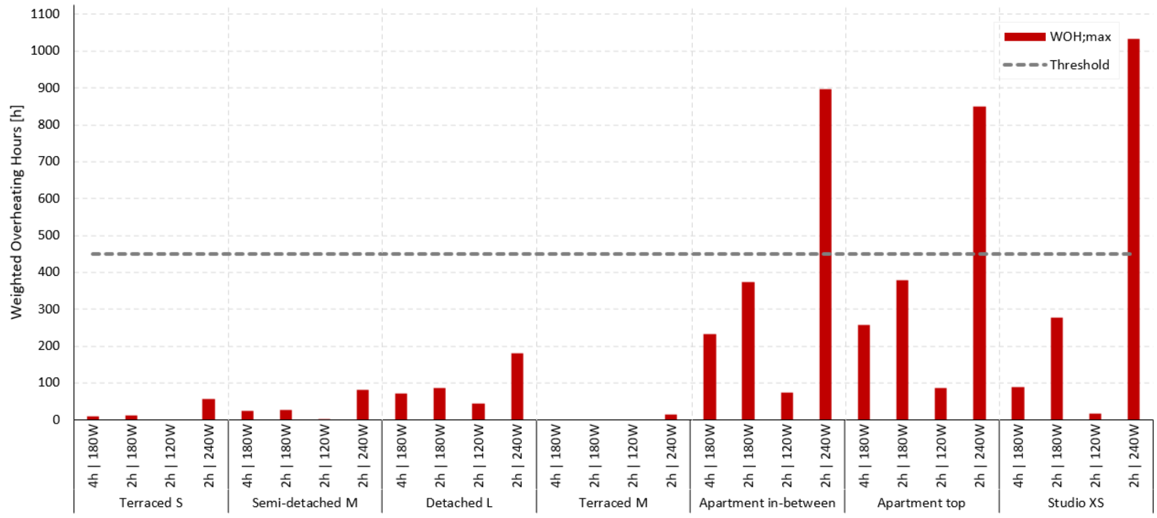

Figure 5.8: Effect of purge ventilation and internal heat load on WOHs, for seven building typologies. The horizontal dotted line indicates the threshold of 450 WOHs

5.2.3. Solar setpoint external shading device

Besides the white and black external shading devices discussed in Section 5.1.3., an additional variant was designed. The shading screens presented in Section 5.1.3. are modeled with a solar setpoint of 150 W/m^2 in the dynamic simulations. The additional variant was designed based on a solar setpoint of 300 W/m^2, for dark external screens. As the solar setpoint is specifically modeled in EnergyPlus, only WOHs are determined for this variant. Figure 5.4 illustrates the results by comparing the dark external shading devices (SD) with 150 and 300 W/m^2. The results indicate that reducing the strictness of the solar setpoint (e.g., activation at higher solar radiation), increases the WOHs in almost all typologies. For the medium terraced house, no difference in WOHs is illustrated as the WOHs remain zero. Nonetheless, the maximum indoor temperature decreases from 27.9°C to 27.8°C.

Figure 5.4 contains the effect of reducing the solar setpoint for timber and CLT frame building structures as well. Between these two variants for the seven typologies, a similar relation is observed as for the heavyweight structures: a setpoint of 300 W/m^2 introduces more WOHs compared to a setpoint of 150 W/m^2. Looking at the apartments, the effects of the solar setpoint are the largest. For these typologies, reducing the solar setpoint results in 1024 and 1016 WOHs for the apartment between two floors and the apartment on the top floor, respectively. Therefore, reducing the solar setpoint may result in exceeding the WOH threshold of 450 hours, depending on the building design.

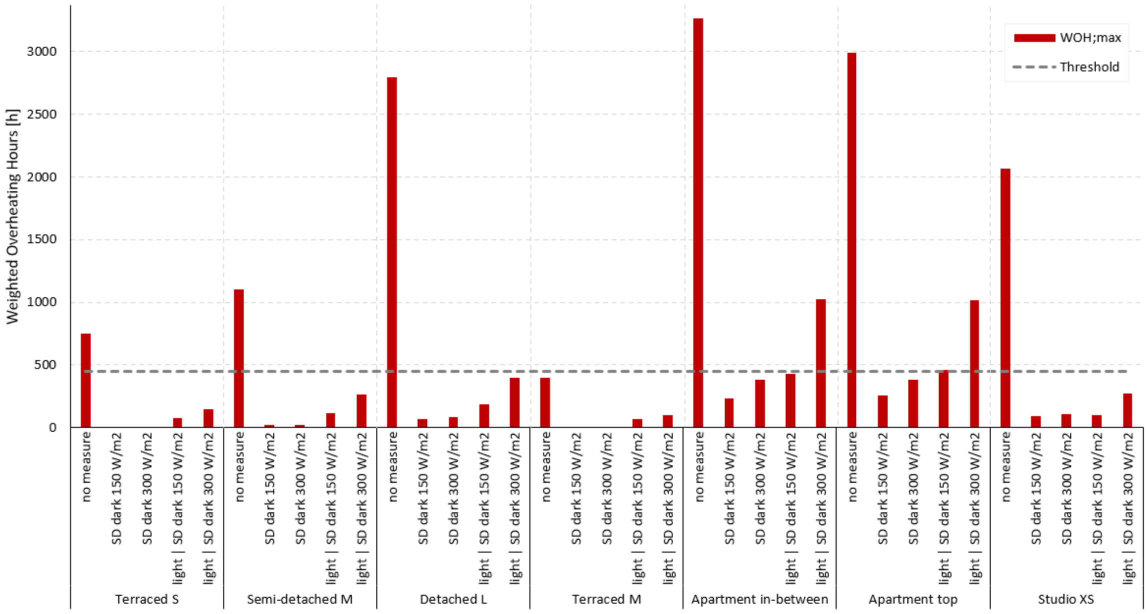

Figure 5.4: Effect solar setpoint for external shading device on WOHs, for seven building typologies. The horizontal dotted line indicates the threshold of 450 WOHs

5.2.3. Relation between TOJuly and WOHs

Similar to Section 5.1.5, the relation between TOJuly and WOHs is discussed by means of the four-quadrant method. Again, it must be noted that the TOJuly values determined in relation to the variants on internal heat load deviate from the method in NTA 8800. The parameter for internal heat load is set to 180 W per person, whereas internal heat load of 120 W and 240 W per person have been studied.

In Tables 5.5 and 5.6, 231 variants related to the different internal heat loads have been classified into the four quadrants (with and without a margin of 10%). Again, the first and fourth quadrants describe results that meet both TOJuly and WOH threshold and results that do not meet both TOJuly and WOH threshold, respectively (indicated with green). The second quadrant contains results for which the WOH threshold of 450 hours is met, but TOJuly exceeds 1.2 (indicated in orange). The third quadrant categorizes variants that meet TOJuly but exceed the WOH threshold (indicated in red). Overall, the division among the quadrants is relatively similar to Tables 5.1 and 5.2, even though the NTA 8800 method was adapted. Moreover, the distribution of typologies in the four quadrants shows more similarities with Table 5.4 than was expected (Table 5.7).

Table 5.5: Results classification of variants in quadrants (no margin)

51,1% 118	4,3% 10
14,7% 34	29,9% 69

Table 5.6: Results classification of variants in quadrants (margin 10%)

52,4% 121	3,0% 7
15,6% 36	29,0% 67

Table 5.7: Number of variants per quadrant, for the seven building typologies

	Number of variants per quadrant						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Q1	26	14	13	20	12	14	22
Q2	2	11	10	11	2	0	0
Q3	0	0	0	0	0	4	3
Q4	5	8	10	2	19	15	8

7 of the 231 variants are reported in the third zone, indicating a mismatch between the TOJuly values and determined WOHs. These variants relate to either the apartment on the top floor and the studio. The largest deviation in the assessment for the risk of overheating is found when summer night ventilation is applied in the studio and apartment, in combination with an internal heat load of 240 W per person.

Although the TOJuly values calculated in this section did not follow the guidelines in the NTA 8800 method, the results in Tables 5.6 and 5.8 indicate that no fundamental differences were found in comparison to the results in Section 5.1. Differences in the assessment for the risk of overheating according to the two methods (e.g., calculating TOJuly and determining WOHs) that have been observed in Section 5.1 are further enlarged if the internal heat load is increased. However, the introduction of new observed mismatches between the two methods in relation to the internal heat load is limited.

Table 5.8: Variants in third quadrant (building typology, variant composition and KPIs), occupant behavior variants

Building typology	**Variant composition**	**TOJuly**	**WOH**	**$T_{i,max}$ [°C]**
Apartment top	b.14 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	1.2	547	30.4
Apartment top	b.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|	1.1	575	30.2
Studio	b.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|	0.8	508	29.5
Apartment top	b.32 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|120W|	1.2	666	31.2
Studio	b.52 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	0.5	537	30.5
Apartment top	b.53 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|120W|	1.1	1140	32.1
Studio	b.54 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|240W|	0.9	876	31.2

5.2.4. Summary observations related to occupant behavior

In Sections 5.2.1 – 5.2.3 several observations were made relating to the effect of occupant behavior on estimating the risk of overheating in residential buildings. A summary of these observations is presented below:

- Differentiating in internal heat load may result in exceeding the threshold level for WOHs. All building typologies are sensitive to decreased and increased internal heat load and the largest relative changes are reported for the studio.

- Calculation of the TOJuly values related to differentiated internal heat loads does not result in major differences in the distribution among the four quadrants when compared to the distribution among quadrants for variants related to building characteristics.
- Reducing the strictness of the solar setpoint (e.g., 150 W/m^2 to 300 W/m^2), results in more WOHs. For some variants, this results in exceeding the WOH threshold of 450 hours.
- Purge ventilation may affect the amount of WOHs, but the impact of this parameter is less strong compared to internal heat load.

5.3. Future climate

The effect of expected increased temperature due to global warming in relation to the risk of overheating is researched by calculating and simulating with a more extreme climate file (e.g., NEN 5060 1%). In Section 3.4.1, the NEN 5060 1% climate file air temperatures were compared with KNMI future climate scenarios. In this section, the results of the assessment for the risk of overheating using the NEN 5060 1% weather data are presented and discussed. For an overview of the complete set of results, please refer to Appendix V.

First, the overall effect of determining the risk of overheating using the NEN 5060 1% weather data is discussed in relation to TOJuly and WOHs. This is followed by a discussion of the effectiveness of overheating reducing measures in the future climate.

Similar to Section 5.2, the NTA 8800 method is adapted to accommodate the use of the NEN 5060 1% climate. Therefore, the calculated TOJuly values do not adhere to the method as it was designed. Additionally, the guidelines for performing dynamic simulations prescribe the use of the NEN 5060 5% climate data, whereas NEN 5060 1% climate data is used for generating the results presented in this section.

5.3.1. Relation TOJuly and WOHs for the future climate

The climate data in the variants related to building characteristics and occupant behavior (58 and 57 variants, respectively) have been adapted to the NEN 5060 1% climate file. As a result, the overall risk of overheating has increased. A warmer climate with more extreme temperatures increased the amount of WOHs drastically. Tables 5.9 and 5.10 present the distribution of the 567 variants (336 related to building characteristics, 231 related to occupant behavior) in the four quadrants, with and without a margin of 10%. The first and fourth quadrants describe results that meet both TOJuly and WOH threshold and results that do not meet both TOJuly and WOH threshold, respectively (indicated with green). The second quadrant contains results for which the WOH threshold of 450 hours is met, but TOJuly exceeds 1.2 (indicated in orange). The third quadrant categorizes variants that meet TOJuly but exceed the WOH threshold (indicated in red). In Tables 5.9 and 5.10, the share of variants that exceed both the TOJuly and WOHs thresholds is the largest, which is in line with the statement that the overall risk of overheating has increased. 369 of the 567 variants exceed a TOJuly value of 1.2 and exceed 450 WOHs. The 22 variants in the third quadrant include 12 variants in which summer night ventilation was applied, or summer night ventilation in combination with the Passive House envelope properties with a low internal heat capacity. Similar to Sections 5.1.4 and 5.2.3, these 12 variants belong to the apartments and studio. Observations made with regard to orientation, envelope properties, and internal heat capacity in the previous sections also hold for the results in this section, although relative differences have increased with the variant categories.

Table 5.9: Results classification of variants in quadrants (no margin)

9,9% 56	4,4% 25
20,6% 117	65,1% 369

Table 5.10: Results classification of variants in quadrants (margin 10%)

10,4% 59	3,9% 22
22,0% 125	63,7% 361

In Table 5.11, the number of variants per quadrant is specified per building typology. For the two apartments, a large majority does not meet the TOJuly and WOHs threshold levels, even though solar reductive measures, summer night ventilation of adapted occupant behavior were included. Moreover, the only variants for which the WOHs threshold of 450 hours is met, include an internal heat load of 120W. All other variants for the apartments exceed this threshold.

Table 5.11: Number of variants per quadrant, for the seven building typologies

	Number of variants per quadrant						
	Terraced small	Semi-detached	Detached	Terraced medium	Apartment in-between	Apartment top	Studio
Q1	25	1	0	12	1	3	17
Q2	19	34	25	41	4	1	1
Q3	1	0	2	0	1	4	14
Q4	36	46	54	28	75	73	49

5.3.2. Effectiveness overheating reducing measures in future climate

Figure 5.10 presents a comparison of three overheating reducing measures using different weather data. The overheating reducing measures included in the graph are dark external shading screens, with a solar setpoint of 150 W/m^2, solar control glazing with a g-value of 0.3, and summer night ventilation. Based on the results in Figure 5.10, it is concluded that meeting the thermal comfort threshold levels in the future climate scenario becomes more challenging for all building typologies. The most effective measures for dwellings include the external shading device and solar control glazing, as the amount of WOHs for these variants remains below 450 WOHs (except for the detached house). For the studio, solar control glazing in the future climate scenario in itself will no longer be sufficient.

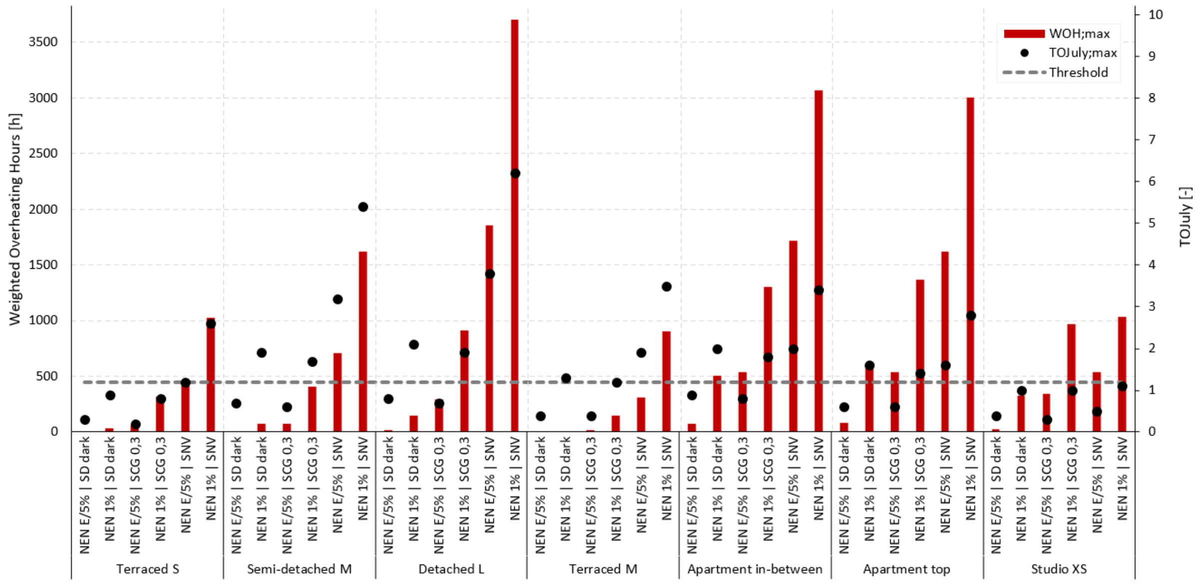

Figure 5.10: Effect overheating reductive measures on TOJuly and WOHs, for future climate, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

In Figure 5.11, the effect of internal heat load for the different climate scenarios is illustrated. The variants in the figure include a dark external shading screen. For the future climate variants, the internal heat load has a large impact on both WOHs and TOJuly. However, the relation between TOJuly and WOHs is less strong for the NEN 5060 1% variants. This observation is mostly related to the dwellings. For the dwellings, the threshold for WOHs is met, whereas TOJuly indicates values above 1.2. Referring to the four quadrants, this would place them in the second (orange) quartile and the TOJuly method underestimates the effect of occupant behavior for these variants. Note that both the climate file and the internal heat load have been adapted in the original method.

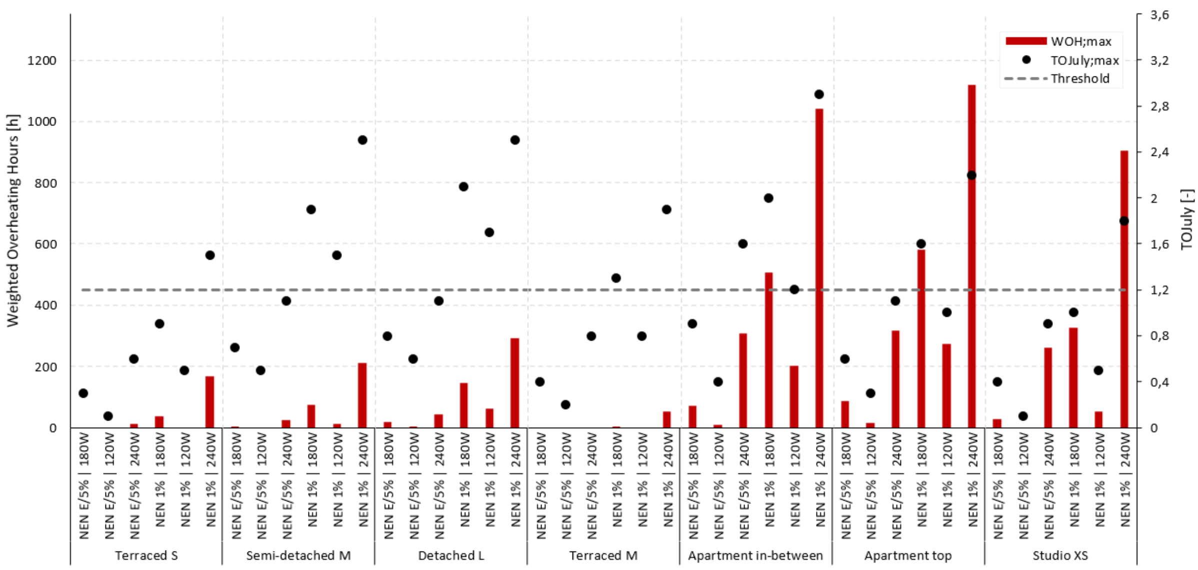

Figure 5.11: Effect of internal heat load on TOJuly and WOHs, for future climate, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

In general, it is observed that the risk for overheating using warmer and more extreme climate data is higher. The effect of this climate data in combination with different building envelope properties is presented in Figure 5.12. Variants with a high internal heat capacity and a low internal heat capacity (e.g., timber frame structure and CLT-based design), and different envelope properties (according to current Building Decree (BD) and Passive House (PH) standards) are included in the graph. For all typologies, the highest WOHs and TOJuly values are generated for designs with a low internal heat capacity. For the apartments, the passive house building envelope reduces the amount of WOHs whereas the TOJuly values increase. Nonetheless, thermal comfort levels are exceeded.

In relation to current and predicted building trends, more timber and/or CLT-based buildings are expected to be built. As can be seen, this introduces a higher risk for overheating for all building typologies. In a future climate, this can result in exceeding the thermal comfort levels of 450 WOHs.

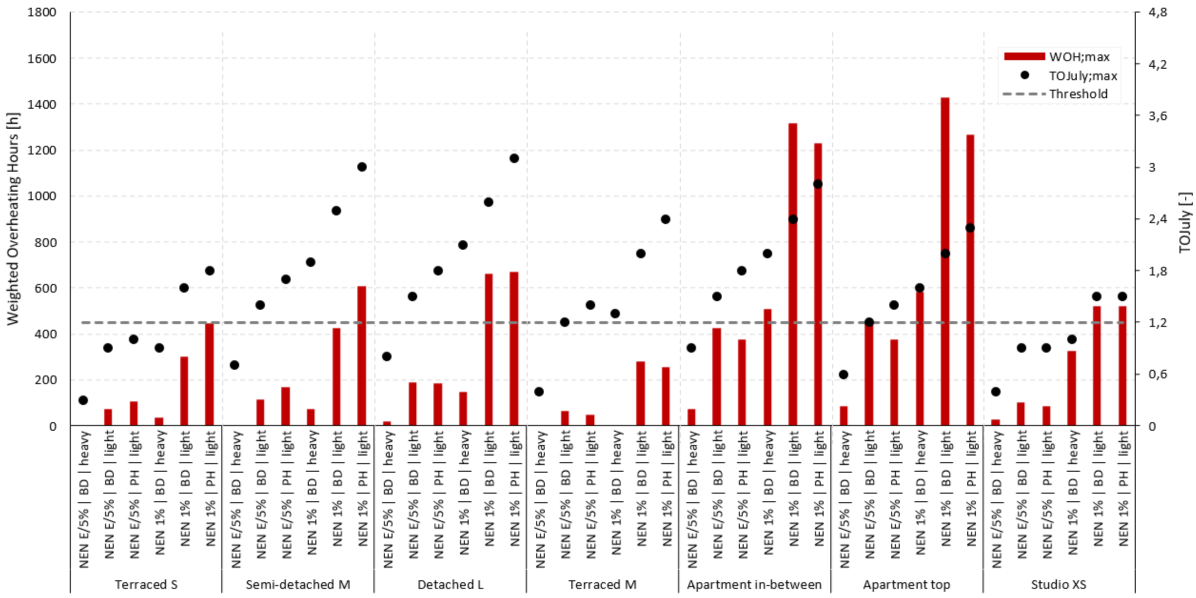

Figure 5.12: Effect of envelope properties and internal heat capacity on TOJuly and WOHs, for future climate, for seven building typologies. The horizontal dotted line indicates the thresholds of 450 WOHs and TOJuly 1,2

5.3.3. Summary observations related to future climate

The observations made with regard to the future climate in Sections 5.3.1 – 5.3.3 are summarized below. The main observations include:

- The future climate introduces a higher risk for overheating according to the determined WOHs. When calculating TOJuly values, this higher risk is present in the results as well.
- The increase in maximum indoor air temperature in the future climate scenario compared to the prescribed climate scenario was limited to approximately 1°C or less across all variants.
- 3.9% of the variants for which both TOJuly and WOHs were determined are categorized in the third quadrant, of which 54% belong to the apartments and studio.
- Overheating reductive measures will not suffice individually in the future climate for the apartments, for the variants in this research.
- Envelope properties may have both a positive and negative effect on the amount of WOHs. However, the observed positive effect is not able to provide a thermally comfortable design.
- A lower internal heat capacity can result in exceeding the WOH threshold of 450 hours in a future climate whereas the climate data prescribed for determining the WOHs results in WOHs below the threshold level.

6. Evaluation of the TOJuly indicator

The TOJuly indicator expresses the risk of overheating, without the need for detailed dynamic simulations (e.g. to determine the Weighted Overheating Hours). In the introduction, a set of research questions was established related to the evaluation of the TOJuly method. The objective of this research is to examine the robustness of the TOJuly indicator, by means of comparative analysis with dynamically simulated WOHs. The research questions will be reviewed in Section 6.1. Followed by a discussion of the limitations of this study in Section 6.2. In Section 6.3, recommendations towards (possible) improvements for the TOJuly method are discussed.

6.1. Review of the main and secondary research questions

In order to provide an answer to the main research question, the secondary research questions will be answered consecutively. The first research questions read as follows:

How are different building typologies and building characteristics assessed according to the TOJuly-method?

To provide an answer to this question, a set of 58 variants for seven building typologies was studied. For these variants, the TOJuly indicator and the amount of WOHs were determined. Using the four-quadrant method, the results are categorized in relation to the assessment of the risk of overheating. Based on this categorization, 263 variants of the 336 variants in total (78.2%) result in a TOJuly value for which the WOHs provided a similar indication for the risk of overheating. For 148 variants (44.0%), the risk of overheating is regarded as acceptable. For 115 variants (34.2%) the risk of overheating is too large according to both the TOJuly indicator and the determined WOHs, as the threshold levels (1,2 and 450 hours, respectively) are exceeded. The risk of overheating is overestimated for 15.8% of the variants related to this variant category (53 variant designs), compared to the determined WOHs. Within these 53 variants, the dwellings are more occurring compared to the apartments and studio. The TOJuly value underestimated the risk of overheating for 6.0% of the variants (20 variant designs), compared to the assessment of the risk based on the results of the dynamic simulations. 50% of the variants in this category are related to the studio.

The highest level of cohesion between TOJuly and WOHs is found for the dwellings, among which the small terraced dwelling shows most variants for which the TOJuly value indicated a similar risk assessment compared to the WOHs threshold. The lowest level of cohesion between the two KPIs is found for the studio.

The assessment of building characteristics according to the TOJuly-method deviates from the determined WOHs for the following parameters: overhang, solar absorption coefficient of materials, orientation, internal heat load, building envelope properties, and summer night ventilation. However, the level of deviation is not similarly significant for all these parameters. The largest mismatch in the assessment based on TOJuly and WOHs is found for the overhang. This is caused by the generalization embedded in the NTA 8800 method and how the effect of an overhang is calculated and categorized, resulting in an underestimated effect on reducing the risk of overheating in TOJuly. For specific typologies, a reduced internal heat capacity (e.g., timber frame or CLT building structure) the threshold for WOHs is complied with whereas the TOJuly threshold is not met. Additionally, a Passive House envelope design reduced the amount of WOHs for apartments while a higher TOJuly was reported. For variants outfitted with a summer night ventilation system, a positive effect on the risk of overheating in both WOHs and TOJuly is observed. However, this positive effect is generally larger in the TOJuly method. For the remaining variants and building characteristic parameters in this research, less significant to no significant differences in the assessment of TOJuly compared to WOHs are reported.

What is the effect of occupant behavior on TOJuly?

Using the similar setup discussed for the previous research question, the effect of occupant behavior on TOJuly was evaluated. Related to this question, a set of 57 variants was designed for the seven building typologies, focusing on internal heat load and purge ventilation. Based on the results of this study, it can be concluded that both the internal heat load and purge ventilation have a significant effect on the amount of WOHs in all building typologies, and therefore may impact the risk of overheating. However, the parameters related to occupant behavior are fixed constants in the NTA 8800, in which the TOJuly method is embedded.

Among all seven typologies in this research, the studio indicates the largest relative changes in relation to internal heat load. To evaluate the effect of internal heat capacity on TOJuly, the methodology behind the calculation was adapted to allow changing the internal heat load from 180 W to 120 W and 240 W per person. Similar to the dynamic simulation, the TOJuly is sensitive to changing the internal heat load. However, the level of sensitivity is not researched in this study. In relation to occupant behavior, the effect of purge ventilation is reported for dynamically determined WOHs. Results imply that the impact of this parameter on the risk of overheating is existent, but smaller compared to the adapted internal heat load. Moreover, building characteristics have a larger contribution towards affecting the risk of overheating compared to occupant behavior.

What is the effect of using different climate scenarios in the TOJuly-method, focusing on future climate change?

Similar to the occupant behavior, the NTA 8800 methodology is adapted to allow generation of results related to this research question. In the NTA 8800, the NEN 5060 Energy climate data is used for determining TOJuly. The weather data is adapted to the NEN 5060 1% climate data to allow calculation of TOJuly for the future climate scenario. Furthermore, the guidelines for performing dynamic simulations for determining the WOHs were no longer followed. Again, this is a result of calculating with different climate data: NEN 5060 1% instead of NEN 5060 5%. Overall, it can be concluded that the future climate scenario introduces a substantially higher risk for overheating in the residential building stock. Furthermore, the increase in maximum indoor air temperature in the future climate scenario compared to the prescribed climate scenario was limited to approximately 1°C or less across all variants.

When the TOJuly is determined based on the future climate scenario, a higher risk is present as well, implicated by the number of variants exceeding the threshold level. In total, both TOJuly and WOHs are determined for 567 variants. 63.7% of these variants exceeded the threshold for WOHs and TOJuly and 10.4% of the variants met both threshold levels. Due to this low amount of variants with an acceptable risk for overheating in this part of the research, it is not possible to determine if a threshold of 1.2 for TOJuly remains reasonable when quantifying the risk of overheating.

3.9% of the variants (22 variant designs) for which both TOJuly and WOHs are determined, report a TOJuly that meets the threshold but a sum of WOHs that exceeds the threshold. Similar to the building characteristics evaluation, a majority of these variants relate to the studio.

In relation to the risk of overheating in a broader perspective, none of the variants (in this study) for apartments met the thermal comfort level threshold of 450 WOHs, even though overheating reductive measures were applied. Additionally, the amount of WOHs determined for a lower internal heat capacity may exceed the limit of 450 WOHs in a future climate scenario, whereas this threshold is not exceeded in the prescribed climate scenario for dynamic simulations.

The main research question in this research was:

How robust is the TOJuly indicator in relation to various building typologies of the Dutch residential building stock, occupant behavior, and climate change?

To classify the robustness of the TOJuly indicator, the four-quadrant method (Table 3.6) was deployed. One of these quadrants is used to determine the robustness of the TOJuly indicator. This quadrant relates to TOJuly values meeting the threshold of 1.2, whereas the maximum of 450 WOHs is exceeded. For results in this quadrant, the TOJuly indicates a false positive assessment of the risk of overheating. Additionally, a margin of 10% was used to accommodate small deviations from the threshold levels, which are present in the derived data. To give an indication for a direction of a probable threshold, a percentage of 5% was defined to be allowed this false-positive assessment quadrant. It can be concluded that, given the assumptions and simplifications in the method for TOJuly, the TOJuly indicator is a fairly robust indicator for determining the risk of overheating in residential buildings. Nonetheless, 6.0% of the variants in the building characteristics category are found in results in a false-positive assessment class. Within the different building categories, the highest level of cohesion between the assessment for the risk of overheating is attributed to the small terraced dwelling. Compared to the dwellings in general, the robustness of the apartments is lower. The least robust variants relate to the studio. Among the building characteristics, the effect of an overhang is the most underestimated parameter in TOJuly.

6.2. Limitations

During the execution of this research, several limitations were encountered that may have an effect on the results.

- First, the quantification of robustness does not rely on a predetermined scale or threshold. In this research, an indication of a threshold for the percentage of false-positive risk assessments was set to 5%. However, there is no information available on which percentage was allowed during the design of the TOJuly indicator before it was employed in practice. A certain level of mismatch and uncertainty must always be taken into account, due to the difference in methods for determining TOJuly and WOHs. Therefore the indicative threshold of 5% was established.
- The dynamic simulations used to determine the WOHs have not been validated by means of measurement data. Additionally, some input parameters for the models are not based on measurement data, nor have a direct scientific background, such as the differentiated internal heat loads.
- In order to perform the dynamic simulations, the houses are divided into multiple zones. For the division of zones, the guidelines in the Dutch Building Decree were applied. As no floorplans for the reference dwellings were available, the minimum requirements for the zones were followed. The division of zones based on actual rooms may impact the results for the KPIs.
- The climate data for the future climate scenario is not based on future climate weather predictions but on NEN 5060 1% which is composed of past weather data. As a result, the weather data used for the future climate may not be representative of current future climate predictions.
- No sensitivity analysis has been executed in this research. It is assumed that the resulting WOHs and TOJuly values are fixed values. However, they should come with a level of uncertainty. For different variants, this may have resulted in deviated categorization of results.

- The selection of parameters for the variants was limited to reduce the number of possible variants. As a consequence, variants that have not been included in this research may have provided a different perspective towards the results and conclusion.
- The risk of overheating is not merely affected by the building or occupants themselves. Additional attributes, such as the Urban Heat Island effect may affect the results (Hwang et al., 2020). The buildings in this research were modeled without surrounding buildings or structures.
- In relation to a broader perspective of the impacts of measures, it can be argued that the simulation period should have been extended to a complete year. The effect of measures on the heating demand is not taken into account. However, the design of a dwelling and implementation of overheating reducing measures may result in a negative or positive effect on the heating demand in winter months.
- No comparison of the TOJuly method in relation to other quantification methods for the risk of overheating was performed. This could have resulted in improved insights for the risk of overheating in general, and coping with design flaws of the TOJuly method.

6.3. Recommendations towards TOJuly

Based on the results presented in Sections 4 and 5, and the conclusions discussed in Sections 6, a set of recommendations for improvement of the TOJuly method is made. These improvements focus on changes related to the TOJuly methodology (e.g., NTA 8800) and suggestions for additional research directly related to TOJuly.

As was discussed in Section 4.2.1, the effect of an overhang is underestimated in relation to the risk of overheating. In the current NTA 8800 methodology (e.g., NTA 8800 A1 2020), an overhang is categorized based on the relative height of the overhang. Based on this relative height the overhang is allocated to one of the three classes for the ‘shade-reduction factors’ (in Dutch 'beschaduwingsreductiefactoren'). During the execution of this research, the effect of an overhang of 0.40m was categorized as introducing no effect. However, the analysis of the results from the dynamic simulations indicated that the overhang of 0.40m did have a positive effect on reducing the risk of overheating. With the addition of more relative height categories, more distinctions can be made for the integration of the assessment of overhangs in NTA 8800.

The second suggestion relates to the solar absorption coefficient parameter in NTA 8800, as was mentioned this parameter is set to 0.6 (NEN, 2020). However, this value is lower compared to most materials used in the built environment. The results in Section 4.2.2 indicate that increasing the solar absorption coefficient has a negative effect on the risk of overheating. It is suggested to increase the solar absorption coefficient while adding a distinction for roof and façade surfaces.

Additionally, further research in the following field and topics is suggested.
During the execution of this research, the effect of apartment height in a building was discussed. Although it affected the WOHs, the TOJuly remained unchanged. Additional research is advised on the effect of building- and apartment heights on the risk of overheating, in relation to dynamic simulations, measurements, and TOJuly.

Moreover, further research may include a sensitivity analysis of the TOJuly. As was established in this research, summer night ventilation, envelope properties, internal heat capacity, and internal heat load seem to have a significant impact on TOJuly. By means of a sensitivity analysis, comprising both dynamic simulations and the NTA 8800 method, the sensitivity of the different parameters can be studied.

In the NTA 8800, the internal heat load is set to 180 W per person. By means of further research, more detailed insight can be provided into the average internal heat load per person. Hypothetically, the heat radiated by humans and equipment may be significantly different in summer compared to winter. As TOJuly is sensitive to the internal heat load, this could reduce the uncertainty of the input parameters in the determination of TOJuly indicator values.

In this research, summer night ventilation was added as one of the design variants. However, multiple options are available when designing and modeling summer night ventilation. Besides the single, temperature-controlled, nighttime activated system applied in this research, different options can be compared and analyzed. For example, a double summer night ventilation system activated 24 hours per day.

Besides the suggestions above, further research may also focus on realistic solar setpoints for automated shading devices. According to the guideline for performing dynamic simulations for determining the risk for overheating, the solar setpoint should be set to 150 W/m2. However, it can be argued that this setpoint is rather strict. By analyzing climate data and historical data for existing automated shading devices, the solar setpoint of 150 W/m2 could be researched. This way, arguments can be collected for keeping the solar setpoint guidelines to 150 W/m2 or decreasing this setpoint to less strict settings. In this research, it was concluded that for some variants, reducing the strictness of the solar setpoint resulted in exceeding the WOH threshold of 450 hours when changing the setpoint from 150 W/m^2 to 300 W/m^2.

7. Conclusions

This research was performed with the objective to evaluate the robustness of the TOJuly indicator. Seven building typologies were designed, related to building characteristics, occupant behavior, and future climate. By means of a comparative analysis between TOJuly and WOHs, the assessment of the risk of overheating for different situations was analyzed. In total 1610 variants were designed for different variant categories and building typologies. To determine the WOHs, Building Performance Simulation models were defined and dynamic simulations were performed in EnergyPlus. The TOJuly values were calculated using the NTA 8800 calculation tool. Besides the TOJuly and WOHs, the maximum indoor temperature was added as third KPI.

Based on the results collected in this research, the following main conclusion is drawn. The TOJuly is a robust method for determining the risk for overheating in the Dutch residential building stock. Among the variants for which the TOJuly method was implemented as intended (e.g., not adapted for internal heat load or future climate), for 6.0% of the variants in the building characteristics category TOJuly indicated an acceptable risk of overheating whereas the threshold for WOHs was exceeded. The highest level of cohesion between the assessment for the risk of overheating in the two methods is attributed to the small terraced dwelling. Overall, the robustness of the apartments is lower compared to the dwellings. The least robust variants relate to the studio. Concerning building characteristics, the addition of an overhang is the most underestimated parameter in TOJuly.

Results related to occupant behavior indicate that both the internal heat load and purge ventilation have a significant effect on the amount of WOHs in all building typologies. However, it remains undefined what the quantitative sensitivity and uncertainty are related to occupant behavior in TOJuly.

Additionally, the effect of future climate was evaluated. For the apartments, none of the measures applied in the included variants reduced the WOHs to 450 hours or less. When the internal heat capacity is reduced (e.g., timber-based building structures), the amount of WOHs may exceed the limit of 450 WOHs in a future climate scenario, whereas this threshold is not exceeded in the prescribed climate scenario for dynamic simulations. The latter observation becomes more relevant in relation to the current building trend of timber-based building. However, it can be a topic of discussion how many years the built environment needs to think and design ahead from today. New, advanced, technological measures or design features that reduce the risk of overheating and provide thermal comfort in 2050 or 2085 might not be available yet. Moreover, the human perception of thermal comfort may change over time (van Marken Lichtenbelt et al., 2017), as well as the occupant's behavior.

Overall, the TOJuly is a useful indicator for assessment of the risk for overheating in the Dutch residential building stock, even though some building typologies and parameters may be over- or underestimated. Further finetuning of the method may improve the robustness as a whole. Moreover, current building trends, such as timber frame and/or CLT structures show to increase the risk of overheating. Gaining insight into the potential overheating, albeit on a superficial level, will become increasingly important and relevant. Moreover, with the TOJuly indicator, the summer season will become more important in the design stage compared to a few years ago. It is acknowledged that dynamic simulations provide more detailed insight into the risk of overheating, but the tradeoff between time, effort, and detailed information is a delicate balance.

8. Further research

Besides the recommendations for further research in relation to the TOJuly, additional further research related to the risk of overheating in general may be beneficial.

This research can be extended by examining the effect of occupant behavior on overheating in buildings. Although some data was collected in this field, the effect of occupants opening windows during the day can be researched more extensively. For high indoor air temperatures, a positive effect on the risk of overheating was found during the execution of this research. Moreover, the occupant behavior can be studied in perspective to the actual use of rooms within a building or dwelling. As it can be expected that people will work from home more in the future compared to the last decade, this may impact the perceived thermal comfort in certain rooms, such as the attic.

Additionally, further research may focus on the distribution of the internal heat load in a residential building. In this research, predetermined distribution criteria were used and were applied for 24 hours per day. Differentiation in the amount of internal heat load per floor or room, taking into account the presence of occupants, may result in new insights in relation to overheating in the residential building stock.

Furthermore, the overall effect of heating and cooling demand for more insulation and/or lower internal heat capacity for year-round situations may be researched. In this research, additional insulation for a timber frame building showed a negative effect on the risk of overheating. However, this research focused on the risk of overheating without looking at the energy demands, or energy demand in winter. In the end, active cooling may result in lower overall energy demand if the energy demand in winter is reduced by the additional insulation levels. In general, timber and CLT-based buildings indicate to be more prone to overheating. Additional research may focus on these design variants specifically and the risk of overheating introduced by this building method. Taking into account the current and projected building trends, the latter suggestion may already be highly relevant.

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10. Appendices

Appendix I Results OAT sensitivity analysis

Table I.1 Results OAT sensitivity analysis

Variant	TOJuly max and WOH max per buidling typology																				
	Terraced S			Semi-detached M			Detached L			Terraced M			Apartment in-between			Apartment top			Studio XS		
	TOJuly	WOH		TOJuly	WOH		TOJuly	WOH		TOJuly	WOH		TOJuly	WOH		TOJuly	WOH		TOJuly	WOH	
	max	WOHmax	Ti,max	max	WOHmax	Ti,max	max	WOHmax	Ti,max	max	WOHmax	Ti,max	max	WOHmax	Ti,max	max	WOHmax	Ti,max	max	WOHmax	Ti,max
base model	0,42	4	28,2	1,08	19	28,6	1,19	62	29,3	0,66	0	27,7	1,2	217	29,6	0,85	155	29,5	0,49	87	28,9
base model_5%	1,34	-	-	2,56	-	-	2,75	-	-	1,78	-	-	2,48	-	-	1,94	-	-	1,31	-	-
base model_1%	5,64	102	28,7	7,22	183	29,1	7,41	366	29,7	5,98	22	28,3	7,41	834	30,1	6,41	731	30	6,14	559	29,4
base model_North-East	0,32	4	28,1	0,84	30	28,8	0,93	60	29,2	0,53	0	27,6	1,02	227	29,5	0,73	161	29,4	0,42	73	28,7
base model_South-East	0,36	0	28	0,93	30	28,7	0,53	58	29,1	0,57	0	27,6	1,08	234	29,6	0,76	174	29,4	0,44	83	28,8
base model_North-West	0,37	5	28,2	0,97	19	28,5	1,06	62	29,2	0,61	0	27,7	1,13	213	29,6	0,79	143	29,4	0,47	65	28,7
base model_South	0,27	0	27,9	0,71	18	28,5	0,78	52	29,1	0,43	0	27,3	0,94	215	29,5	0,68	111	29,2	0,36	48	28,6
base model_West	0,41	12	28,3	1,06	23	28,6	1,16	68	29,3	0,66	0	27,6	1,2	145	29,3	0,84	76	28,9	0,49	80	28,8
base model_North	0,33	3	28,1	0,85	23	28,6	0,94	59	29,2	0,54	0	27,4	1,06	239	29,6	0,77	137	29,2	0,43	79	28,7
base model_East	0,34	8	28,2	0,9	35	28,8	0,99	66	29,2	0,56	0	27,5	1,06	256	29,5	0,75	142	29,2	0,44	113	28,9
base model_spec.int.heat cap. 200-280	1,12	157	30,3	1,82	230	30,7	1,9	349	31,4	1,44	83	29,4	1,76	786	32	1,42	664	31,8	1,05	265	29,9
base model_Passive House (qv;10 0.15, Rc 8;8;10 u 0.7, ggl 0.5)	0,55	19	28,5	1,53	44	28,8	1,66	112	29,4	1,02	0	28	1,64	225	29,4	1,1	163	29,2	0,54	96	28,8
base model_Building Decree+ (qv;10 0.15, Rc 6;6.5;8, U 1.0, ggl 0.5)	0,41	10	28,3	1,15	25	28,6	1,24	63	29,2	0,74	0	27,8	1,34	181	29,3	0,9	122	29,2	0,47	69	28,7
base model_qv;10 0.15	0,48	8	28,3	1,17	24	28,6	1,27	67	29,3	0,72	0	27,7	1,34	260	29,7	0,92	187	29,5	0,54	126	29
base model_125% glass surface	0,77	26	28,7	1,73	60	29,2	1,45	173	30,1	1,15	2	28,1	1,76	431	30,3	1,27	345	30,1	0,75	290	29,5
base model_solar control glazing g;gl 0.3	0,04	0	27,4	0,1	0	27,5	0,1	0	28	0,07	0	27	0,23	26	28,6	0,18	20	28,5	0,11	12	28,2
base model_solar control glazing g;gl 0.4	0,11	0	27,7	0,27	0	27,9	0,29	11	28,5	0,17	0	27,1	0,46	52	28,9	0,34	25	28,5	0,19	28	28,5
base model_no shading device	1,98	722	31,7	4	1039	32,3	4,38	2691	34,8	2,77	334	30,7	3,47	3216	34	2,55	2620	33,6	1,64	2022	32,3
base model_dark shade screen	0,28	0	27,7	0,72	1	28,1	0,79	14	28,5	0,44	0	27,3	0,9	64	28,9	0,63	45	28,8	0,36	27	28,4
base model_white shade screen 300W/m2	-	17	28,5	-	54	29	-	190	29,8	-	0	28	-	567	30,3	-	447	30,1	-	249	29,2
base model_dark shade screen 300W/m2	-	3	28,1	-	17	28,5	-	71	29,1	-	0	27,6	-	360	29,7	-	282	29,6	-	105	28,7
base model_overhang 0.80m	0,31	0	27,9	0,6	10	28,3	0,65	32	28,9	0,36	0	27,5	0,78	142	29,3	0,56	98	29,2	0,49	43	28,6
base model_overhang 0.40m	0,42	2	28,1	1,08	15	28,5	1,19	50	29,1	0,66	0	27,4	1,2	164	29,3	0,85	81	29	0,49	59	28,7
base model_C4c	0,6	19	28,4	1,33	40	28,8	1,43	110	29,5	0,84	0	27,8	1,58	575	30,1	1,06	428	29,9	0,84	503	29,5
base model_D5a	0,8	24	28,5	1,58	44	28,8	1,65	130	29,6	1,01	0	27,8	2,04	695	30,2	1,33	502	30	1,59	661	29,6
base model_D3	0,55	10	28,3	1,26	27	28,6	1,36	80	29,4	0,78	0	27,6	1,5	335	29,7	1,02	213	29,3	0,77	229	29,1
base model_2h purge ventilation 6 L/s.m2	-	10	28,3	-	26	28,7	-	75	29,4	-	0	27,8	-	355	29,9	-	265	29,7	-	268	29,3
base model_2h purge ventilation 3 L/s.m2	-	10	28,4	-	28	28,8	-	79	29,5	-	0	27,8	-	397	30	-	290	29,8	-	343	29,5
base model_4h ventilation 4.2 L/s.m2	0,15	-	-	0,52	-	-	0,62	-	-	0,31	-	-	0,43	-	-	0,37	-	-	0,2	-	-
base model_int.heat load 120W	0,17	0	27,5	0,73	1	28	0,89	33	28,8	0,36	0	27,1	0,61	48	28,8	0,44	38	28,7	0,16	5	28
base model_int.heat load 240W	0,83	37	28,9	1,49	59	29,2	1,52	113	29,8	1,07	6	28,3	1,96	549	30,4	1,39	435	30,2	1,05	458	29,8
base model_ + 1 resident	0,96	50	29,1	1,55	66	29,3	1,51	111	29,8	1,28	16	28,6	2,48	839	30,9	1,78	662	30,7	2,67	2338	31,6
base model_SNV double auto temp (studio single)	0,07	1	28	0,33	10	28,4	0,52	49	29	0,14	0	27,6	0,12	95	29	0,13	71	29	0,14	10	28,2
base model_SNV single auto temp	0,24	2	28,1	0,79	10	28,4	0,97	55	29,1	0,41	0	27,6	0,59	100	29,1	0,47	72	29	0,14	10	28,2
base model_solar absorptioncoeff. Roof:0.9 Facade:0.7	0,49	10	28,3	1,18	27	28,7	1,3	76	29,4	0,74	0	27,7	1,23	223	29,5	0,99	203	29,4	0,5	86	28,9
Attic as living area	-	0	27,9	-	10	28,3	-	47	29	-	-		-	-		-	-		-	-	
Windows open during 08-22h	-	80	30,2	-	100	30,3	-	150	30,7	-	62	30	-	191	30,7	-	170	30,6	-	89	30,1

Appendix II Overview combination variants

Table II.1 Variants and composition building characteristics and occupant behavior

<table>
<tr><th>Variants Building characterstics</th><th>Variants Occupant behavior</th></tr>
<tr><td>a.1 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>b.1 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.2 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>b.2 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.3 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>b.3 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.4 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>b.4 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>b.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.6 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>b.6 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.7 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>b.7 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.8 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>b.8 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.9 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>b.9 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.10 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>b.10 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.11 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>b.11 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.12 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>b.12 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.13 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.13 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.14 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.14 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.15 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.15 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.16 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.16 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.17 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.17 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W</td></tr>
<tr><td>a.18 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.18 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|120W</td></tr>
<tr><td>a.19 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.19 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|240W</td></tr>
<tr><td>a.20 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.20 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>b.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|</td></tr>
<tr><td>a.22 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>b.22 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|180W|</td></tr>
<tr><td>a.23 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>b.23 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|180W|</td></tr>
<tr><td>a.24 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>b.24 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|180W|</td></tr>
<tr><td>a.25 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>b.25 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.26 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>b.26 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|2h|180W|</td></tr>
<tr><td>a.27 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>b.27 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|2h|180W|</td></tr>
<tr><td>a.28 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>b.28 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|2h|180W|</td></tr>
<tr><td>a.29 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.29 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|2h|180W|</td></tr>
<tr><td>a.30 |NEN E|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>b.30 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.31 |NEN E|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.31 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|120W|</td></tr>
<tr><td>a.32 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>b.32 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|120W|</td></tr>
<tr><td>a.33 |NEN E|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>b.33 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|120W|</td></tr>
<tr><td>a.34 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>b.34 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|120W|</td></tr>
<tr><td>a.35 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.35 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.36 |NEN E|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>b.36 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|240W|</td></tr>
<tr><td>a.37 |NEN E|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.37 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|240W|</td></tr>
<tr><td>a.38 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>b.38 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|240W|</td></tr>
<tr><td>a.39 |NEN E|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>b.39 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|240W|</td></tr>
<tr><td>a.40 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>b.40 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td></tr>
<tr><td>a.41 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>b.41 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|120W|</td></tr>
<tr><td>a.42 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>b.42 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|240W|</td></tr>
<tr><td>a.43 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>b.43 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|180W|</td></tr>
<tr><td>a.44 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>b.44 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|120W|</td></tr>
<tr><td>a.45 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>b.45 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|240W|</td></tr>
<tr><td>a.46 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>b.46 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td></tr>
<tr><td>a.47 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>b.47 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|120W|</td></tr>
<tr><td>a.48 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>b.48 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|240W|</td></tr>
<tr><td>a.49 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>b.49 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|180W|</td></tr>
<tr><td>a.50 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|C4c|-|180W|</td><td>b.50 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|120W|</td></tr>
<tr><td>a.51 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|C4c|-|180W|</td><td>b.51 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|240W|</td></tr>
<tr><td>a.52 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D5a|-|180W|</td><td>b.52 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td></tr>
<tr><td>a.53 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D5a|-|180W|</td><td>b.53 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|120W|</td></tr>
<tr><td>a.54 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|C4c|-|180W|</td><td>b.54 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|240W|</td></tr>
<tr><td>a.55 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D5a|-|180W|</td><td>b.55 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|180W|</td></tr>
<tr><td>a.56 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D2|-|180W|</td><td>b.56 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|120W|</td></tr>
<tr><td>a.57 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|C4c|-|180W|</td><td>b.57 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|240W|</td></tr>
<tr><td>a.58 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D5a|-|180W|</td><td></td></tr>
</table>

Table II.2 Variants and composition future climate

<table>
<tr><th>Variants future climate, building characterstics</th><th>Variants future climate, occupant behavior</th></tr>
<tr><td>c.1 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.59 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.2 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.60 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.3 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.61 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.4 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.62 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.5 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.63 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.6 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.64 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.7 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.65 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.8 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.66 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.9 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.67 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.10 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.68 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.11 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.69 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.12 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.70 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.13 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.71 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.14 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.72 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.15 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.73 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.16 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.74 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.17 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.75 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W</td></tr>
<tr><td>c.18 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.76 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|120W</td></tr>
<tr><td>c.19 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.77 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|240W</td></tr>
<tr><td>c.20 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.78 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.21 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.79 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|</td></tr>
<tr><td>c.22 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.80 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|180W|</td></tr>
<tr><td>c.23 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.81 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|180W|</td></tr>
<tr><td>c.24 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.82 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|180W|</td></tr>
<tr><td>c.25 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.83 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.26 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.84 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|2h|180W|</td></tr>
<tr><td>c.27 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.85 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|2h|180W|</td></tr>
<tr><td>c.28 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.86 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|2h|180W|</td></tr>
<tr><td>c.29 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.87 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|2h|180W|</td></tr>
<tr><td>c.30 |NEN 1%|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.88 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.31 |NEN 1%|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.89 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|120W|</td></tr>
<tr><td>c.32 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.90 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|120W|</td></tr>
<tr><td>c.33 |NEN 1%|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.91 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|120W|</td></tr>
<tr><td>c.34 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.92 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|120W|</td></tr>
<tr><td>c.35 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.93 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.36 |NEN 1%|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.94 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|240W|</td></tr>
<tr><td>c.37 |NEN 1%|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.95 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|240W|</td></tr>
<tr><td>c.38 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.96 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|240W|</td></tr>
<tr><td>c.39 |NEN 1%|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.97 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|240W|</td></tr>
<tr><td>c.40 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.98 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td></tr>
<tr><td>c.41 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.99 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|120W|</td></tr>
<tr><td>c.42 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.100 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|240W|</td></tr>
<tr><td>c.43 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.101 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|180W|</td></tr>
<tr><td>c.44 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.102 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|120W|</td></tr>
<tr><td>c.45 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.103 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|240W|</td></tr>
<tr><td>c.46 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.104 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td></tr>
<tr><td>c.47 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.105 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|120W|</td></tr>
<tr><td>c.48 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.106 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|240W|</td></tr>
<tr><td>c.49 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.107 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|180W|</td></tr>
<tr><td>c.50 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|C4c|-|180W|</td><td>c.108 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|120W|</td></tr>
<tr><td>c.51 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|C4c|-|180W|</td><td>c.109 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|240W|</td></tr>
<tr><td>c.52 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D5a|-|180W|</td><td>c.110 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td></tr>
<tr><td>c.53 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D5a|-|180W|</td><td>c.111 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|120W|</td></tr>
<tr><td>c.54 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|C4c|-|180W|</td><td>c.112 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|240W|</td></tr>
<tr><td>c.55 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D5a|-|180W|</td><td>c.113 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|180W|</td></tr>
<tr><td>c.56 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D2|-|180W|</td><td>c.114 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|120W|</td></tr>
<tr><td>c.57 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|C4c|-|180W|</td><td>c.115 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|240W|</td></tr>
<tr><td>c.58 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D5a|-|180W|</td><td></td></tr>
</table>

Appendix III Results variants building characteristics

Table III.1 Results variants building characteristics

<table>
<tr><th rowspan="4">Variant</th><th rowspan="4"></th><th colspan="21">TOJuly max and WOH max per buidling typology</th></tr>
<tr><th colspan="3">Terraced S</th><th colspan="3">Semi-detached M</th><th colspan="3">Detached L</th><th colspan="3">Terraced M</th><th colspan="3">Apartment in-between</th><th colspan="3">Apartment top</th><th colspan="3">Studio XS</th></tr>
<tr><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th></tr>
<tr><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th></tr>
<tr><td>a.1 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>a.1</td><td>0,4</td><td>9</td><td>28,3</td><td>1,1</td><td>24</td><td>28,7</td><td>1,2</td><td>71</td><td>29,4</td><td>0,7</td><td>0</td><td>27,9</td><td>1,2</td><td>232</td><td>29,7</td><td>0,9</td><td>258</td><td>29,8</td><td>0,5</td><td>90</td><td>28,9</td></tr>
<tr><td>a.2 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>a.2</td><td>0,3</td><td>5</td><td>28,2</td><td>0,8</td><td>37</td><td>28,9</td><td>0,9</td><td>66</td><td>29,3</td><td>0,5</td><td>0</td><td>27,8</td><td>1</td><td>233</td><td>29,5</td><td>0,7</td><td>250</td><td>29,7</td><td>0,4</td><td>75</td><td>28,7</td></tr>
<tr><td>a.3 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>a.3</td><td>0,3</td><td>2</td><td>28,1</td><td>0,9</td><td>35</td><td>28,8</td><td>1</td><td>67</td><td>29,2</td><td>0,6</td><td>0</td><td>27,7</td><td>1,1</td><td>250</td><td>29,6</td><td>0,8</td><td>268</td><td>29,7</td><td>0,4</td><td>88</td><td>28,8</td></tr>
<tr><td>a.4 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>a.4</td><td>0,3</td><td>5</td><td>28,3</td><td>1</td><td>23</td><td>28,6</td><td>1,1</td><td>69</td><td>29,3</td><td>0,6</td><td>0</td><td>27,8</td><td>1,1</td><td>226</td><td>29,6</td><td>0,8</td><td>243</td><td>29,7</td><td>0,5</td><td>66</td><td>28,7</td></tr>
<tr><td>a.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>a.5</td><td>0,2</td><td>55</td><td>29,4</td><td>0,6</td><td>77</td><td>29,7</td><td>0,7</td><td>297</td><td>31</td><td>0,4</td><td>21</td><td>28,8</td><td>0,8</td><td>540</td><td>30,8</td><td>0,6</td><td>542</td><td>30,8</td><td>0,3</td><td>340</td><td>29,8</td></tr>
<tr><td>a.6 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>a.6</td><td>0,1</td><td>26</td><td>28,7</td><td>0,4</td><td>132</td><td>30</td><td>0,4</td><td>187</td><td>30,3</td><td>0,1</td><td>10</td><td>28,2</td><td>0,5</td><td>81</td><td>29,1</td><td>0,4</td><td>89</td><td>29,2</td><td>0,1</td><td>95</td><td>28,8</td></tr>
<tr><td>a.7 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>a.7</td><td>0,2</td><td>63</td><td>29,1</td><td>0,5</td><td>137</td><td>29,8</td><td>0,6</td><td>306</td><td>30,5</td><td>0,3</td><td>26</td><td>28,6</td><td>0,7</td><td>422</td><td>30,1</td><td>0,5</td><td>436</td><td>30,2</td><td>0,3</td><td>492</td><td>30</td></tr>
<tr><td>a.8 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>a.8</td><td>0,1</td><td>16</td><td>28,4</td><td>0,4</td><td>63</td><td>29,2</td><td>0,3</td><td>159</td><td>30,2</td><td>0,1</td><td>3</td><td>27,9</td><td>0,7</td><td>183</td><td>30,1</td><td>0,5</td><td>203</td><td>30,1</td><td>0,2</td><td>21</td><td>28,4</td></tr>
<tr><td>a.9 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>a.9</td><td>1,9</td><td>750</td><td>31,7</td><td>4</td><td>1103</td><td>32,4</td><td>4,4</td><td>2792</td><td>34,8</td><td>2,8</td><td>394</td><td>30,9</td><td>3,5</td><td>3269</td><td>34,1</td><td>2,6</td><td>2989</td><td>33,9</td><td>1,6</td><td>2064</td><td>32,3</td></tr>
<tr><td>a.10 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>a.10</td><td>0,7</td><td>486</td><td>30,7</td><td>3,1</td><td>1518</td><td>32,8</td><td>2,6</td><td>2234</td><td>33,5</td><td>1</td><td>281</td><td>29,9</td><td>1,8</td><td>881</td><td>31</td><td>1,3</td><td>850</td><td>31</td><td>0,7</td><td>1004</td><td>30,5</td></tr>
<tr><td>a.11 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>a.11</td><td>1,7</td><td>849</td><td>31,4</td><td>3,7</td><td>1497</td><td>32,6</td><td>4,1</td><td>2967</td><td>34</td><td>2,6</td><td>494</td><td>30,7</td><td>3,3</td><td>2913</td><td>33</td><td>2,4</td><td>2675</td><td>32,9</td><td>1,5</td><td>2991</td><td>32,7</td></tr>
<tr><td>a.12 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>a.12</td><td>0,8</td><td>315</td><td>30,2</td><td>2,9</td><td>934</td><td>31,6</td><td>2,4</td><td>2071</td><td>33,4</td><td>1,3</td><td>227</td><td>29,4</td><td>3,2</td><td>1372</td><td>32,6</td><td>2,4</td><td>1284</td><td>32,5</td><td>0,9</td><td>370</td><td>29,5</td></tr>
<tr><td>a.13 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.13</td><td>0,3</td><td>0</td><td>27,8</td><td>0,7</td><td>2</td><td>28,1</td><td>0,8</td><td>19</td><td>28,6</td><td>0,4</td><td>0</td><td>27,4</td><td>0,9</td><td>72</td><td>29</td><td>0,6</td><td>85</td><td>29,1</td><td>0,4</td><td>28</td><td>28,4</td></tr>
<tr><td>a.14 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.14</td><td>0,3</td><td>0</td><td>27,8</td><td>0,7</td><td>8</td><td>28,3</td><td>0,8</td><td>19</td><td>28,6</td><td>0,5</td><td>0</td><td>27,4</td><td>0,9</td><td>150</td><td>29,3</td><td>0,7</td><td>170</td><td>29,4</td><td>0,4</td><td>27</td><td>28,4</td></tr>
<tr><td>a.15 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.15</td><td>0,2</td><td>0</td><td>27,5</td><td>0,6</td><td>5</td><td>28,2</td><td>0,7</td><td>14</td><td>28,4</td><td>0,4</td><td>0</td><td>27,2</td><td>0,8</td><td>85</td><td>29</td><td>0,6</td><td>104</td><td>29,2</td><td>0,3</td><td>16</td><td>28,2</td></tr>
<tr><td>a.16 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.16</td><td>0,3</td><td>0</td><td>28</td><td>0,8</td><td>3</td><td>28,1</td><td>0,9</td><td>25</td><td>28,7</td><td>0,5</td><td>0</td><td>27,5</td><td>1</td><td>121</td><td>29,2</td><td>0,7</td><td>139</td><td>29,3</td><td>0,4</td><td>50</td><td>28,6</td></tr>
<tr><td>a.17 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.17</td><td></td><td>3</td><td>28,1</td><td></td><td>23</td><td>28,6</td><td></td><td>81</td><td>29,2</td><td></td><td>0</td><td>27,8</td><td></td><td>380</td><td>29,8</td><td></td><td>382</td><td>29,9</td><td></td><td>109</td><td>28,8</td></tr>
<tr><td>a.18 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.18</td><td></td><td>4</td><td>28,2</td><td></td><td>30</td><td>28,7</td><td></td><td>85</td><td>29,2</td><td></td><td>0</td><td>27,7</td><td></td><td>405</td><td>30</td><td></td><td>406</td><td>30,1</td><td></td><td>121</td><td>28,7</td></tr>
<tr><td>a.19 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.19</td><td></td><td>0</td><td>28</td><td></td><td>35</td><td>28,7</td><td></td><td>78</td><td>29,1</td><td></td><td>0</td><td>27,7</td><td></td><td>324</td><td>29,6</td><td></td><td>333</td><td>29,8</td><td></td><td>68</td><td>28,6</td></tr>
<tr><td>a.20 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.20</td><td></td><td>16</td><td>28,4</td><td></td><td>34</td><td>28,7</td><td></td><td>117</td><td>29,4</td><td></td><td>0</td><td>28</td><td></td><td>451</td><td>30,1</td><td></td><td>456</td><td>30,1</td><td></td><td>205</td><td>29</td></tr>
<tr><td>a.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>a.21</td><td>1,5</td><td>274</td><td>30,5</td><td>2,7</td><td>466</td><td>31,2</td><td>3</td><td>1121</td><td>32,9</td><td>1,8</td><td>111</td><td>29,9</td><td>2,5</td><td>1387</td><td>32,2</td><td>1,8</td><td>1301</td><td>32,1</td><td>1,6</td><td>905</td><td>30,9</td></tr>
<tr><td>a.22 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>a.22</td><td>0,5</td><td>179</td><td>29,8</td><td>2</td><td>647</td><td>31,5</td><td>1,4</td><td>873</td><td>31,9</td><td>0,8</td><td>68</td><td>29,2</td><td>2,2</td><td>596</td><td>30,5</td><td>1,6</td><td>581</td><td>30,6</td><td>0,7</td><td>707</td><td>30,1</td></tr>
<tr><td>a.23 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>a.23</td><td>1,3</td><td>335</td><td>30,2</td><td>2,5</td><td>585</td><td>31,2</td><td>2,7</td><td>1153</td><td>32,3</td><td>1,6</td><td>142</td><td>29,7</td><td>1,9</td><td>1451</td><td>31,8</td><td>1,3</td><td>1362</td><td>31,8</td><td>1,5</td><td>1401</td><td>31,3</td></tr>
<tr><td>a.24 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>a.24</td><td>0,7</td><td>80</td><td>29,3</td><td>1,9</td><td>424</td><td>30,6</td><td>1,8</td><td>702</td><td>31,7</td><td>1</td><td>38</td><td>28,7</td><td>2,5</td><td>671</td><td>31,4</td><td>1,8</td><td>652</td><td>31,4</td><td>0,9</td><td>247</td><td>29,2</td></tr>
<tr><td>a.25 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>a.25</td><td>1,2</td><td>454</td><td>31</td><td>3,2</td><td>710</td><td>31,7</td><td>3,8</td><td>1860</td><td>33,9</td><td>1,9</td><td>307</td><td>30,3</td><td>2</td><td>1717</td><td>32,8</td><td>1,6</td><td>1619</td><td>32,7</td><td>0,5</td><td>537</td><td>30,5</td></tr>
<tr><td>a.26 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>a.26</td><td>0,4</td><td>294</td><td>30,1</td><td>2,5</td><td>975</td><td>32</td><td>2,2</td><td>1618</td><td>32,7</td><td>0,7</td><td>219</td><td>29,5</td><td>1</td><td>434</td><td>30,1</td><td>0,8</td><td>440</td><td>30,2</td><td>0,2</td><td>224</td><td>29,1</td></tr>
<tr><td>a.27 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>a.27</td><td>1,1</td><td>548</td><td>30,6</td><td>3</td><td>976</td><td>31,8</td><td>3,5</td><td>2055</td><td>33,2</td><td>1,7</td><td>400</td><td>30</td><td>1,9</td><td>1531</td><td>31,8</td><td>1,5</td><td>1445</td><td>31,7</td><td>0,5</td><td>883</td><td>30,7</td></tr>
<tr><td>a.28 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>a.28</td><td>0,5</td><td>230</td><td>29,7</td><td>2,3</td><td>618</td><td>31</td><td>2</td><td>1708</td><td>32,6</td><td>0,9</td><td>184</td><td>29,1</td><td>1,9</td><td>667</td><td>31,5</td><td>1,5</td><td>654</td><td>31,5</td><td>0,3</td><td>67</td><td>28,5</td></tr>
<tr><td>a.29 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.29</td><td>0,5</td><td>2</td><td>28,1</td><td>1,2</td><td>20</td><td>28,6</td><td>1</td><td>55</td><td>29,2</td><td>0,8</td><td>0</td><td>27,7</td><td>1,3</td><td>168</td><td>29,5</td><td>1</td><td>190</td><td>29,6</td><td>0,6</td><td>70</td><td>28,8</td></tr>
<tr><td>a.30 |NEN E|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>a.30</td><td>0,7</td><td>8</td><td>28,2</td><td>1,8</td><td>32</td><td>28,7</td><td>1,5</td><td>74</td><td>29,1</td><td>1,3</td><td>0</td><td>27,9</td><td>1,9</td><td>147</td><td>29,1</td><td>1,3</td><td>156</td><td>29,1</td><td>0,7</td><td>59</td><td>28,6</td></tr>
<tr><td>a.31 |NEN E|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.31</td><td>0,9</td><td>74</td><td>29,5</td><td>1,4</td><td>114</td><td>29,9</td><td>1,5</td><td>187</td><td>30,3</td><td>1,2</td><td>64</td><td>29</td><td>1,5</td><td>426</td><td>31,1</td><td>1,2</td><td>456</td><td>31,2</td><td>0,9</td><td>101</td><td>29,2</td></tr>
<tr><td>a.32 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>a.32</td><td>1</td><td>107</td><td>29,6</td><td>1,7</td><td>167</td><td>30</td><td>1,8</td><td>185</td><td>30,2</td><td>1,4</td><td>49</td><td>29,1</td><td>1,8</td><td>376</td><td>30,6</td><td>1,4</td><td>376</td><td>30,6</td><td>0,9</td><td>87</td><td>28,9</td></tr>
<tr><td>a.33 |NEN E|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>a.33</td><td>1,2</td><td>114</td><td>30</td><td>2</td><td>201</td><td>30,5</td><td>1,7</td><td>329</td><td>31</td><td>1,6</td><td>101</td><td>29,3</td><td>1,9</td><td>639</td><td>31,6</td><td>1,5</td><td>651</td><td>31,8</td><td>1,1</td><td>210</td><td>29,6</td></tr>
<tr><td>a.34 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>a.34</td><td>1,4</td><td>166</td><td>30</td><td>2,5</td><td>290</td><td>30,5</td><td>2,2</td><td>346</td><td>30,8</td><td>2</td><td>28</td><td>28,7</td><td>2,4</td><td>573</td><td>31,1</td><td>1,9</td><td>567</td><td>31,2</td><td>1,2</td><td>203</td><td>29,3</td></tr>
<tr><td>a.35 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.35</td><td></td><td>25</td><td>28,6</td><td></td><td>94</td><td>29,2</td><td></td><td>257</td><td>29,9</td><td></td><td>3</td><td>28,2</td><td></td><td>685</td><td>30,4</td><td></td><td>679</td><td>30,5</td><td></td><td>312</td><td>29,3</td></tr>
<tr><td>a.36 |NEN E|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>a.36</td><td></td><td>52</td><td>28,7</td><td></td><td>214</td><td>29,3</td><td></td><td>453</td><td>29,9</td><td></td><td>16</td><td>28,3</td><td></td><td>691</td><td>30,1</td><td></td><td>641</td><td>30,1</td><td></td><td>306</td><td>29</td></tr>
<tr><td>a.37 |NEN E|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.37</td><td></td><td>146</td><td>29,9</td><td></td><td>266</td><td>30,4</td><td></td><td>396</td><td>30,9</td><td></td><td>98</td><td>29,2</td><td></td><td>1024</td><td>31,8</td><td></td><td>1016</td><td>31,9</td><td></td><td>272</td><td>29,5</td></tr>
<tr><td>a.38 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>a.38</td><td></td><td>229</td><td>30</td><td></td><td>390</td><td>30,5</td><td></td><td>514</td><td>30,8</td><td></td><td>99</td><td>29,4</td><td></td><td>947</td><td>31,3</td><td></td><td>908</td><td>31,3</td><td></td><td>260</td><td>29,3</td></tr>
<tr><td>a.39 |NEN E|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>a.39</td><td></td><td>266</td><td>30,4</td><td></td><td>486</td><td>31,1</td><td></td><td>740</td><td>31,7</td><td></td><td>192</td><td>29,7</td><td></td><td>1620</td><td>32,6</td><td></td><td>1541</td><td>32,7</td><td></td><td>511</td><td>30,1</td></tr>
<tr><td>a.40 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>a.40</td><td></td><td>385</td><td>30,4</td><td></td><td>724</td><td>31,2</td><td></td><td>991</td><td>31,6</td><td></td><td>86</td><td>29,1</td><td></td><td>1580</td><td>32,1</td><td></td><td>1460</td><td>32,1</td><td></td><td>494</td><td>29,8</td></tr>
<tr><td>a.41 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>a.41</td><td>0,1</td><td>42</td><td>29,1</td><td>0,5</td><td>60</td><td>29,4</td><td>0,6</td><td>229</td><td>30,6</td><td>0,2</td><td>14</td><td>28,6</td><td>0,4</td><td>289</td><td>30</td><td>0,3</td><td>304</td><td>30,1</td><td>0,1</td><td>60</td><td>28,9</td></tr>
<tr><td>a.42 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>a.42</td><td>0,9</td><td>486</td><td>31,6</td><td>1,8</td><td>649</td><td>32</td><td>2</td><td>1179</td><td>33,2</td><td>1,3</td><td>262</td><td>30,8</td><td>1,2</td><td>1064</td><td>32,3</td><td>1,1</td><td>1021</td><td>32,3</td><td>0,5</td><td>245</td><td>29,9</td></tr>
<tr><td>a.43 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>a.43</td><td>0,2</td><td>101</td><td>29,8</td><td>0,7</td><td>162</td><td>30,2</td><td>0,9</td><td>520</td><td>31,7</td><td>0,4</td><td>48</td><td>29,3</td><td>0,6</td><td>511</td><td>30,8</td><td>0,5</td><td>504</td><td>30,8</td><td>0,2</td><td>197</td><td>29,6</td></tr>
<tr><td>a.44 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>a.44</td><td>1,2</td><td>829</td><td>32,6</td><td>2,4</td><td>1138</td><td>33</td><td>2,8</td><td>2117</td><td>34,7</td><td>1,8</td><td>278</td><td>30,7</td><td>1,7</td><td>1753</td><td>33,4</td><td>1,4</td><td>1665</td><td>33,4</td><td>0,6</td><td>524</td><td>30,8</td></tr>
<tr><td>a.45 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>a.45</td><td>0,9</td><td>163</td><td>30</td><td>2,1</td><td>304</td><td>30,6</td><td>2,5</td><td>793</td><td>32,2</td><td>1,2</td><td>79</td><td>29,5</td><td>1,3</td><td>710</td><td>31,2</td><td>1</td><td>692</td><td>31,2</td><td>0,5</td><td>220</td><td>29,6</td></tr>
<tr><td>a.46 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>a.46</td><td>1,8</td><td>818</td><td>32,5</td><td>3,6</td><td>1289</td><td>33,2</td><td>3,4</td><td>2178</td><td>34,7</td><td>2,5</td><td>477</td><td>31,6</td><td>1,9</td><td>1719</td><td>33,3</td><td>1,6</td><td>1631</td><td>33,3</td><td>1</td><td>406</td><td>30,5</td></tr>
<tr><td>a.47 |NEN E|SW|sihc 500-700|BD|125%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>a.47</td><td>1,5</td><td>401</td><td>31</td><td>3</td><td>718</td><td>31,8</td><td>3,6</td><td>1718</td><td>34</td><td>1,8</td><td>256</td><td>30,5</td><td>2</td><td>1445</td><td>32,5</td><td>1,5</td><td>1353</td><td>32,4</td><td>0,8</td><td>660</td><td>31</td></tr>
<tr><td>a.48 |NEN E|SW|sihc 200-300|PH|125%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>a.48</td><td>2,5</td><td>1481</td><td>33,9</td><td>4,8</td><td>2334</td><td>34,7</td><td>4,7</td><td>3992</td><td>36,8</td><td>3,5</td><td>599</td><td>31,7</td><td>2,6</td><td>2952</td><td>34,8</td><td>2,2</td><td>2787</td><td>34,7</td><td>1,3</td><td>985</td><td>31,9</td></tr>
<tr><td>a.49 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>a.49</td><td>1</td><td>107</td><td>29,6</td><td>1,7</td><td>167</td><td>30</td><td>1,8</td><td>185</td><td>30,2</td><td>1,4</td><td>49</td><td>29,1</td><td>1,8</td><td>376</td><td>30,6</td><td>1,4</td><td>376</td><td>30,6</td><td>0,9</td><td>87</td><td>28,9</td></tr>
<tr><td>a.50 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|C4c|-|180W|</td><td>a.50</td><td>0,4</td><td>0</td><td>27,9</td><td>0,9</td><td>4</td><td>28,1</td><td>1</td><td>31</td><td>28,7</td><td>0,6</td><td>0</td><td>27,4</td><td>1,2</td><td>278</td><td>29,4</td><td>0,8</td><td>292</td><td>29,5</td><td>0,6</td><td>234</td><td>28,9</td></tr>
<tr><td>a.51 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|C4c|-|180W|</td><td>a.51</td><td>1,3</td><td>219</td><td>29,9</td><td>2,1</td><td>303</td><td>30,3</td><td>2,1</td><td>348</td><td>30,5</td><td>1,7</td><td>78</td><td>29,3</td><td>2,2</td><td>909</td><td>31,2</td><td>1,7</td><td>845</td><td>31,2</td><td>1,3</td><td>522</td><td>29,6</td></tr>
<tr><td>a.52 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D5a|-|180W|</td><td>a.52</td><td>0,5</td><td>2</td><td>27,9</td><td>1,1</td><td>12</td><td>28,2</td><td>1,1</td><td>36</td><td>28,7</td><td>0,7</td><td>0</td><td>27,4</td><td>1,6</td><td>347</td><td>29,5</td><td>1</td><td>350</td><td>29,5</td><td>1,3</td><td>321</td><td>29</td></tr>
<tr><td>a.53 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D5a|-|180W|</td><td>a.53</td><td>1,5</td><td>268</td><td>30</td><td>2,4</td><td>357</td><td>30,4</td><td>2,4</td><td>404</td><td>30,6</td><td>2</td><td>88</td><td>29,3</td><td>2,8</td><td>1095</td><td>31,3</td><td>2</td><td>1010</td><td>31,3</td><td>2</td><td>671</td><td>29,7</td></tr>
<tr><td>a.54 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|C4c|-|180W|</td><td>a.54</td><td>2,4</td><td>2265</td><td>34,5</td><td>4,9</td><td>3158</td><td>35,2</td><td>5,6</td><td>5744</td><td>37,8</td><td>3,4</td><td>1583</td><td>33</td><td>3,1</td><td>5103</td><td>36,1</td><td>2,6</td><td>4715</td><td>36</td><td>1,1</td><td>1370</td><td>31,8</td></tr>
<tr><td>a.55 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D5a|-|180W|</td><td>a.55</td><td>1,8</td><td>749</td><td>31,4</td><td>4,1</td><td>1106</td><td>32,1</td><td>4,7</td><td>2883</td><td>34,7</td><td>2,5</td><td>559</td><td>30,5</td><td>2,9</td><td>2933</td><td>33,5</td><td>2,1</td><td>2622</td><td>33,4</td><td>1</td><td>970</td><td>30,9</td></tr>
<tr><td>a.56 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D2|-|180W|</td><td>a.56</td><td>2,1</td><td>1522</td><td>33,8</td><td>4,3</td><td>2214</td><td>34,5</td><td>5</td><td>3988</td><td>36,6</td><td>3</td><td>1003</td><td>32,6</td><td>2,7</td><td>3273</td><td>35,1</td><td>2,2</td><td>3091</td><td>35</td><td>0,9</td><td>813</td><td>31,4</td></tr>
<tr><td>a.57 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|C4c|-|180W|</td><td>a.57</td><td>1,5</td><td>691</td><td>31,3</td><td>3,7</td><td>894</td><td>31,9</td><td>4,3</td><td>2677</td><td>34,6</td><td>2,2</td><td>507</td><td>30,5</td><td>2,4</td><td>2665</td><td>33,3</td><td>1,8</td><td>2408</td><td>33,2</td><td>0,7</td><td>877</td><td>30,8</td></tr>
<tr><td>a.58 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D5a|-|180W|</td><td>a.58</td><td>2,8</td><td>2481</td><td>34,7</td><td>5,4</td><td>3432</td><td>35,4</td><td>6,2</td><td>6221</td><td>38,1</td><td>3,8</td><td>1720</td><td>33,1</td><td>3,6</td><td>5628</td><td>36,4</td><td>2,9</td><td>5158</td><td>36,2</td><td>1,4</td><td>1561</td><td>31,9</td></tr>
</table>

Appendix IV Results variants occupant behavior

Table IV.1 Results variants occupant behavior

Variant		TOJuly max and WOH max per buidling typology																				
		Terraced S			Semi-detached M			Detached L			Terraced M			Apartment in-between			Apartment top			Studio XS		
		TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max
b.1 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	b.1	0,4	9	28,3	1,1	24	28,7	1,2	71	29,4	0,7	0	27,9	1,2	232	29,7	0,9	258	29,8	0,5	90	28,9
b.2 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	b.2	0,3	5	28,2	0,8	37	28,9	0,9	66	29,3	0,5	0	27,8	1	233	29,5	0,7	250	29,7	0,4	75	28,7
b.3 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	b.3	0,3	2	28,1	0,9	35	28,8	1	67	29,2	0,6	0	27,7	1,1	250	29,6	0,8	268	29,7	0,4	88	28,8
b.4 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	b.4	0,3	5	28,3	1	23	28,6	1,1	69	29,3	0,6	0	27,8	1,1	226	29,6	0,8	243	29,7	0,5	66	28,7
b.5 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	b.5		12	28,4		28	28,8		87	29,5		0	27,9		373	30		379	30		277	29,4
b.6 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	b.6		12	28,3		46	29,1		83	29,4		0	27,8		358	29,9		369	29,9		241	29,1
b.7 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	b.7		6	28,2		45	28,9		78	29,3		0	27,8		393	29,9		399	30		274	29,2
b.8 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	b.8		13	28,4		29	28,7		86	29,5		0	27,9		353	29,9		360	29,9		237	29,1
b.9 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	b.9	0,2	0	27,6	0,7	2	28,1	0,9	36	28,9	0,4	0	27,3	0,6	54	28,9	0,4	62	29	0,2	5	28
b.10 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	b.10	0,1	0	27,5	0,5	10	28,3	0,7	33	28,8	0,3	0	27,2	0,5	52	28,8	0,4	60	28,9	0,1	1	27,8
b.11 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	b.11	0,1	0	27,3	0,6	10	28,2	0,8	33	28,7	0,3	0	27,1	0,5	57	28,8	0,4	66	29	0,1	5	27,9
b.12 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	b.12	0,1	0	27,5	0,6	2	28	0,8	33	28,8	0,3	0	27,2	0,6	46	28,8	0,4	56	28,9	0,2	2	27,8
b.13 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	b.13	0,8	43	29	1,5	61	29,2	1,5	131	29,8	1,1	11	28,5	2	566	30,5	1,4	557	30,5	1,1	469	29,8
b.14 |NEN E|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	b.14	0,6	42	28,9	1,2	89	29,5	1,2	126	29,7	0,9	9	28,3	1,7	554	30,3	1,2	547	30,4	1	427	29,6
b.15 |NEN E|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	b.15	0,7	34	28,8	1,3	82	29,4	1,3	120	29,7	0,9	8	28,3	1,8	587	30,4	1,3	573	30,4	1	464	29,7
b.16 |NEN E|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	b.16	0,7	44	28,9	1,4	66	29,2	1,4	128	29,7	1	9	28,4	1,9	546	30,4	1,3	540	30,4	1	427	29,6
b.17 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W	b.17		12	28,4		28	28,8		87	29,5		0	27,9		373	30		379	30		277	29,4
b.18 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|120W	b.18		0	27,6		3	28,1		43	29		0	27,3		75	29		87	29,2		16	28,3
b.19 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|240W	b.19		56	29,2		82	29,4		180	30		15	28,6		898	30,8		851	30,8		1032	30,5
b.20 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|180W|	b.20	1,2	240	30,5	2,2	351	31	2,3	490	31,5	1,8	111	29,8	2,1	756	31,6	1,7	729	31,6	1	266	29,7
b.21 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|	b.21	0,6	24	28,5	1,3	32	28,7	1,4	129	29,6	0,8	2	28	1,6	598	30,2	1,1	575	30,2	0,8	508	29,5
b.22 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|180W|	b.22	1,5	493	31	2,6	649	31,4	2,7	922	32,1	2,1	217	30,2	2,6	1653	32,3	2	1499	32,3	1,5	940	30,4
b.23 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|180W|	b.23	0,7	26	28,5	1,6	50	28,9	1,7	155	29,7	1	3	28	2	722	30,3	1,3	691	30,3	1,6	671	29,6
b.24 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|180W|	b.24	1,8	589	31,1	3	752	31,5	3,1	1037	32,2	2,4	250	30,3	3,3	1976	32,5	2,4	1769	32,5	2,3	1249	30,6
b.25 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|2h|180W|	b.25		322	30,8		471	31,3		634	31,8		140	30,1		1100	32		1036	32		548	30,1
b.26 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|2h|180W|	b.26		37	28,7		43	28,9		229	29,9		6	28,1		1150	30,7		1044	30,7		1465	30,4
b.27 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|2h|180W|	b.27		837	31,6		991	31,9		1355	32,6		360	30,6		2998	33,2		2641	33,1		2616	31,5
b.28 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|2h|180W|	b.28		47	28,8		88	29,2		276	30		11	28,2		1471	30,9		1298	30,9		2024	30,7
b.29 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|2h|180W|	b.29		1019	31,8		1169	32,1		1595	32,8		449	30,7		3718	33,5		3225	33,3		3504	31,8
b.30 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|120W|	b.30	0,7	84	29,6	1,7	171	30,2	1,9	288	30,8	1,2	56	29,1	1,3	306	30,6	1	318	30,6	0,5	36	28,6
b.31 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|120W|	b.31	0,2	0	27,7	0,9	3	28	1,1	58	29,1	0,5	0	27,3	0,8	196	29,3	0,6	219	29,4	0,3	42	28,4
b.32 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|120W|	b.32	0,9	148	29,9	2	268	30,4	2,2	512	31,3	1,5	72	29,3	1,7	702	31,1	1,2	666	31,2	0,7	226	29,1
b.33 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|120W|	b.33	0,3	0	27,7	1,1	10	28,2	1,3	65	29,1	0,6	0	27,3	1,1	257	29,4	0,7	268	29,4	0,6	71	28,5
b.34 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|120W|	b.34	1,1	178	30	2,3	311	30,5	2,5	586	31,4	1,7	79	29,3	2,1	816	31,3	1,5	785	31,3	1,2	288	29,2
b.35 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|240W|	b.35	1,8	542	31,4	2,8	678	31,7	2,8	786	32,1	2,4	252	30,6	3,1	1467	32,6	2,4	1363	32,5	1,7	782	30,6
b.36 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|240W|	b.36	1,1	115	29,3	1,8	106	29,3	1,8	305	30,2	1,3	28	28,6	2,5	1357	31,1	1,7	1246	31,1	1,7	1581	30,6
b.37 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|240W|	b.37	2,3	1140	32,1	3,2	1246	32,3	3,2	1477	32,8	2,8	535	31,1	3,7	3387	33,6	2,8	3011	33,5	2,4	2631	31,7
b.38 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|240W|	b.38	1,4	162	29,3	2,1	202	29,6	2,1	347	30,2	1,6	32	28,7	3,1	1633	31,2	2,1	1466	31,2	2,8	1958	30,8
b.39 |NEN E|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|240W|	b.39	2,7	1380	32,2	3,7	1456	32,5	3,6	1699	33	3,2	637	31,2	4,6	4032	33,8	3,4	3553	33,7	3,5	3364	31,9
b.40 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|	b.40	0,3	0	27,8	0,7	2	28,1	0,8	19	28,6	0,4	0	27,4	0,9	72	29	0,6	85	29,1	0,4	28	28,4
b.41 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|120W|	b.41	0,1	0	27	0,5	0	27,5	0,6	3	28,1	0,2	0	26,8	0,4	10	28,2	0,3	16	28,3	0,1	0	27,5
b.42 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|240W|	b.42	0,6	13	28,5	1,1	25	28,7	1,1	43	29	0,8	0	28	1,6	306	29,8	1,1	316	29,8	0,9	262	29,3
b.43 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|180W|	b.43		0	27,8		0	27,6		24	28,7		0	27,4		120	29,2		143	29,3		80	28,7
b.44 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|120W|	b.44		0	27,1		30	28,8		3	28,2		0	26,8		15	28,3		20	28,5		0	27,6
b.45 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|2h|240W|	b.45		19	28,6		30	28,8		50	29,2		0	28,1		491	30,1		481	30,1		605	29,8
b.46 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|	b.46		3	28,1		23	28,6		81	29,2		0	27,8		380	29,8		382	29,9		109	28,8
b.47 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|120W|	b.47		0	27,4		2	28		31	28,7		0	27,2		114	29		135	29,2		2	27,9
b.48 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|240W|	b.48		39	28,8		85	29,2		180	29,7		9	28,3		798	30,6		760	30,6		512	29,6
b.49 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|180W|	b.49		9	28,3		28	28,7		106	29,4		0	27,8		591	30,2		576	30,2		325	29,2
b.50 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|120W|	b.50		0	27,5		4	28,1		39	28,8		0	27,2		188	29,3		211	29,4		16	28,1
b.51 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|2h|240W|	b.51		61	29		128	29,3		245	29,8		14	28,5		1310	31		1206	31		1149	30,3
b.52 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	b.52	1,2	454	31	3,2	710	31,7	3,8	1860	33,9	1,9	307	30,3	2	1717	32,8	1,6	1619	32,7	0,5	537	30,5
b.53 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|120W|	b.53	0,8	274	30,5	2,8	501	31,2	3,4	1554	33,5	1,5	190	29,9	1,4	1199	32,1	1,1	1140	32,1	0,3	292	30
b.54 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|240W|	b.54	1,7	683	31,6	3,7	966	32,1	4,2	2238	34,3	2,4	426	30,8	2,7	2354	33,4	2,1	2175	33,3	0,9	876	31,2
b.55 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|180W|	b.55		577	31,3		896	31,9		2327	34,3		447	30,5		2214	33,1		2036	33,1		780	30,9
b.56 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|120W|	b.56		350	30,7		621	31,4		1916	33,9		289	30,1		1538	32,5		1435	32,4		422	30,2
b.57 |NEN E|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|240W|	b.57		904	31,9		1214	32,5		2806	34,8		631	31		3087	33,8		2816	33,7		1302	31,6

Appendix V Results future climate

Table V.1 Results variants future climate, building characteristics

<table>
<tr><th rowspan="4">Variant</th><th rowspan="4"></th><th colspan="21">TOJuly max and WOH max per buidling typology</th></tr>
<tr><th colspan="3">Terraced S</th><th colspan="3">Semi-detached M</th><th colspan="3">Detached L</th><th colspan="3">Terraced M</th><th colspan="3">Apartment in-between</th><th colspan="3">Apartment top</th><th colspan="3">Studio XS</th></tr>
<tr><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th><th>TOJuly</th><th colspan="2">WOH</th></tr>
<tr><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th><th>max</th><th>WOHmax</th><th>Ti,max</th></tr>
<tr><td>c.1 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.1</td><td>1,3</td><td>117</td><td>28,8</td><td>2,6</td><td>205</td><td>29,1</td><td>2,8</td><td>402</td><td>29,8</td><td>1,8</td><td>38</td><td>28,4</td><td>2,5</td><td>866</td><td>30,1</td><td>1,9</td><td>936</td><td>30,2</td><td>1,3</td><td>577</td><td>29,4</td></tr>
<tr><td>c.2 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.2</td><td>1</td><td>118</td><td>28,8</td><td>2,2</td><td>279</td><td>29,4</td><td>2,3</td><td>400</td><td>29,8</td><td>1,5</td><td>36</td><td>28,3</td><td>2,2</td><td>882</td><td>30,2</td><td>1,7</td><td>950</td><td>30,3</td><td>1,2</td><td>584</td><td>29,5</td></tr>
<tr><td>c.3 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.3</td><td>1,1</td><td>102</td><td>28,6</td><td>2,3</td><td>244</td><td>29,2</td><td>2,5</td><td>383</td><td>29,6</td><td>1,6</td><td>34</td><td>28,3</td><td>2,3</td><td>922</td><td>30,2</td><td>1,8</td><td>1004</td><td>30,3</td><td>1,2</td><td>591</td><td>29,4</td></tr>
<tr><td>c.4 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|</td><td>c.4</td><td>1,2</td><td>122</td><td>28,8</td><td>2,4</td><td>228</td><td>29,1</td><td>2,6</td><td>398</td><td>29,8</td><td>1,7</td><td>36</td><td>28,4</td><td>2,4</td><td>854</td><td>30,2</td><td>1,9</td><td>928</td><td>30,3</td><td>1,3</td><td>526</td><td>29,4</td></tr>
<tr><td>c.5 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.5</td><td>0,8</td><td>315</td><td>29,5</td><td>1,7</td><td>410</td><td>29,7</td><td>1,9</td><td>916</td><td>30,8</td><td>1,2</td><td>151</td><td>29</td><td>1,8</td><td>1305</td><td>30,8</td><td>1,4</td><td>1371</td><td>30,9</td><td>1</td><td>967</td><td>30</td></tr>
<tr><td>c.6 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.6</td><td>0,4</td><td>246</td><td>29,2</td><td>1,3</td><td>617</td><td>30,1</td><td>1,2</td><td>772</td><td>30,4</td><td>0,3</td><td>114</td><td>28,7</td><td>1,3</td><td>579</td><td>29,6</td><td>1</td><td>658</td><td>29,7</td><td>0,5</td><td>779</td><td>29,7</td></tr>
<tr><td>c.7 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.7</td><td>0,7</td><td>343</td><td>29,5</td><td>1,6</td><td>542</td><td>29,9</td><td>1,7</td><td>938</td><td>30,9</td><td>1,1</td><td>187</td><td>29</td><td>1,7</td><td>1402</td><td>30,8</td><td>1,4</td><td>1476</td><td>30,9</td><td>0,9</td><td>1365</td><td>30,6</td></tr>
<tr><td>c.8 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|-|D2|-|180W|</td><td>c.8</td><td>0,4</td><td>159</td><td>28,7</td><td>1,2</td><td>400</td><td>29,6</td><td>1</td><td>723</td><td>30,2</td><td>0,5</td><td>93</td><td>28,3</td><td>1,7</td><td>647</td><td>29,8</td><td>1,3</td><td>732</td><td>29,9</td><td>0,6</td><td>342</td><td>29</td></tr>
<tr><td>c.9 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.9</td><td>3,7</td><td>1904</td><td>31,7</td><td>6,5</td><td>2749</td><td>32,4</td><td>7</td><td>5603</td><td>34,5</td><td>4,9</td><td>1220</td><td>31</td><td>5,4</td><td>5710</td><td>33,5</td><td>4,4</td><td>5405</td><td>33,4</td><td>3,2</td><td>3845</td><td>32,4</td></tr>
<tr><td>c.10 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.10</td><td>1,8</td><td>1639</td><td>31,2</td><td>5,4</td><td>3692</td><td>33</td><td>4,8</td><td>5009</td><td>33,9</td><td>2,4</td><td>1088</td><td>30,5</td><td>3,4</td><td>2574</td><td>31,7</td><td>2,7</td><td>2582</td><td>31,7</td><td>1,7</td><td>2990</td><td>31,8</td></tr>
<tr><td>c.11 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.11</td><td>3,5</td><td>2087</td><td>31,8</td><td>6,1</td><td>3297</td><td>32,7</td><td>6,6</td><td>5787</td><td>34,6</td><td>4,6</td><td>1389</td><td>31</td><td>5,2</td><td>5985</td><td>33,9</td><td>4,2</td><td>5721</td><td>33,9</td><td>3</td><td>5477</td><td>33,3</td></tr>
<tr><td>c.12 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|-|D2|-|180W|</td><td>c.12</td><td>2,1</td><td>1036</td><td>30,4</td><td>5,1</td><td>2493</td><td>32,2</td><td>4,5</td><td>4558</td><td>33,4</td><td>2,9</td><td>869</td><td>29,8</td><td>5,2</td><td>2814</td><td>32,2</td><td>4,2</td><td>2792</td><td>32,2</td><td>2</td><td>1333</td><td>30,5</td></tr>
<tr><td>c.13 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.13</td><td>0,9</td><td>36</td><td>28,4</td><td>1,9</td><td>73</td><td>28,7</td><td>2,1</td><td>147</td><td>29,1</td><td>1,3</td><td>3</td><td>28</td><td>2</td><td>507</td><td>29,6</td><td>1,6</td><td>582</td><td>29,7</td><td>1</td><td>325</td><td>28,9</td></tr>
<tr><td>c.14 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.14</td><td>0,9</td><td>44</td><td>28,4</td><td>2</td><td>104</td><td>28,8</td><td>2,1</td><td>162</td><td>29,1</td><td>1,4</td><td>4</td><td>28</td><td>2,1</td><td>690</td><td>30</td><td>1,6</td><td>788</td><td>30,1</td><td>1,1</td><td>356</td><td>29,1</td></tr>
<tr><td>c.15 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.15</td><td>0,8</td><td>23</td><td>28,1</td><td>1,7</td><td>94</td><td>28,7</td><td>1,8</td><td>124</td><td>28,9</td><td>1,2</td><td>1</td><td>27,8</td><td>1,9</td><td>538</td><td>29,6</td><td>1,5</td><td>628</td><td>29,7</td><td>0,9</td><td>280</td><td>28,8</td></tr>
<tr><td>c.16 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.16</td><td>1</td><td>61</td><td>28,5</td><td>2,1</td><td>95</td><td>28,7</td><td>2,3</td><td>179</td><td>29,2</td><td>1,5</td><td>13</td><td>28,1</td><td>2,2</td><td>641</td><td>29,9</td><td>1,7</td><td>738</td><td>30,1</td><td>1,1</td><td>412</td><td>29,2</td></tr>
<tr><td>c.17 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.17</td><td></td><td>147</td><td>28,8</td><td></td><td>261</td><td>29,2</td><td></td><td>469</td><td>29,8</td><td></td><td>52</td><td>28,4</td><td></td><td>1271</td><td>30,7</td><td></td><td>1354</td><td>30,8</td><td></td><td>643</td><td>29,5</td></tr>
<tr><td>c.18 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.18</td><td></td><td>146</td><td>28,8</td><td></td><td>309</td><td>29,4</td><td></td><td>475</td><td>29,8</td><td></td><td>51</td><td>28,4</td><td></td><td>1248</td><td>30,6</td><td></td><td>1329</td><td>30,6</td><td></td><td>657</td><td>29,5</td></tr>
<tr><td>c.19 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.19</td><td></td><td>133</td><td>28,7</td><td></td><td>321</td><td>29,3</td><td></td><td>464</td><td>29,8</td><td></td><td>57</td><td>28,4</td><td></td><td>1106</td><td>30,4</td><td></td><td>1176</td><td>30,4</td><td></td><td>598</td><td>29,5</td></tr>
<tr><td>c.20 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.20</td><td></td><td>224</td><td>29,1</td><td></td><td>331</td><td>29,4</td><td></td><td>570</td><td>30,1</td><td></td><td>89</td><td>28,7</td><td></td><td>1408</td><td>30,7</td><td></td><td>1473</td><td>30,7</td><td></td><td>868</td><td>29,8</td></tr>
<tr><td>c.21 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.21</td><td>3,1</td><td>815</td><td>30,3</td><td>4,8</td><td>1341</td><td>31</td><td>5,2</td><td>2646</td><td>32,4</td><td>3,6</td><td>489</td><td>29,8</td><td>4,2</td><td>2779</td><td>31,8</td><td>3,3</td><td>2747</td><td>31,9</td><td>3,2</td><td>1965</td><td>31,1</td></tr>
<tr><td>c.22 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.22</td><td>1,5</td><td>849</td><td>30,2</td><td>4</td><td>1796</td><td>31,4</td><td>3</td><td>2387</td><td>32,1</td><td>2</td><td>515</td><td>29,7</td><td>3,9</td><td>1888</td><td>31,2</td><td>3,1</td><td>1932</td><td>31,2</td><td>1,7</td><td>2347</td><td>31,3</td></tr>
<tr><td>c.23 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.23</td><td>2,9</td><td>899</td><td>30,4</td><td>4,6</td><td>1398</td><td>31</td><td>4,9</td><td>2701</td><td>32,4</td><td>3,3</td><td>549</td><td>29,9</td><td>3,4</td><td>3699</td><td>32,5</td><td>2,7</td><td>3625</td><td>32,5</td><td>3</td><td>2954</td><td>31,7</td></tr>
<tr><td>c.24 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|-|D2|-|180W|</td><td>c.24</td><td>1,9</td><td>460</td><td>29,5</td><td>3,7</td><td>1239</td><td>30,9</td><td>3,6</td><td>1842</td><td>31,5</td><td>2,4</td><td>292</td><td>29</td><td>4,3</td><td>1607</td><td>31,1</td><td>3,4</td><td>1671</td><td>31,1</td><td>2</td><td>1002</td><td>30,1</td></tr>
<tr><td>c.25 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.25</td><td>2,6</td><td>1025</td><td>31</td><td>5,4</td><td>1617</td><td>31,7</td><td>6,2</td><td>3704</td><td>33,6</td><td>3,5</td><td>906</td><td>30,4</td><td>3,4</td><td>3068</td><td>32,3</td><td>2,8</td><td>3004</td><td>32,2</td><td>1,1</td><td>1038</td><td>30,5</td></tr>
<tr><td>c.26 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.26</td><td>1,2</td><td>952</td><td>30,5</td><td>4,4</td><td>2228</td><td>32,1</td><td>4,1</td><td>3728</td><td>33</td><td>1,6</td><td>815</td><td>30</td><td>2</td><td>1200</td><td>30,6</td><td>1,7</td><td>1249</td><td>30,7</td><td>0,5</td><td>815</td><td>30</td></tr>
<tr><td>c.27 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.27</td><td>2,4</td><td>1189</td><td>31,1</td><td>5,1</td><td>2006</td><td>31,9</td><td>5,8</td><td>3910</td><td>33,7</td><td>3,3</td><td>1063</td><td>30,5</td><td>3,2</td><td>3299</td><td>32,6</td><td>2,7</td><td>3235</td><td>32,6</td><td>1</td><td>1805</td><td>30,9</td></tr>
<tr><td>c.28 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|</td><td>c.28</td><td>1,3</td><td>785</td><td>29,9</td><td>4,1</td><td>1493</td><td>31,4</td><td>3,9</td><td>3815</td><td>32,6</td><td>2</td><td>716</td><td>29,5</td><td>3,3</td><td>1318</td><td>31,1</td><td>2,8</td><td>1360</td><td>31,2</td><td>0,6</td><td>301</td><td>29</td></tr>
<tr><td>c.29 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.29</td><td>1,4</td><td>82</td><td>28,7</td><td>2,7</td><td>169</td><td>29,1</td><td>2,4</td><td>333</td><td>29,7</td><td>2</td><td>28</td><td>28,3</td><td>2,7</td><td>751</td><td>30</td><td>2,1</td><td>840</td><td>30,2</td><td>1,4</td><td>487</td><td>29,3</td></tr>
<tr><td>c.30 |NEN 1%|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.30</td><td>1,9</td><td>171</td><td>28,8</td><td>3,6</td><td>305</td><td>29,2</td><td>3,3</td><td>455</td><td>29,6</td><td>2,8</td><td>85</td><td>28,5</td><td>3,4</td><td>725</td><td>29,8</td><td>2,7</td><td>765</td><td>29,8</td><td>1,6</td><td>505</td><td>29,2</td></tr>
<tr><td>c.31 |NEN 1%|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.31</td><td>1,6</td><td>302</td><td>30,1</td><td>2,5</td><td>424</td><td>30,6</td><td>2,6</td><td>660</td><td>31</td><td>2</td><td>278</td><td>29,6</td><td>2,4</td><td>1317</td><td>31,8</td><td>2</td><td>1430</td><td>31,9</td><td>1,5</td><td>522</td><td>29,6</td></tr>
<tr><td>c.32 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.32</td><td>1,8</td><td>445</td><td>30,2</td><td>3</td><td>606</td><td>30,6</td><td>3,1</td><td>670</td><td>30,8</td><td>2,4</td><td>257</td><td>29,7</td><td>2,8</td><td>1227</td><td>31,2</td><td>2,3</td><td>1265</td><td>31,3</td><td>1,5</td><td>519</td><td>29,5</td></tr>
<tr><td>c.33 |NEN 1%|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 150|-|-|D2|-|180W|</td><td>c.33</td><td>2,1</td><td>441</td><td>30,6</td><td>3,3</td><td>650</td><td>31,2</td><td>2,9</td><td>983</td><td>31,8</td><td>2,6</td><td>425</td><td>29,9</td><td>3</td><td>1727</td><td>32,3</td><td>2,6</td><td>1832</td><td>32,4</td><td>1,9</td><td>762</td><td>30</td></tr>
<tr><td>c.34 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.34</td><td>2,4</td><td>611</td><td>30,6</td><td>4</td><td>891</td><td>31,2</td><td>3,6</td><td>1030</td><td>31,5</td><td>3,3</td><td>215</td><td>29,2</td><td>3,6</td><td>1634</td><td>31,7</td><td>3</td><td>1665</td><td>31,8</td><td>2,1</td><td>766</td><td>29,9</td></tr>
<tr><td>c.35 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.35</td><td></td><td>275</td><td>29,2</td><td></td><td>491</td><td>29,8</td><td></td><td>903</td><td>30,6</td><td></td><td>159</td><td>28,8</td><td></td><td>1991</td><td>31,5</td><td></td><td>2035</td><td>31,6</td><td></td><td>1097</td><td>30,1</td></tr>
<tr><td>c.36 |NEN 1%|SW|sihc 500-700|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.36</td><td></td><td>437</td><td>29,4</td><td></td><td>818</td><td>30</td><td></td><td>1379</td><td>30,8</td><td></td><td>263</td><td>29</td><td></td><td>1962</td><td>31,2</td><td></td><td>1936</td><td>31,2</td><td></td><td>1067</td><td>30</td></tr>
<tr><td>c.37 |NEN 1%|SW|sihc 200-300|BD|100%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.37</td><td></td><td>540</td><td>30,6</td><td></td><td>791</td><td>31,1</td><td></td><td>1090</td><td>31,7</td><td></td><td>418</td><td>30</td><td></td><td>2499</td><td>33</td><td></td><td>2562</td><td>33,1</td><td></td><td>930</td><td>30,2</td></tr>
<tr><td>c.38 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.38</td><td></td><td>761</td><td>30,6</td><td></td><td>1136</td><td>31,2</td><td></td><td>1423</td><td>31,6</td><td></td><td>432</td><td>30,1</td><td></td><td>2384</td><td>32,4</td><td></td><td>2362</td><td>32,4</td><td></td><td>922</td><td>30,1</td></tr>
<tr><td>c.39 |NEN 1%|SW|sihc 200-300|BD|125%|g;gl 0.6|sd dark 300|-|-|D2|-|180W|</td><td>c.39</td><td></td><td>811</td><td>31,1</td><td></td><td>1254</td><td>31,8</td><td></td><td>1796</td><td>32,6</td><td></td><td>669</td><td>30,4</td><td></td><td>3477</td><td>34,2</td><td></td><td>3479</td><td>34,2</td><td></td><td>1445</td><td>30,8</td></tr>
<tr><td>c.40 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd dark 300|-|-|D2|-|180W|</td><td>c.40</td><td></td><td>1131</td><td>31,1</td><td></td><td>1756</td><td>31,9</td><td></td><td>2324</td><td>32,5</td><td></td><td>442</td><td>29,7</td><td></td><td>3410</td><td>33,6</td><td></td><td>3330</td><td>33,5</td><td></td><td>1422</td><td>30,7</td></tr>
<tr><td>c.41 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.41</td><td>0,5</td><td>197</td><td>29,2</td><td>1,3</td><td>286</td><td>29,4</td><td>1,5</td><td>669</td><td>30,5</td><td>0,7</td><td>102</td><td>28,8</td><td>0,9</td><td>628</td><td>30</td><td>0,8</td><td>678</td><td>30,1</td><td>0,3</td><td>237</td><td>28,8</td></tr>
<tr><td>c.42 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.42</td><td>1,5</td><td>1017</td><td>31,8</td><td>2,8</td><td>1378</td><td>32,1</td><td>3,3</td><td>2233</td><td>33,2</td><td>2</td><td>729</td><td>31,1</td><td>1,9</td><td>1897</td><td>32,2</td><td>1,7</td><td>1892</td><td>32,3</td><td>0,8</td><td>507</td><td>30</td></tr>
<tr><td>c.43 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.43</td><td>0,8</td><td>366</td><td>29,7</td><td>1,8</td><td>521</td><td>30,1</td><td>2,2</td><td>1229</td><td>31,4</td><td>1,1</td><td>264</td><td>29,3</td><td>1,3</td><td>1032</td><td>30,6</td><td>1,1</td><td>1066</td><td>30,7</td><td>0,4</td><td>449</td><td>29,4</td></tr>
<tr><td>c.44 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.3|sd none|-|SNV|D2|-|180W|</td><td>c.44</td><td>2</td><td>1571</td><td>32,6</td><td>3,7</td><td>2172</td><td>33,1</td><td>4,4</td><td>3618</td><td>34,5</td><td>2,7</td><td>773</td><td>30,8</td><td>2,5</td><td>2878</td><td>33,2</td><td>2,2</td><td>2831</td><td>33,2</td><td>1</td><td>933</td><td>30,7</td></tr>
<tr><td>c.45 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.45</td><td>2,1</td><td>478</td><td>29,9</td><td>3,9</td><td>806</td><td>30,5</td><td>4,5</td><td>1697</td><td>31,8</td><td>2,5</td><td>344</td><td>29,5</td><td>2,5</td><td>1360</td><td>30,7</td><td>2,1</td><td>1373</td><td>30,8</td><td>1,1</td><td>467</td><td>29,5</td></tr>
<tr><td>c.46 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.46</td><td>2,8</td><td>1533</td><td>32,6</td><td>5,3</td><td>2407</td><td>33,4</td><td>5,1</td><td>3671</td><td>34,6</td><td>3,8</td><td>1059</td><td>31,8</td><td>2,8</td><td>2797</td><td>32,9</td><td>2,5</td><td>2723</td><td>32,9</td><td>1,5</td><td>745</td><td>30,4</td></tr>
<tr><td>c.47 |NEN 1%|SW|sihc 500-700|BD|125%|g;gl 0.6|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.47</td><td>3</td><td>921</td><td>30,8</td><td>5,1</td><td>1611</td><td>31,6</td><td>5,9</td><td>3394</td><td>33,3</td><td>3,5</td><td>831</td><td>30,4</td><td>3,3</td><td>2570</td><td>31,7</td><td>2,8</td><td>2507</td><td>31,7</td><td>1,6</td><td>1215</td><td>30,8</td></tr>
<tr><td>c.48 |NEN 1%|SW|sihc 200-300|PH|125%|g;gl 0.5|sd none|oh 0.80|SNV|D2|-|180W|</td><td>c.48</td><td>3,8</td><td>2534</td><td>33,8</td><td>6,8</td><td>3972</td><td>34,8</td><td>6,8</td><td>6082</td><td>36,4</td><td>5</td><td>1379</td><td>31,7</td><td>3,7</td><td>4602</td><td>34,2</td><td>3,2</td><td>4433</td><td>34,2</td><td>2</td><td>1669</td><td>31,6</td></tr>
<tr><td>c.49 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D2|-|180W|</td><td>c.49</td><td>1,8</td><td>445</td><td>30,2</td><td>3</td><td>606</td><td>30,6</td><td>3,1</td><td>670</td><td>30,8</td><td>2,4</td><td>257</td><td>29,7</td><td>2,8</td><td>1227</td><td>31,2</td><td>2,3</td><td>1265</td><td>31,3</td><td>1,5</td><td>519</td><td>29,5</td></tr>
<tr><td>c.50 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|C4c|-|180W|</td><td>c.50</td><td>1,1</td><td>76</td><td>28,3</td><td>2,2</td><td>99</td><td>28,4</td><td>2,3</td><td>241</td><td>29,1</td><td>1,5</td><td>11</td><td>27,9</td><td>2,3</td><td>993</td><td>29,9</td><td>1,8</td><td>1094</td><td>30</td><td>1,4</td><td>855</td><td>29,4</td></tr>
<tr><td>c.51 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|C4c|-|180W|</td><td>c.51</td><td>2</td><td>748</td><td>30,3</td><td>3,3</td><td>908</td><td>30,7</td><td>3,4</td><td>1036</td><td>30,9</td><td>2,7</td><td>391</td><td>29,7</td><td>3,2</td><td>2178</td><td>31,6</td><td>2,6</td><td>2168</td><td>31,7</td><td>1,9</td><td>1347</td><td>30,1</td></tr>
<tr><td>c.52 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|-|D5a|-|180W|</td><td>c.52</td><td>1,5</td><td>97</td><td>28,3</td><td>2,6</td><td>156</td><td>28,6</td><td>2,7</td><td>265</td><td>29,1</td><td>1,8</td><td>15</td><td>27,9</td><td>3</td><td>1148</td><td>30</td><td>2,2</td><td>1247</td><td>30,1</td><td>2,5</td><td>1012</td><td>29,5</td></tr>
<tr><td>c.53 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd dark 150|-|-|D5a|-|180W|</td><td>c.53</td><td>2,5</td><td>847</td><td>30,3</td><td>3,8</td><td>1019</td><td>30,7</td><td>4</td><td>1151</td><td>31</td><td>3,2</td><td>437</td><td>29,7</td><td>4,1</td><td>2490</td><td>31,8</td><td>3,2</td><td>2460</td><td>31,8</td><td>3</td><td>1628</td><td>30,3</td></tr>
<tr><td>c.54 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|C4c|-|180W|</td><td>c.54</td><td>3,5</td><td>3629</td><td>34,2</td><td>6,6</td><td>4975</td><td>35,1</td><td>7,6</td><td>8105</td><td>37,3</td><td>4,7</td><td>3052</td><td>32,9</td><td>4,2</td><td>7604</td><td>35,3</td><td>3,6</td><td>7043</td><td>35,2</td><td>1,6</td><td>2411</td><td>31,8</td></tr>
<tr><td>c.55 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D5a|-|180W|</td><td>c.55</td><td>3,4</td><td>1810</td><td>31,4</td><td>6,4</td><td>2383</td><td>32,2</td><td>7,2</td><td>5523</td><td>34,5</td><td>4,3</td><td>1503</td><td>30,4</td><td>4,3</td><td>5026</td><td>33</td><td>3,5</td><td>4603</td><td>33</td><td>1,8</td><td>1940</td><td>31</td></tr>
<tr><td>c.56 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D2|-|180W|</td><td>c.56</td><td>3,2</td><td>2631</td><td>34</td><td>6,1</td><td>3785</td><td>34,8</td><td>7,1</td><td>6090</td><td>36,6</td><td>4,4</td><td>2061</td><td>32,9</td><td>3,8</td><td>5061</td><td>34,8</td><td>3,3</td><td>4879</td><td>34,8</td><td>1,4</td><td>1430</td><td>31,4</td></tr>
<tr><td>c.57 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|C4c|-|180W|</td><td>c.57</td><td>2,9</td><td>1645</td><td>31,3</td><td>5,8</td><td>1975</td><td>31,9</td><td>6,6</td><td>5155</td><td>34,3</td><td>3,8</td><td>1390</td><td>30,4</td><td>3,7</td><td>4582</td><td>32,9</td><td>3,1</td><td>4250</td><td>32,8</td><td>1,3</td><td>1730</td><td>30,9</td></tr>
<tr><td>c.58 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd none|-|SNV|D5a|-|180W|</td><td>c.58</td><td>4,1</td><td>3912</td><td>34,3</td><td>7,4</td><td>5314</td><td>35,2</td><td>8,5</td><td>8692</td><td>37,5</td><td>5,3</td><td>3315</td><td>32,9</td><td>4,9</td><td>8402</td><td>35,6</td><td>4,1</td><td>7702</td><td>35,4</td><td>2,1</td><td>2821</td><td>31,9</td></tr>
</table>

Table V.1 Results variants future climate, occupant behavior

Variant		TOJuly max and WOH max per buidling typology																				
		Terraced S			Semi-detached M			Detached L			Terraced M			Apartment in-between			Apartment top			Studio XS		
		TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max	TOJuly max	WOH WOHmax	WOH Ti,max
c.59 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	c.59	1,3	117	28,8	2,6	205	29,1	2,8	402	29,8	1,8	38	28,4	2,5	866	30,1	1,9	936	30,2	1,3	577	29,4
c.60 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	c.60	1	118	28,8	2,2	279	29,4	2,3	400	29,8	1,5	36	28,3	2,2	882	30,2	1,7	950	30,3	1,2	584	29,5
c.61 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	c.61	1,1	102	28,6	2,3	244	29,2	2,5	383	29,6	1,6	34	28,3	2,3	922	30,2	1,8	1004	30,3	1,2	591	29,4
c.62 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|180W|	c.62	1,2	122	28,8	2,4	228	29,1	2,6	398	29,8	1,7	36	28,4	2,4	854	30,2	1,9	928	30,3	1,3	526	29,4
c.63 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	c.63		182	28,9		278	29,3		514	29,9		65	28,5		1292	30,6		1382	30,7		1090	30
c.64 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	c.64		187	28,9		371	29,5		510	29,9		68	28,5		1314	30,6		1396	30,7		1114	30
c.65 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	c.65		156	28,8		332	29,4		490	29,8		67	28,4		1404	30,7		1486	30,7		1112	30
c.66 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W|	c.66		188	29		310	29,3		505	29,9		66	28,5		1271	30,6		1352	30,7		1034	30
c.67 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	c.67	0,7	16	28,1	2,1	70	28,5	2,3	246	29,3	1,2	1	27,8	1,7	412	29,4	1,3	483	29,5	0,6	167	28,5
c.68 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	c.68	0,6	19	28,1	1,7	109	28,8	1,9	243	29,3	1	0	27,8	1,4	414	29,4	1,1	493	29,6	0,5	167	28,5
c.69 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	c.69	0,6	5	27,9	1,8	91	28,6	2,1	233	29,2	1,1	0	27,7	1,5	453	29,5	1,2	528	29,6	0,6	172	28,5
c.70 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|120W|	c.70	0,6	21	28,1	1,9	87	28,6	2,1	243	29,3	1,2	1	27,8	1,6	397	29,4	1,2	471	29,6	0,6	147	28,4
c.71 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	c.71	1,9	310	29,4	3,1	394	29,7	3,2	586	30,2	2,4	141	28,9	3,4	1564	30,9	2,7	1640	31	2,1	1317	30,4
c.72 |NEN 1%|NE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	c.72	1,6	312	29,4	2,7	494	29,9	2,7	585	30,2	2,1	136	28,9	3,1	1589	30,9	2,4	1655	31	2	1349	30,4
c.73 |NEN 1%|SE|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	c.73	1,7	288	29,2	2,8	445	29,7	2,9	565	30,1	2,2	127	28,8	3,2	1676	31	2,5	1750	31	2	1322	30,4
c.74 |NEN 1%|NW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|-|240W|	c.74	1,8	315	29,4	2,9	427	29,7	3	582	30,2	2,3	136	28,9	3,3	1543	30,9	2,6	1618	31	2,1	1252	30,3
c.75 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|180W	c.75		182	28,9		278	29,3		514	29,9		65	28,5		1292	30,6		1382	30,7		1090	30
c.76 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|120W	c.76		30	28,2		95	28,7		318	29,4		6	27,9		603	29,7		696	29,8		326	28,9
c.77 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D2|2h|240W	c.77		450	29,7		535	29,9		788	30,4		219	29,1		2344	31,5		2364	31,5		2469	31,2
c.78 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|180W|	c.78	2,1	762	30,9	3,6	1051	31,4	3,8	1346	31,9	2,9	441	30,3	3,3	1903	32	2,7	1904	32,1	1,7	863	30,1
c.79 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|180W|	c.79	1,5	229	28,8	2,9	265	29	3	582	29,8	2	97	28,3	2,8	1627	30,5	2,2	1690	30,6	1,7	1363	30
c.80 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|180W|	c.80	2,4	1299	31,1	4	1628	31,6	4,2	2174	32,2	3,2	700	30,3	3,7	3363	32,6	3	3245	32,5	2,1	2097	30,9
c.81 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|180W|	c.81	1,9	259	28,8	3,3	351	29,1	3,5	649	29,8	2,4	115	28,3	3,6	1840	30,7	2,7	1891	30,7	3	1630	30,2
c.82 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|180W|	c.82	3	1470	31,2	4,6	1833	31,7	4,8	2405	32,3	3,8	799	30,4	4,7	3812	32,8	3,7	3646	32,7	3,4	2559	31,1
c.83 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|2h|180W|	c.83		1067	31,2		1418	31,6		1773	32,1		587	30,5		2724	32,4		2686	32,5		1556	30,8
c.84 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|2h|180W|	c.84		383	29,2		384	29,2		884	30,2		204	28,6		2742	31,3		2727	31,3		3092	31,1
c.85 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|2h|180W|	c.85		2124	31,6		2473	32		3189	32,7		1115	30,7		5477	33,5		5135	33,3		4691	32,2
c.86 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|2h|180W|	c.86		446	29,2		575	29,5		1009	30,2		248	28,6		3180	31,5		3100	31,5		3842	31,4
c.87 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|2h|180W|	c.87		2483	31,8		2811	32,2		3648	32,8		1313	30,8		6405	33,8		5925	33,6		5991	32,6
c.88 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|120W|	c.88	1,5	354	30	3	603	30,6	3,3	896	31,2	2,2	227	29,6	2,3	1025	31	1,9	1062	31,1	1	301	29,1
c.89 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|120W|	c.89	0,9	39	28,1	2,3	84	28,3	2,6	352	29,3	1,4	8	27,7	1,9	770	29,6	1,5	854	29,8	0,9	425	28,8
c.90 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|120W|	c.90	1,7	547	30	3,3	854	30,6	3,6	1393	31,4	2,5	319	29,5	2,7	1764	31,4	2,1	1778	31,4	1,3	749	29,5
c.91 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|120W|	c.91	1,2	46	28,1	2,7	136	28,5	3	386	29,3	1,7	11	27,7	2,5	877	29,7	1,9	970	29,8	1,8	543	28,9
c.92 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|120W|	c.92	2,1	608	30	3,9	956	30,7	4,2	1535	31,5	2,9	355	29,5	3,4	1990	31,5	2,6	2003	31,5	2,1	907	29,7
c.93 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D2|-|240W|	c.93	2,9	1408	31,8	4,2	1699	32,1	4,3	1916	32,5	3,6	798	31	4,3	3144	33	3,5	3057	33	2,6	1883	31,2
c.94 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|C4c|-|240W|	c.94	2,2	571	29,6	3,4	539	29,6	3,5	940	30,3	2,7	264	28,9	3,8	2843	31,5	2,9	2804	31,5	2,7	2979	31,2
c.95 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|C4c|-|240W|	c.95	3,2	2519	32,1	4,7	2746	32,5	4,8	3170	32,9	4	1390	31,2	4,9	5608	33,9	3,9	5272	33,7	3,1	4620	32,3
c.96 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd white 150|-|-|D5a|-|240W|	c.96	2,7	671	29,6	3,9	734	29,8	4	1041	30,4	3,1	293	29	4,6	3236	31,7	3,6	3156	31,6	4,2	3593	31,4
c.97 |NEN 1%|SW|sihc 200-300|PH|100%|g;gl 0.5|sd white 150|-|-|D5a|-|240W|	c.97	3,9	2846	32,3	5,4	3075	32,6	5,5	3525	33	4,7	1567	31,3	6	6376	34,2	4,7	5939	34	4,7	5658	32,6
c.98 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|-|180W|	c.98	0,9	36	28,4	1,9	73	28,7	2,1	147	29,1	1,3	3	28	2	507	29,6	1,6	582	29,7	1	325	28,9
c.99 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|-|120W|	c.99	0,5	0	27,6	1,5	12	28,1	1,7	61	28,6	0,8	0	27,4	1,2	202	28,9	1	272	29	0,5	53	28,1
c.100 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|-|240W|	c.100	1,5	166	29	2,5	212	29,2	2,5	292	29,5	1,9	53	28,6	2,9	1042	30,4	2,2	1120	30,4	1,8	904	29,8
c.101 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|2h|180W|	c.101		56	28,5		21	28,1		202	29,2		8	28,1		778	30		876	30,1		644	29,5
c.102 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|2h|120W|	c.102		0	27,7		290	29,4		78	28,7		0	27,5		294	29,1		374	29,2		105	28,4
c.103 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 150|-|D2|2h|240W|	c.103		256	29,2		290	29,4		374	29,7		86	28,7		1582	30,8		1675	30,9		1693	30,6
c.104 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|-|180W|	c.104		147	28,8		261	29,2		469	29,8		52	28,4		1271	30,7		1354	30,8		643	29,5
c.105 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|-|120W|	c.105		27	28,2		117	28,7		305	29,4		3	27,9		678	30		763	30,1		201	28,5
c.106 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|-|240W|	c.106		343	29,4		463	29,7		697	30,3		162	28,9		2125	31,5		2164	31,5		1422	30,4
c.107 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|2h|180W|	c.107		219	29		354	29,4		628	30,1		87	28,6		1920	31,2		1979	31,3		1212	30,1
c.108 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|2h|120W|	c.108		49	28,3		160	28,8		398	29,6		16	28		1026	30,4		1114	30,4		397	29
c.109 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd dark 300|-|D2|2h|240W|	c.109		506	29,7		667	30		963	30,6		247	29,2		3152	32,1		3113	32,1		2668	31,2
c.110 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|180W|	c.110	2,6	1025	31	5,4	1617	31,7	6,2	3704	33,6	3,5	906	30,4	3,4	3068	32,3	2,8	3004	32,2	1,1	1038	30,5
c.111 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|120W|	c.111	2	704	30,5	4,9	1233	31,2	5,7	3180	33,2	3	671	30	2,7	2228	31,6	2,3	2210	31,6	0,7	611	29,9
c.112 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|-|240W|	c.112	3,2	1457	31,5	5,9	2101	32,1	6,6	4269	34	4,1	1208	30,8	4,1	4057	32,9	3,4	3900	32,8	1,6	1711	31,2
c.113 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|180W|	c.113		1495	31,3		2061	32		4757	34		1309	30,6		3961	32,7		3829	32,6		1510	30,9
c.114 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|120W|	c.114		1001	30,7		1556	31,5		4107	33,6		961	30,2		2875	32		2810	31,9		855	30,2
c.115 |NEN 1%|SW|sihc 500-700|BD|100%|g;gl 0.6|sd none|-|SNV|D2|2h|240W|	c.115		2103	31,9		2709	32,5		5442	34,5		1709	31		5252	33,4		4978	33,3		2498	31,7