Residential Buildings With Low Heat Demand

The impact of design variables on the heat demand of a residential building in the Netherlands.

M.A. Nicolaï

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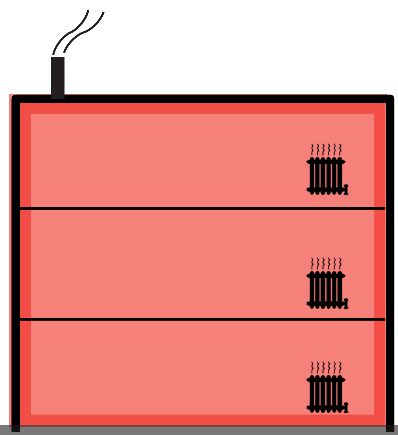
Building Technology

TU Delft



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The impact of design variables on the heat demand of a residential building in the Netherlands.

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Marc Nicolaï
Delft, June 2017

Summary

This study is about the impact of early design decisions on the heat demand of a small residential building. Heat demand is a significant part of the energy use of residential buildings in the Netherlands. Reducing this demand will reduce the strain on national energy resources and even allow buildings to become energy neutral or independant with the addition of energy supply and storage systems.

Based on a case study building of 8 appartments, the simulation study explores the impact of several individual design aspects: insulation, orientation of glass facades and building shape. Furthermore the balcony facade of the case study building is compared to a plain facade and a sunspaces (balconies with a glass facade) in terms of heat demand and comfortable use (operative temperature).

Based on these studies the case study building is completely re-designed with the goal of reaching a minimal level of heat demand.

Based on these studies and the re-design a final set of design guidelines is developed for designers interested in designing small residential buildings with low heat demand.

Samenvatting

Dit onderzoek gaat over de invloed van vroege ontwerpbeslissingen op de warmtevraag van een klein woongebouw. Warmtevraag is een significant aandeel van het energiegebruik van woongebouwen in Nederland. Het verminderen van deze warmtevraag zal de druk op de nationale energie voorziening verminderen en zelfs energieneutrale of energie onafhankelijke woongebouwen mogelijk maken met de toevoeging van energie opwekking- en opslagsystemen.

Op basis van een gekozen voorbeeldgebouwontwerp van acht appartementen, verkent een simulatie studie de invloed van verscheidene individuele ontwerp aspecten: isolatie, orientatie van glas facades en gebouwvorm. Achtereenvolgens is ook de balkon-facade van het voorbeeldgebouwontwerp vergeleken met een kale facade en een facade met zonneruimtes (balkons met glasgevel ervoor) qua warmtevraag en comfortabel gebruik (temperatuur).

Op basis van deze studies is het voorbeeldontwerp herontworpen met als doelstelling een zo laag mogelijke warmtevraag.

Het uiteindelijke eindproduct is een set richtlijnen voor ontwerpers die geïnteresseerd zijn in het ontwerpen van kleine woongebouwen met lage warmtevraag.

Contents

Terminology

g value
The amount of solar heat that passes through a window or sunshading element.

Heat demand
Annual energy demand per square meter floor area required for the heating flow of the heat balance simulation to maintain the set minimum temperature. [kWh/m^2]

R-value or Rc
The heat resistance of a partition. [m^{2}K/W]

SHGC (ZTA)
Solar Heat Gain Coefficient, the amount of solar heat that passes through a window. Known as ZTA in Dutch and g-value in European English.

U-value
The heat transmittance value of a partition, the opposite of the R-value. [W/m^{2}K]

1. Introduction

1.1 Problem statement

Worldwide both governmental and corporate parties have committed to significantly reduce emissons that have been linked to climate changing effects. This generally translates to reducing the use of fossil fuels by switching to sustainable energy sources such as wind and solar, and by reducing energy demand in general.

Energy consumption of buildings makes up a significant percentage of total energy demand in the Netherlands. A large part of this is due to heating demand. To meet the energy goals set by international agreements on energy use reduction the EU demands all new buildings to be (nearly) energy neutral by the 31st of december 2020.

Because design changes are costly, it is preferable that designers are aware of the impact their design decisions can have on heat demand. By taking this into account in an early stage of the design development, mistakes can be avoided that would require an investment of time and money to correct (see also Figure 1).

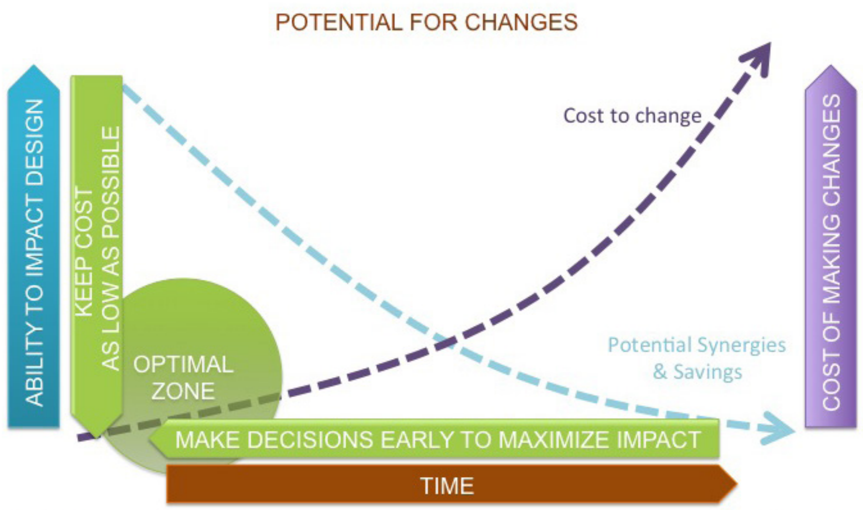


Figure 1 Early decisions have more impact and cost less. (image source: http://sagelivingtoronto.com/integrated-design-process)

1.2 Societal Relevance

Two current trends are putting pressure on energy demand reduction in buildings. One is the creation of new legislation by governments that set higher demands on new buildings in terms of energy performance.

The second trend is a societal shift away from centralized energy supply and towards local supply and storage. Homeowners are becoming their own energy suppliers by investing in pv panels and whole neighbourhoods are investing in seasonal heat storage systems. This shift from a centralized to a decentralized energy grid (see Figure 2) is increasing consumer awareness on energy use.

1.3 Scientific Relevance

This study seeks to bridge the gap between designers and scientific study of heat demand by creating a document that is understandable for designers and based on empirical study. Although a societal shift has already occurred, spurring many designers to focus more on energy use reduction, actual hard data on the influence of design decisions on heat demand is hard to come by and even less accessible to building designers. Raw data is not something a designer can use to determine what course of action they should take when it comes to design decisions. Instead this data needs to be translated into a language that is understandable for a designer. This language consists of physical aspects of a building and the presentation of guidelines should be in a visual format with information presented in a way that is easy to grasp for anyone, not just building physics experts.

Reducing energy demand is the first step of the trias energetica (see Figure 3), a widely accepted general approach strategy to creating (nearly) zero energy buildings. Reducing energy demand directly and dramatically decreases the strain on the next steps, since lower demand directly translates to lower capacity requirements for energy supply and storage.

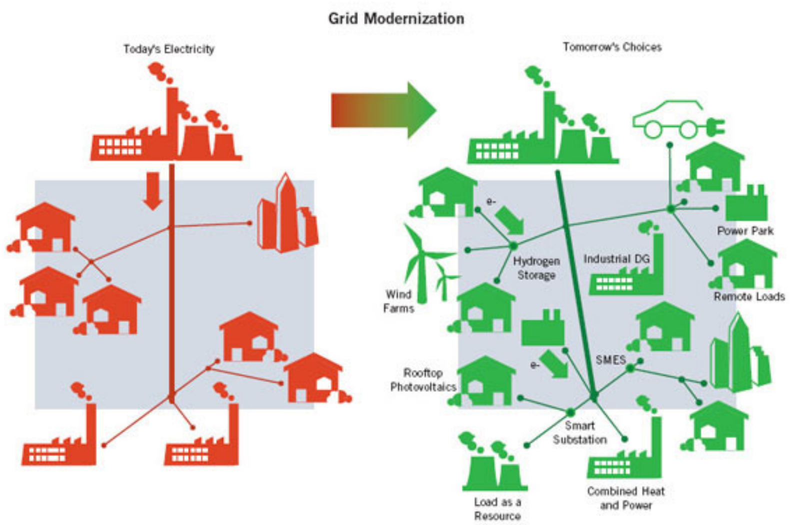


Figure 2 Centralized grid and decentralized grid

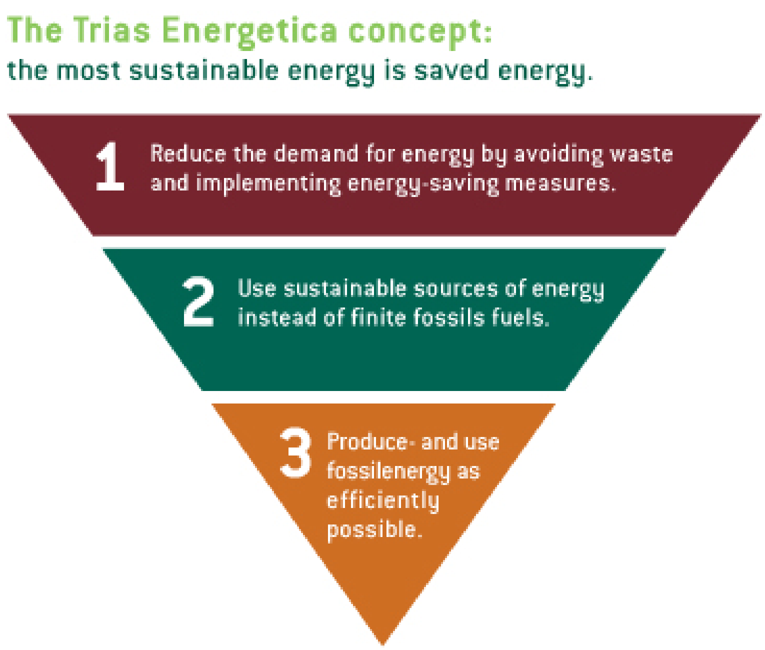


Figure 3 Process overview (image source; http://www.eurima.org/energy-efficiency-in-buildings/trias-energetica)

2. Approach & methodology

2.1 Research Questions and goals

2.1.1 Main research question

As in any study a research question has been formulated that describes a specific lack of knowledge and the desired final product. In this case the lack of knowledge is the specific impact of design decisions on the heat demand of a residential building in the Netherlands. The answer to this question is to be formulated in a product for designers that is easy to read and understand.

What is the impact of early design decisions on the heat demand of a residential building in the Netherlands and what heat demand reduction guidelines can be established for designers?

2.1.2 Sub-questions

To further define what needs to be defined before the main question can be answered the following sub-questions have been formulated:

- What design variables are relevant to the heat demand of a building?
- How can the impact of a design variable on the heating demand of a residential building be calculated?
- How can the findings of a heating demand impact study be applied to an actual building?
- How can guidelines for designers best be formulated?

2.1.3 Goals

Following the sub-questions several goals can be defined:

- Literature & heat theory review: a literature review, a study of the theory on calculating heat demand and of early design decisions that might impact the heat demand of a small residential building.
- Selection and validation of heat demand calculation model: establish and validate a method for estimating annual heat demand through simulation of a small residential building.
- Heat demand impact studies: Heating demand impact studies of individual design variables to quantify this impact and create a clear picture of which variables have the most impact.
- Case building re-design: Discussion and application of guidelines in a case study. Preliminary design guidelines based on impact studies that are applied to a re-design.
- Final guidelines for heat demand reduction: A final set of guidelines for designers that want to design residential buildings with low heat demand.

2.2 Process

2.2.1 Process overview

The process is defined by several stages (also see Figure 4):

1. Review of relevant information
2. Preparation of study
3. Study of relevant variables
4. Creation of final products based on study results

2.2.2 Review phase

The preparation phase consists of two parts: a

Literature, theory and case studies to establish what is known and what is currently common practice in terms of heat demand calculation and design for heat demand reduction in residential buildings.

2. Investigate building heat demand modelling methods and determine which method to use for calculating annual heat demand of study scenarios and concept designs.

3. Categorize influential early design variables and estimate their impact on annual heating demand through simulation.

4. Establish a first set of guidelines based on literature study and impact studies to be used in re-design.

5. Apply guidelines to re-design scenarios for a small residential building and validate with simulation.

6. Refine guidelines into a final product that is instantly understandable for designers.

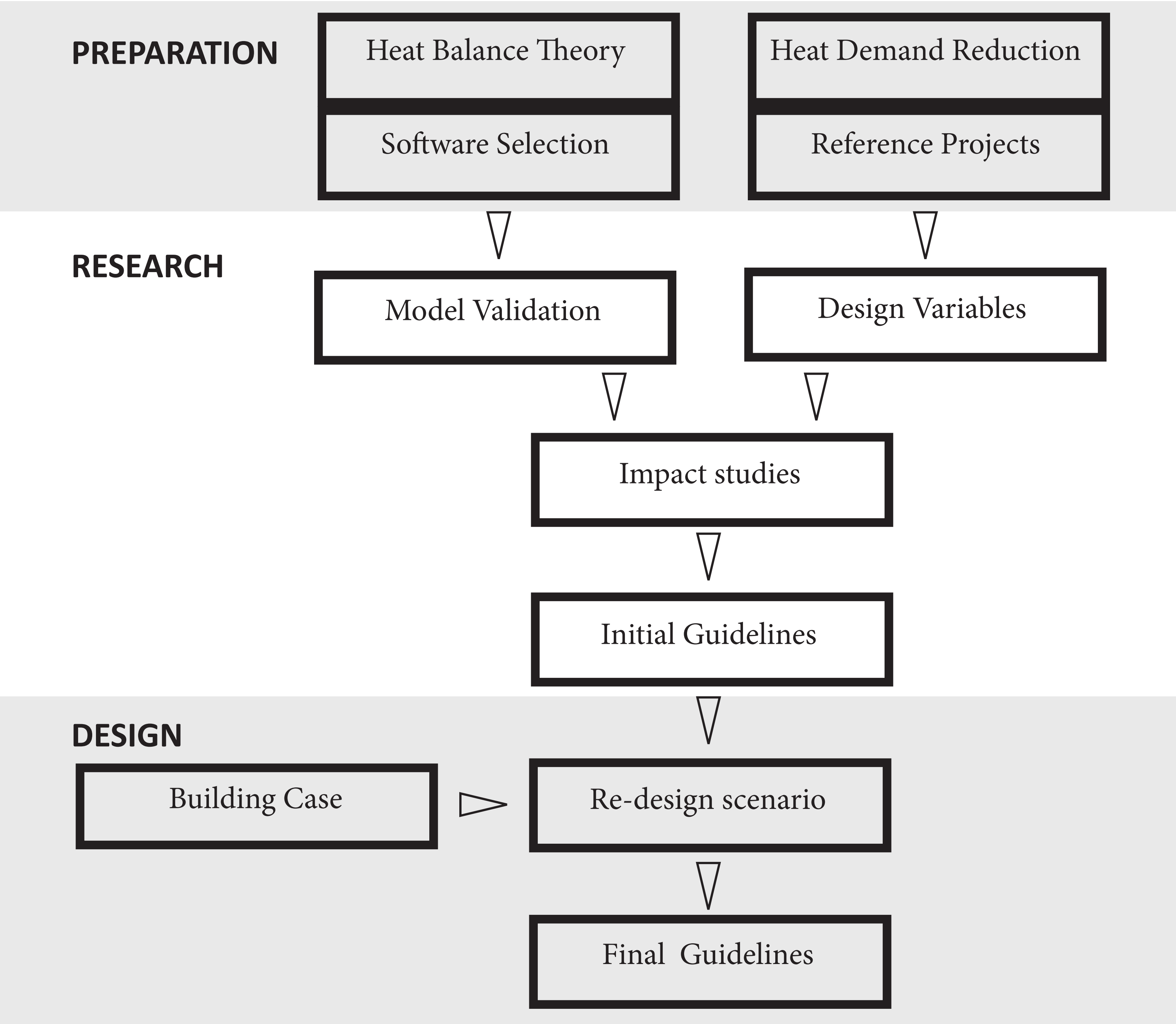


Figure 4 Process overview

3. Heat demand in residential buildings

3.1 Introduction to heat demand

3.1.1 Occupant comfort and health

It is commonly accepted that comfort and health of building occupants demands a stable temperature roughly in between 18 and 26 degrees Celsius. In this study the heating setpoint, the temperature below which the heating will be turned on, will be set at 19 degrees Celsius and the cooling setpoint at 26.

The specific preferred comfort temperature differs per gender, age, personal health and personal desire so it is hard to be more specific unless the specific users and their personal desires are known. In case of an elderly home for example a higher minimum temperature like 21 degrees could be assumed and cooling is more important due to the risks posed by fragile health during heat waves.

3.1.2 Climate conditions in the Netherlands

The outside temperature in the Netherlands often goes well below the minimum of 18 and therefore heating is a common requirement for residential buildings. The days that the outdoor temperature goes above 26 degrees in the Netherlands are limited and therefore cooling systems in residential buildings are a rare sight. High solar gains can cause overheating and therefore sunshading and natural ventilation are often applied as methods to keep indoor temperatures from rising above comfort levels.

3.1.3 Heat supply systems

Heat demand in the Netherlands is most commonly met by central heating systems. Heat is supplied by either an individual boiler per domicile or by a larger boiler or set of boilers that supply an entire building. This heat is then transported by water flow to radiators placed throughout the dwellings (see figure to the right). This same system usually also supplies hot water for other domestic use known as DHW (Domestic Hot Water).

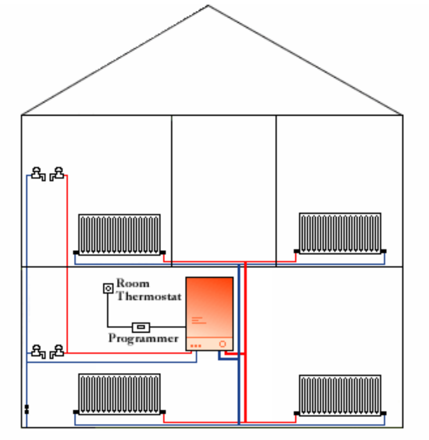


Figure 5 Schematic of central heating in a home. (Image source; http://www.huurders-helpdesk.info/centraleverwarming)

3.1.4 Goals and policies

BENG (Bijna Energie Neutraal Gebouw) is a Dutch acronym for the goal of making a house or residential building (nearly) energy neutral, equal to the NZEB or Nearly Zero Energy Building. BENG defines three criteria that must be met for residential buildings (source: RVO):

- maximum combined heating and cooling demand of 25 kWh/m^2
- maximum primary energy from fossil fuels of 25 kWh/m^2
- minimum 50% of energy from renewables

These criteria are often met by including energy supply systems such as solar panels to compensate for heat demand and to keep primary energy use low.

'Passive house' is a strategy that is aimed at reducing heat loss to such a bare minimum that it almost completely negates the demand for heating. Instead it relies on internal heat gain and possibly some solar heat gain to compensate for the small amount of heat loss. The maximum combined heating and cooling demand for a passive house is defined at 15 kWh/m^2.

3.2 Heat balance theory

3.2.1 Heat gains and losses

An accepted and relatively simple method for estimating the required energy to maintain a desired indoor temperature is the heat balance method. This method relies on only looking at the general flows of heat as inputs and outputs. Assuming the heating will kick in at a set minimum, or setpoint, the heating demand can be calculated by assuming this minimum as the indoor temperature. For the heat demand of a (part of a) building a heat balance calculation can be made based on the heat gains and losses of the building (Linden, 2000). These heat gains and losses are defined as follows (see also Figure 6):

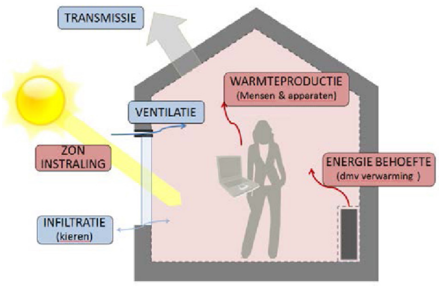


Figure 6 Visualization of heat gains and losses (Image source: Jansen & van der Ham, 2016)

- Transmission: heat transmission through the building skin.
- Ventilation: intentional air refreshment with air from outside.
- Infiltration: unintentional air refreshment with air from outside due to leaks in the building skin.
- Solar heat load: Solar heat radiation that enters the building through transparant surfaces.
- Internal heat load: Internal heat production caused by occupants, appliances and lighting.
- Energy demand: heating or cooling energy that is required to keep the temperature at a set minimum or maximum temperature.

Technically speaking ventilation and infiltration are mass flows, but for the heat balance method only the sensible heat difference between in-going and out-going air is taken into account to simplify the calculation.

The **steady state heat balance** equation looks like this:

$Q_{trans}+Q_{vent}+Q_{inf}+Q_{sun}+Q_{int}+Q_{demand}=0$ [W]

This formula simply states that the combined total of all heat gains and losses as defined by transmission, ventilation, infiltration, solar gain, internernal gain and demand (heating or cooling) should be 0 for the temperature to remain at the desired minimum. In this formula positive values are heat gains while negative values are heat losses. When the value for demand is positive, there is a demand for more heat supply and when it is negative there is a demand for a loss of heat, also known as cooling. In the Netherlands cooling of residential buildings is uncommon and airconditioners are a rare sight due to the limited amount of days per year that they would be required to run.

The **dynamic heat balance** equation is used to calculate the temperature change of a room over time. This equation takes into account the dynamic nature of temperature in a building and looks like this:

$$C.dT_i(t)/dt = Q_{i,sol}(t) + Q_{i,int}(t) - H_{tot} . (T_e(t) - T_i(t))$$

This formula allows for calculating the temperature change per time increment. This will allow the simulation to calculate hourly tmeperature change and if necessary the energy demand created to heat the building to the minimum set temperature (19 degrees).

3.2.3 Transmission loss

Transmission loss is determined by the heat transfer characteristics of the building skin (or facade), the surface area of the building skin and the temperature difference of the air inside and the air outside. If it is hotter outside than inside there will actually be transmission gain, but in this study the focus is on winter situations in which heating is required and by defenition the outside temperature will be lower than the desired inside temperature.

$$Q_{trans} = U \cdot A \cdot (T_e - T_i) \text{ [W]}$$

U	heat transfer coefficient of partition	[W/m²K]
A	surface area of the partition	[m²]
T_e	temperature of exterior	[°C]
T_i	temperature of interior	[°C]

3.2.4 Ventilation and infiltration loss

Ventilation and infiltration **heat flows** are determined by the respective air flows, the density and heat capacity of air, and the temperature difference between the air inside and the air outside.

$$Q_{vent} = V_{vent} \cdot \rho \cdot c_p \cdot (T_e - T_i) \text{ [W]}$$

$$Q_{inf} = V_{inf} \cdot \rho \cdot c_p \cdot (T_e - T_i) \text{ [W]}$$

V_{vent}	air flow for ventilation	[m³/s]
V_{inf}	air flow for infiltration	[m³/s]
ρ	air density (approx. 1.2)	[kg/m³]
c_p	heat capacity of air (approx. 1000)	[J/kg.K]
T_e	temperature of exterior	[°C]
T_i	temperature of interior	[°C]

Heat loss through ventilation can be reduced by the application of a heat recovery system that transfers heat from outbound air onto inbound air. This does require all ventilation air heading into and out of the building to go through one central processing unit.

Infiltration depends on the airtightness of the facade in the face of wind force suction and the behaviour of the occupant (opening doors and windows). Infiltration could be described as uncontrolled air leakage and can only be roughly estimated. It is defined by NEN 2687 into several categories as shown in Figure 7.

3.2.5 Solar heat gain

The solar heat flow is determined by the surface area of the glass receiving solar radiation, the intensity of the solar radiation and the Solar Heat Gain Coefficient (US) or g-value (EU).

$$Q_{sun} = A_{glass} \cdot q_{sun} \cdot SHGC \text{ [W]}$$

A_{glass}	surface area of glass in sunlight	[m²]
q_{sun}	intensity of solar radiation	[W/m²]
SHGC	Solar Heat Gain Coefficient or g-value	[-]

3.2.6 Internal heat gain

Internal heat flow is determined by adding the heat gain by occupants, appliances and lighting. These can be precisely calculated in specific cases. For this study the average number of the NEN7120 norms is used: 4 W/m^2.

$$Q_{int} = Q_{occupants} + Q_{appliances} + Q_{lighting} \text{ [W]}$$

3.2.7 Internal thermal mass

Internal thermal mass (dQ_{int}) is the heat stored in the mass of the building or room. In general this mass mostly consists of the walls and floors. To calculate the heat stored per square meter in a single type of surface the following formula can be used:

$$\boldsymbol{Q} = \rho \cdot c \cdot d \cdot \Delta T \ [J/m^2]$$

This part is only included in dynamic analyses and not used in the static heat bealance equation.

Klasse	Woningvolume in m^3		Maximale $q_{v;10}$	$q_{v;10}/m^2$
	Groter dan	Tot en met	(dm^3/s)	($dm^3/s \cdot m^2$)
1 **Basis**	-	250	100	1,0
	250	500	150	1,0
	500	-	200	1,0
2 **Goed**	-	250	50	0,6
	250	-	80	0,4
3 **Uitstekend**	-	250	15	0,15
	250	-	30	0,15

Figure 7 Infiltration qualification of buildings as defined by NEN 2687 (image source: Nieman Group B.V.).

3.3 Heat demand reduction strategies

3.3.1 Reducing heat loss with insulation

Just like a person can wear a thicker coat to stay warm, so a building can insulate itself to keep heat. Better insulation means slower flow of heat through the facade in the form of transmission. This reduces heat loss and directly translates to reduced demand for heat gain.

Facade insulation in the Netherlands has a long history due to the temperate climate and occasional cold winters. Although many northern european countries have a tradition of building houses from wood, the Netherlands saw an early adoption of brick instead. Inner city houses in the Netherlands were required to be made mainly of brick (due to fire hazard concerns) since the late middle ages and it was also used for larger projects such as town halls and churches. Brick isn't as insulating as wood however and in the temperate climate of the Netherlands this was a problem. Early examples of air gaps between two sets of brick walls have been found dating back up to 300 years (Kooij, 2013). Often these were applied in special buildings with higher safety requirements (such as prisons) or higher environmental requirements (such as libraries). Since the beginning of the 20th century these air gaps have become more ccommon in residential buildings. The oil crisis in the late 20th century increased public awareness and concern about energy use and since then the addition of insulation material in these air gaps (see Figure 8) became more commonplace.

Figure 8 Cavity wall example (image source: en.wikipedia.org/wiki/Cavity_wall)

The main material of windows, glass, also isn't very insulating. The U value of a single pane of glass is 5.8, which is three times the maximum average value of 1.6 allowed by the 2012 Dutch building codes. This has resulted in the same solution used for brick walls: air gaps. Frames made of wood (and more recently also aluminum or composite) hold together several sets of panes (double or triple, see Figure 9) with air gaps in between. The air gaps significantly reduce the heat flow since air has very low heat transmittance. Although the addition of standard insulation material isn't an option because it isn't transparent, the insulation value can be improved by filling the air gaps with gasses like argon which further reduces heat transmission. Modern technology has now reached a point where the glass area of a high performance window (e.g. U= 0.5) can be more insulating than the frame (e.g. U= 1.1). See Figure 11 for full overview of U values of different window types.

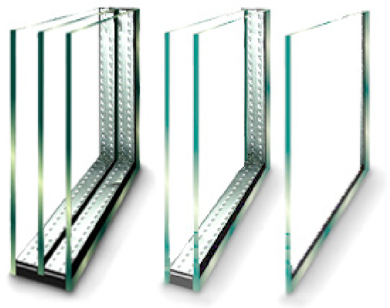


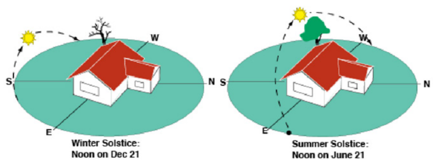
Figure 9 Triple, double and single pane glazing examples. (image source: www.hoe-koopik.nl/dubbel-glas/isolatieglas)

3.3.2 Increasing solar heat gain through windows

Of all the building design aspects related to heat demand reduction orientation is one of the most important (Pacheco et al, 2012) and frequently studied (Morrissey et al, 2011). When applied in the early stages of design it can be a low-cost measure that greatly benefits reducing heat demand. Orientation directly influences passive solar heating gains and can be of great benefit to the effective placement of solar energy supply systems.

In temperate climates where the sun's azimuth is high in summer and low in winter an orientation towards the equator (south on the northern hemisphere) is generally accepted as most beneficial. In general the longest side of a building should face south (Mingfang, 2002) both for solar heat gain in winter and control of gain in summer. The ideal range of orientation is shown in

To optimally make use of solar heat gain a high percentage of glass is required in the facade. Furthermore this glass will have to be sufficiently



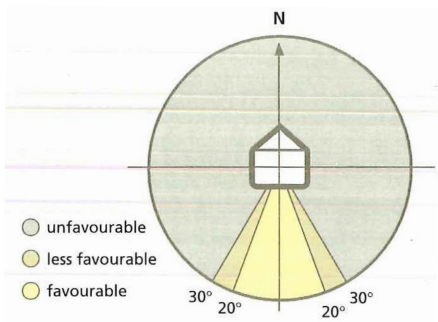


Figure 10 Diagram showing favourable orientations. (image source: Shittich, Solar Architecture)

		U-waarde [W/(m²K)]	TL-factor [-]	g-factor [-]
Ramen	Blank enkel glas	5,8	0,90	0,80
	Blank dubbel glas	2,8	0,80	0,70
	HR++-glas (niet zonwerend)	1,0-1,2	0,70-0,80	0,50-0,65
	Drievoudig begla-zing (niet zonwe-rend)	0,5-0,9	0,60-0,75	0,50-0,60
Platdakramen met HR++-glas	HR++-gelaagd vei-ligheidsglas (niet zonwerend)	1,1-1,2	0,80-0,85	0,60-0,65
Daklichtkoepels (inclusief geïso-leerde dakop-stand, transparant)	Dubbelwandig kunststof	2,8	0,85	0,80
	Driewandig kunststof	1,9	0,8	0,75
	HR++-glas met kunststof enkel-wandig koepel	0,7-0,8	0,70-0,75	0,50-0,55

Figure 11 U values of window types (source: Energie Vademecum, 2015)

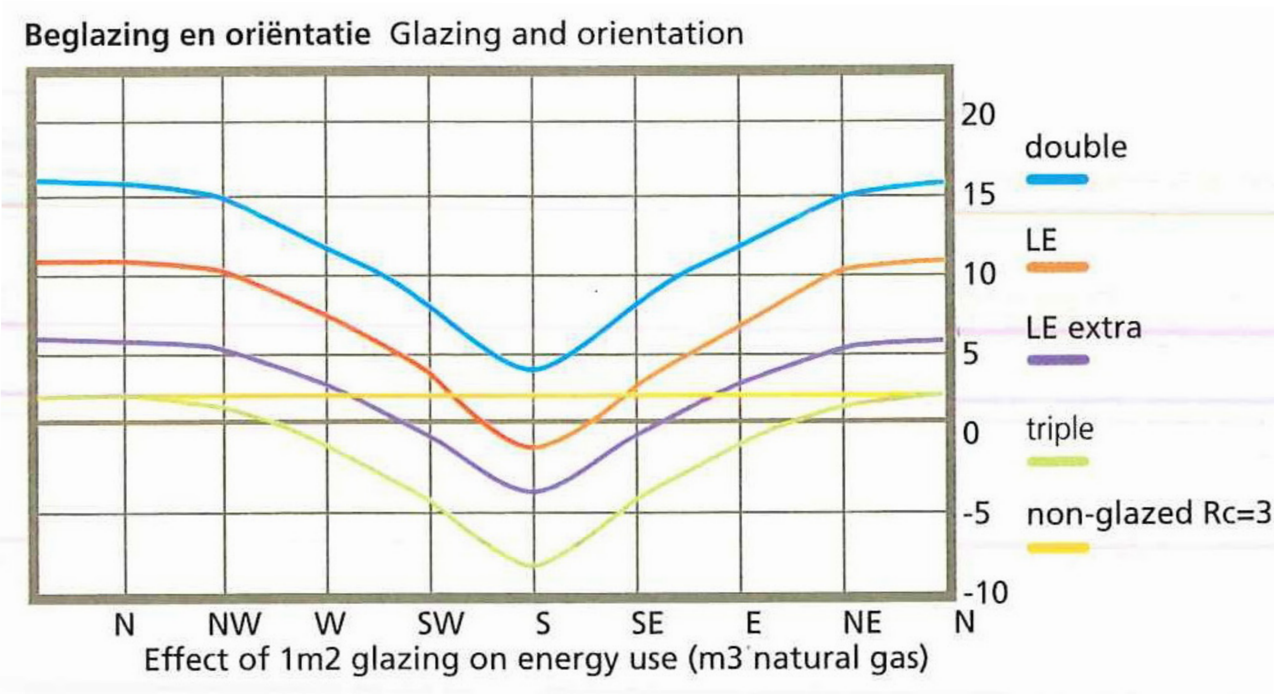


Figure 12 Glazing and orientation (Image source: Schittich, Solar Architecture)

insulating for the benefit of solar gain not to be outweighed by increased heat loss. In Figure 12 this is examplified by the impact on energy use (in this case quantified by cubic metres of gas required for heating) of different types of (insulating) glass at varying orientations. Obviously the impact is strongest when facing south (on the northern hemisphere). The yellow line represents a building without glass and an Rc value of 3 for the facade. With double glazing the benefit of solar gain never outweighs the increased heat loss due to poorer insulation. Double glass roughly equals a U value of 1.6 or Rc value of 0.7. At better insulation values however the solar gains start to outweigh the heat loss. At triple glazing the heat loss is sufficiently reduced that the glazing only provides benefit.

3.3.3 Relation of building shape to heat demand

The building shape has direct impact on the amount of total energy loss through the building skin and the amount of solar radiation it receives. Two key factors influence this impact: compactness and shape factor. What shape is preferable depends solely on the climate of the location the building will be placed in.

The compactness of a building is its ratio of exterior surface area to interior volume. In the context of heat demand, exterior surface area translates to loss. The higher the surface area the more loss. So ideally a building has a low ratio of exterior surfacea area to interior volume since this directly translates to lower heat loss and therefore lower heat demand.

The shape factor of a building is the ratio of building length to building depth. Together with orientation this

Climate is a key factor in determining what shape a building should be. In locations nearing the polar regions temperatures tend to be so low and solar radiation so limited that solar heat gain is unlikely to outweigh heat loss, compactness is the most relevant factor. In the temperate climate of the Netherlands winter temperatures are relatively mild and solar gains significant enough for shape factor to be more relevant.

3.3.4 Sunspaces

An application of solar heat gain theory is the use of sunspaces. Enclosed zones with a glass facade, traditionally seen as outside of the main thermal boundary or skin of the building. These spaces make use of passive solar gain to heat up and can provide several benefits (see Figure 13). They can act as a buffer zone between inside and outside air temperature, they can pre-heat incoming ventilation air and they can provide comfortable use during periods with sun but cold outside air.

The second energy strategy described in the Energie Vademecum is solar house architecture (see Figure 14). In this strategy house design is focused on solar heat gain. This design strategy is rooted in the design aspects a broadder array of design aspects: south facing glass facades, building shape and glazed additions such as atria or conseratories.

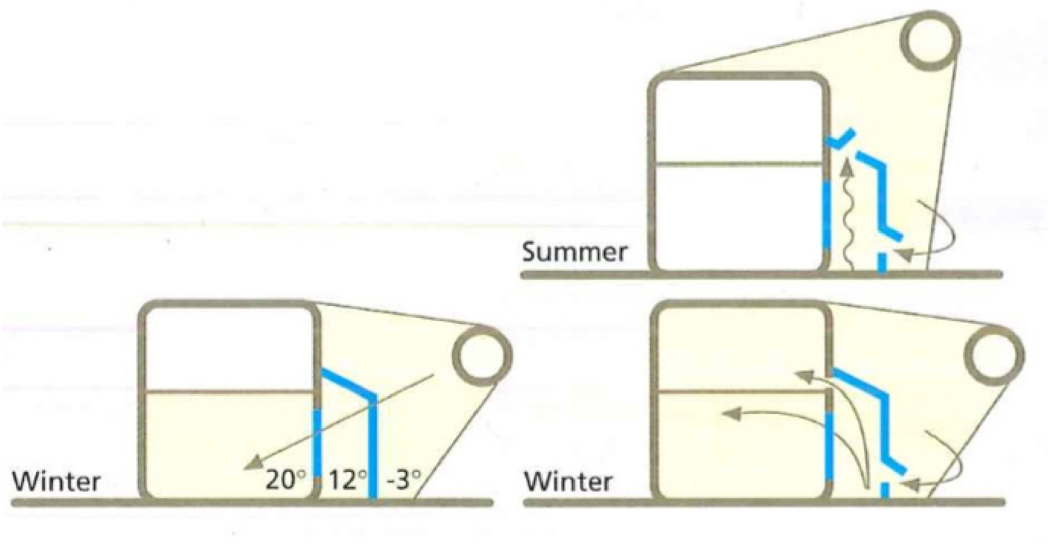


Figure 13 Beneficial use of atria and conservatories (Image source: Solar Architecture)

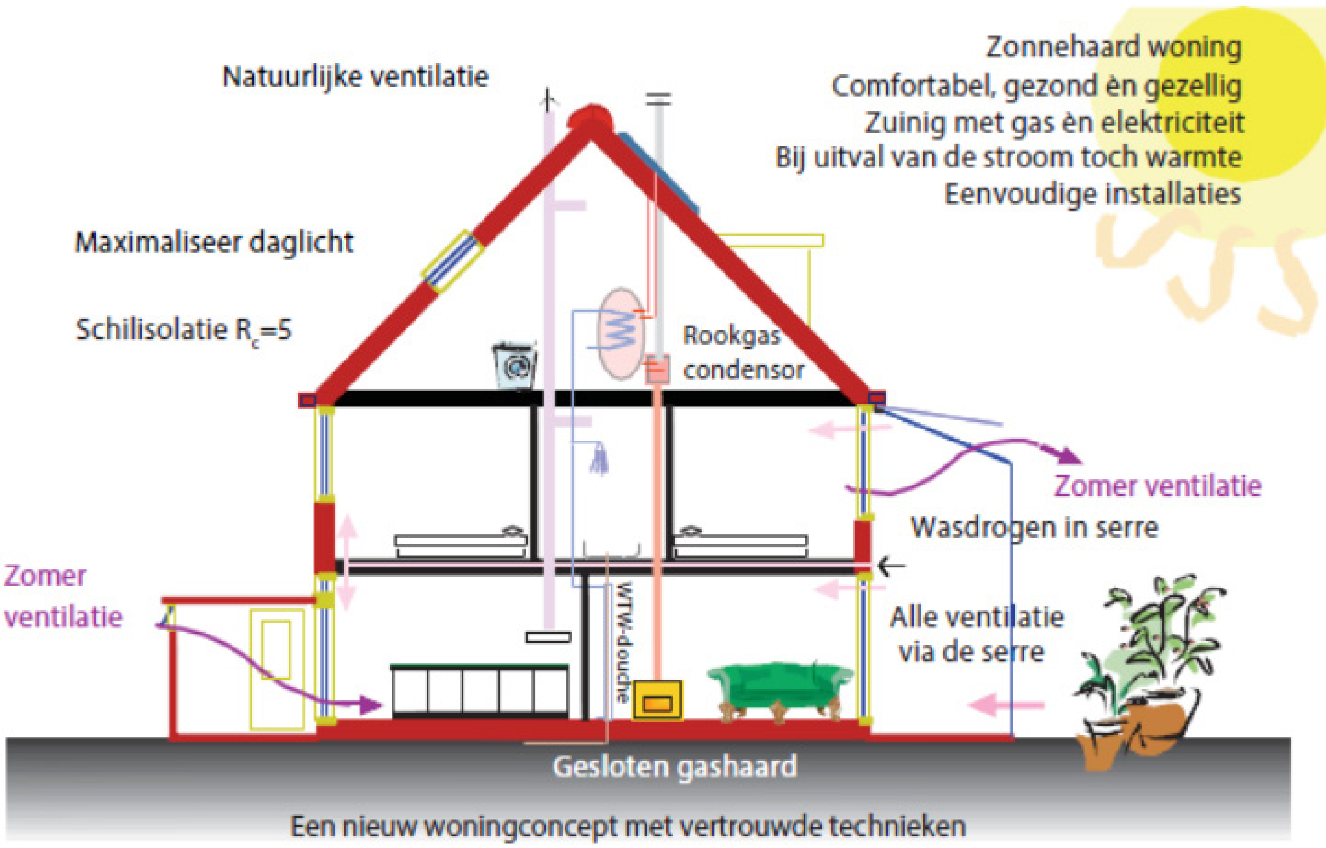


Figure 14 Typical Dutch home making use of solar heat. (source: Energie Vademecum)

3.4 Review conclusions

3.4.1 Heat balance

Heat balance theory is an accepted method of calculating heating demand in buildings. To validate the final method used in this study a comparison can be made between the chosen method and other calculation methods such as hand calculation.

3.4.2 Heat demand reduction variables

All the strategies mentioned can be translated into individual design variables to be used in this study.

The variables that will be studied are:
- insulation of facades: Rc 1 t o 8 to give a good idea of the impact as Rc increases.
- window insulation values: 1,6 and 0.7. 1.6 is the building code maximum and 0.7 an average value for triple glazing.
- orientation of glazed facade will be studied at all orientations from North to South.
- building shape will be studied in the form of two extremes: very compact and increased shape factor for solar gain.
- the impact of sunspaces will be compared to balconies and plain facade.

4.1 Freiburg SSSH

Figure 16 Sideview of SSSH (photo). The northern side is closed and flat while the southern side is rounded and consists of only windows and TI panels that maximize the gain of passive solar heat. (source: Voss, Stahl, & Goetzberger, 1994)

4.1.1 Introduction

The Freiburg SSSH (Self-Sustaining Solar House) is an experimental house developed by the Fraunhofer Institute in collaboration with architect Dieter Holken (Voss, Stahl, & Goetzberger, 1994). The energy demand of the house, both thermal and electric, is solely supplied by solar energy. Surplus energy is stored in the form of hydrogen created by electrolysis which can be used by a fuel cell to supply energy during times of insufficient supply.

4.1.2 Analysis

The Freiburg SSSH has many energy related systems and design elements to accomplish its goal of being energy self-sufficient. Analyzing these systems and design elements allows for better understanding of what could be relevant for this study.

The systems side supplies both hot water and electricity from solar energy (see Figure 18). PV panels provide electricity for domestic use. This electricity can be partly stored in a battery for peak use and large volume storage occurs by using the electricity to create hydrogen through electrolysis. Hot water is gained from solar collectors and is stored in a water storage tank.

The design elements are focused on harvesting passive solar heat and daylight. All rooms have at least some windows (roughly) facing south and the rest of the facade consists of trombe walls with TI (transparent insulation). These allow light to pass through to the mass of the building on the inside while providing a high insulation value that prevents the heat from escaping in winter (see Figure 15).

4.1.3 Relevance

Of the heating demand aspects of this study the most interesting aspect is the fact that the house was designed so that every room has windows facing south, (i.e. the winter sun) (see Figure 17)

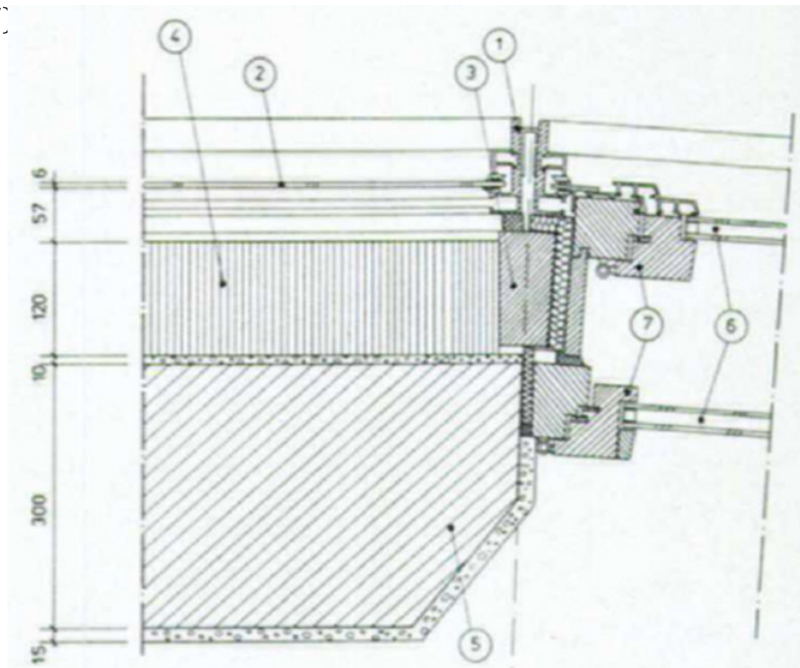


Figure 15 Detail drawing of a TI wall (left) and a twin set of double glazed windows (right). TI stands for Transparent Insulation and in this case allows for solar heat to pass through the insulation layer and heat the mass behind it. (source: Voss, Stahl, & Goetzberger, 1994)

Figure 17 Front view of SSSH. (source: Voss, Stahl, & Goetzberger, 1994)

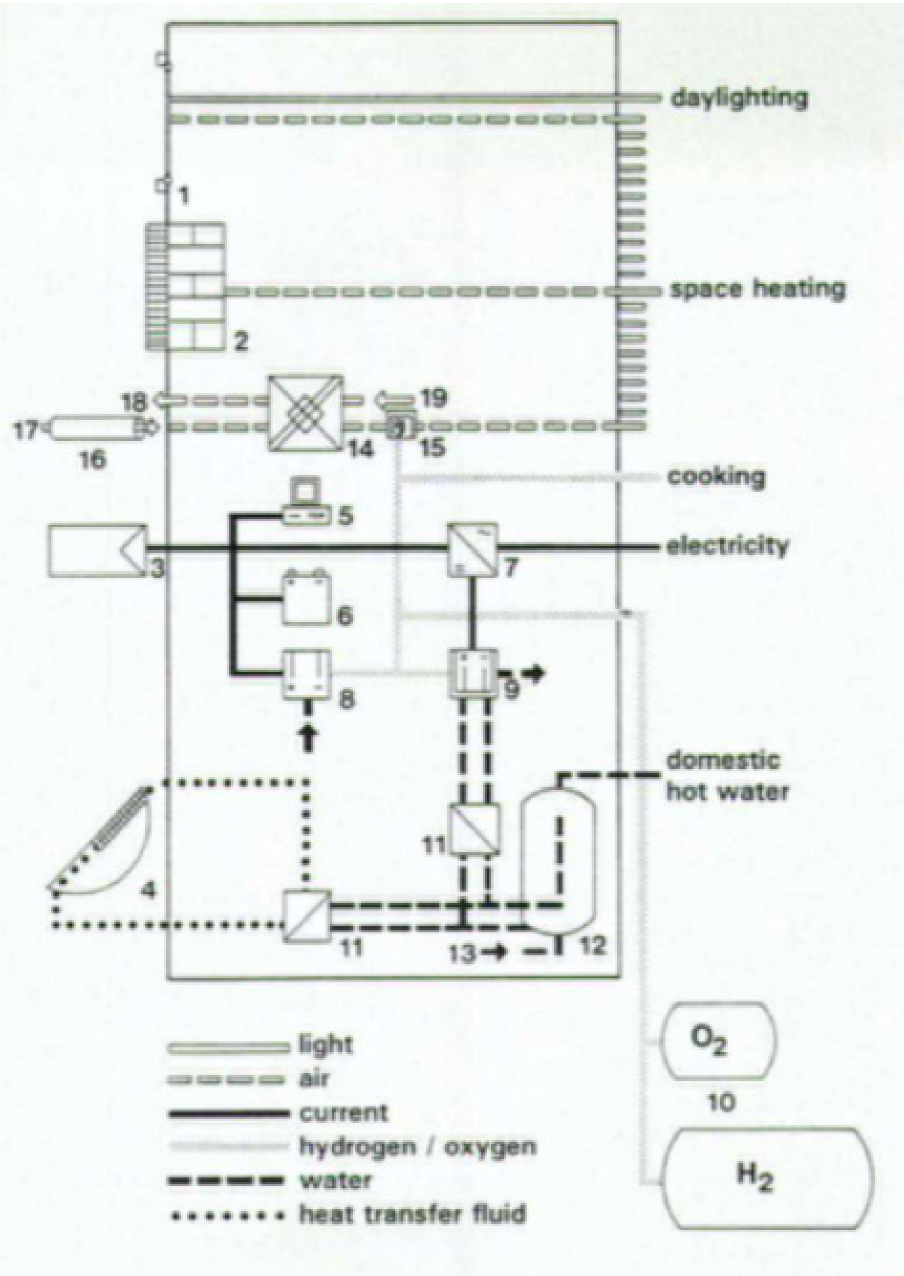


Figure 18 Schematic of the energy systems of the SSSH. Description:
1: windows, 2: TI wall, 3: PV generator, 4: thermal collector, 5: control and data acquisition, 6: battery, 7: inverter, 8: electrolyser, 9: fuel cell, 10: H_2 and O_2 storage tanks, 11: heat exchanger, 12: water storage tank, 13: mains water, 14: ventilation heat recovery, 15: heater. 16: subterranean heat exchanger, 17: ambient air, 18: exhaust air, 19: return air.
(source: Voss, Stahl, & Goetzberger, 1994)

4.2 BedZED

4.1.1 Introduction

On the outskirts of sub-urban London a new neighbourhood was developed with a lot of attention to innovative energy concepts. BedZED or Beddington Zero Energy Development is a project in which engineering office ARUP was responsible for the zero energy concept development and building physics part of the design. The resulting design delivered a set of identical terraced housing rows with extremely low energy demand (see Figure 19).

4.1.2 Analysis

BedZED has many new ideas incorporated into its design and an effort was made to make the systems side almost completely redundant through smart design elements. These design elements consist of several different applications of heat principles such as passive solar heat gain and combined use (see Figure 20). The overall ambition was to reduce the heating demand to such an extent (2 Wh/m^2) that only a low capacity centralized heating system for the whole neighbourhood, fueled by locally sourced pulpwood, would be sufficient as a back-up system.

The southern facades consist purely of sunspaces. They allow sunlight entry over the whole height of the facade and allow light to enter deep into the living spaces. Not only does this provide a lot of natural light it also provides passive solar heat gain.

The northern side of the houses are adjoined to workspaces that have an almost opposite heat and cold demand profile. This allows for a combined use situation in which the internal heat gain by occupants is never a negative factor. The workspaces are designed for minimum solar heat entry and rely on diffuse light for daylight which should seriously reduce glare issues.

Finally the facades are extremely well insulated to make maximum use of the passive gains. This means that the building can sustain a heat balance with very low heat gains.

4.1.3 Relevance

Although like the SSSH the focus of this design was in part on relying mostly on solar heat gain, the big difference is that the BedZED houses would not have extensive systems like the H_2 generation and storage of the SSSH. Instead the buidling physics concept focusses purely on passive gains and heat loss reduction. No wonder that this approach was actually realized because it should be a lot cheaper.

Figure 19 Photo of BedZED houses (source: ARUP).

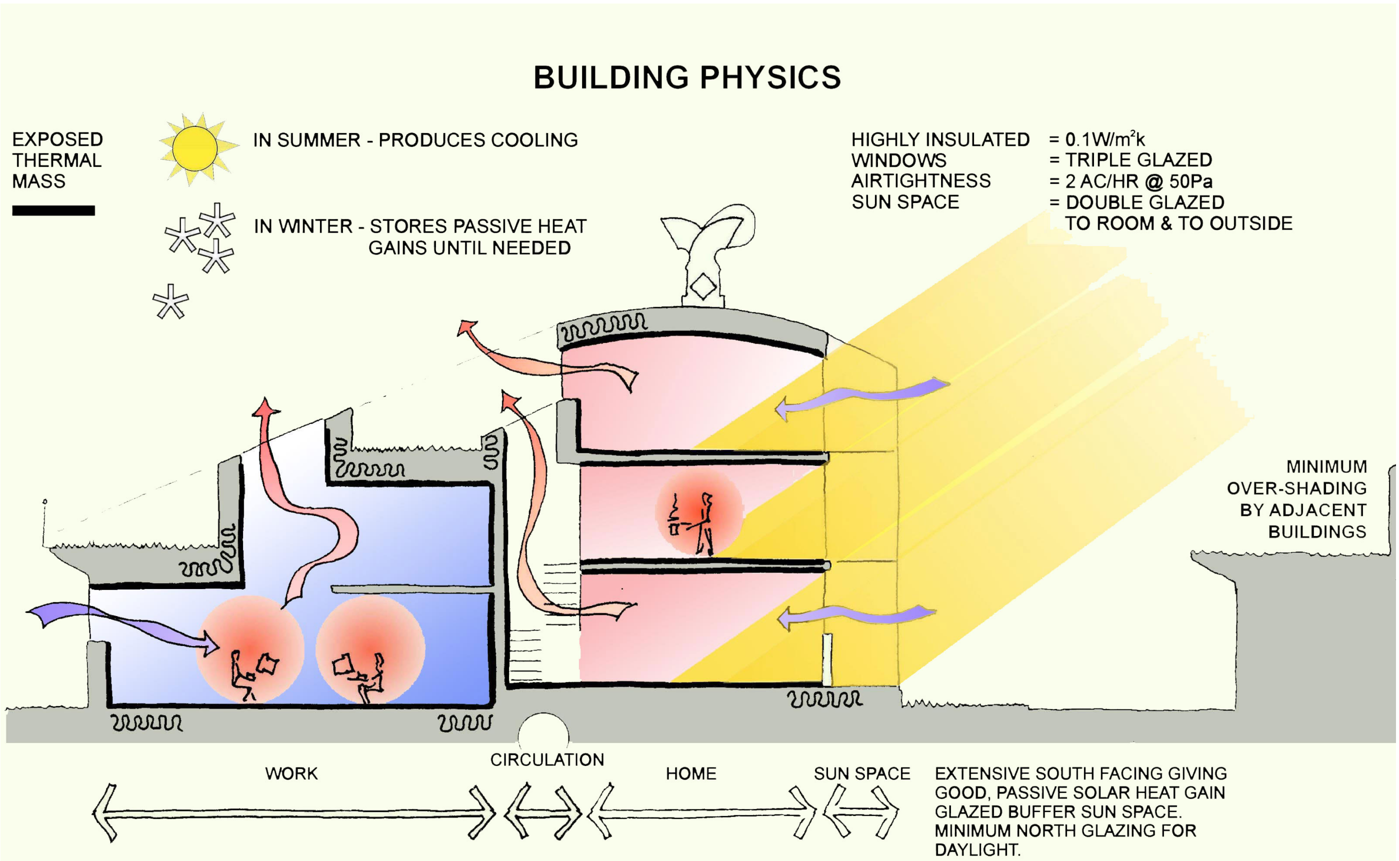


Figure 20 Schematic explanation of builddding physics aspects of BedZED (source: ARUP).

5. Modelling the case study building

5.1 Energy modelling software

5.1.1 Introduction

To calculate the heat or cold demand of a building for a whole year based on weather data for every hour of the year a dynamic energy simulation has to be performed. Therefore it has become common practice to use energy modelling software to run these calculations. A lot of this software is based on EnergyPlus. EnergyPlus is energy modelling software developed by the U.S. Department of Energy first released in 1998 (Crawley et al., 2001). It is used to model the energy consumption for all temperature and electricity related systems. The heat simulations are based on heat balance theory and include the dynamic effects of thermal mass.

Based on the goals of this study and academic requirements the criteria for software tool selection were:

- The tool should be easy enough to learn to use within the scope of this study.
- The tool should be able to give detailed results including heat demand and operative temperature on an hourly basis per zone.

5.1.2 Software choice

Based on the criteria above several programs were considered for use:

- TRNSYS
- DesignBuilder
- Honeybee (a Grasshopper plug-in)

TRNSYS (Transient system simulation tool) is commonly used for many energy related simulations due to its capabilities for simulating complex systems. The input for TRNSYS is purely numerical and lacks a geometry modelling interface. Instead it focusses more on systems and databases (see Figure 21). It has recently added a plug-in for Google Sketchup (TRNSYS3D) to allow users to import their models from Sketchup into TRNSYS.

DesignBuilder is an input interface for EnergyPlus that allows for modelling and assigning values in a 3D environment (see Figure 21). It's software specifically developed for engineers and architects.

Honeybee is a plug-in for grashhopper. Geometry input is modelled in Rhino modelling software and then connected to calculation modules in Grashopper, which is a graphical interface for programming connected to Rhino geometry that is most commonly used for parametric design. The Honeybee plug-in provides specialized calculation modules for thermal energy related simulations (see Figure 21). Honeybee has free and publicly available tutorials provided by one of the plug-in developers from MIT, Chris Mackey. This makes getting started with the software more appealing. After comparing these three options TRNSYS was dismissed because it is unnecessarily complex for the relatively simple simulations of this study. So the choice came down to either DesignBuilder or Honeybee which were comparable in many ways.

Honeybee was eventually chosen over DesignBuilder for three reasons: Firstly because of its promising results in a study by fellow student, Anne Leeuw, on energy producing high rise facades (Leeuw, 2016); secondly because of the tutorials that are so easily available for it; and finally because of the transparancy and flexibility of its calculation

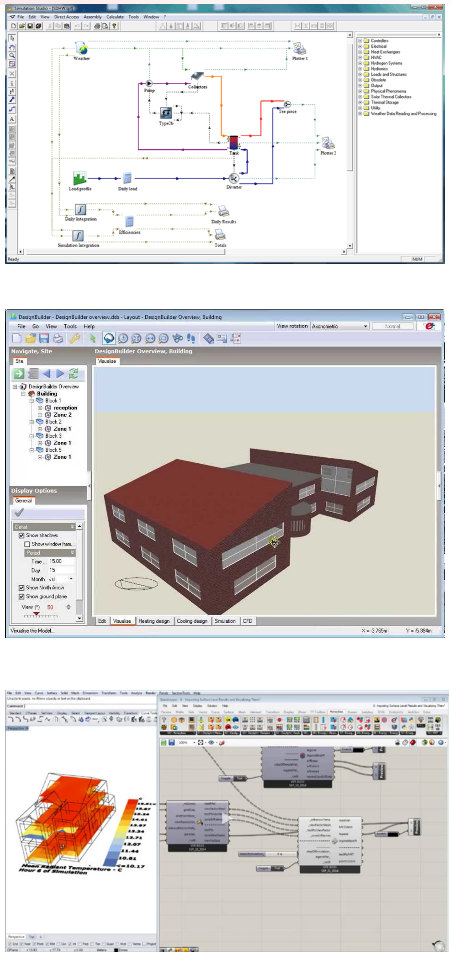


Figure 21 Overview of the interfaces of TRNSYS (top), DesignBuilder (middle) and Honeybee (bottom)

5.2 Model development and validation

5.2.1 Case study building description

The building that will be re-designed based on the findings of this study is a small residential building built in Berlin. It has two apartments on each floor with the three top floors being identical and the bottom floor slightly differing due to the space required for entrance, storage and utilities.
One facade is almost completely glazed(roughly 80%) and has balconies, the other facades have identical windows with sliding panes. The facade opposite the balconies has roughly 20% glazing and the side facades roughly 10%.

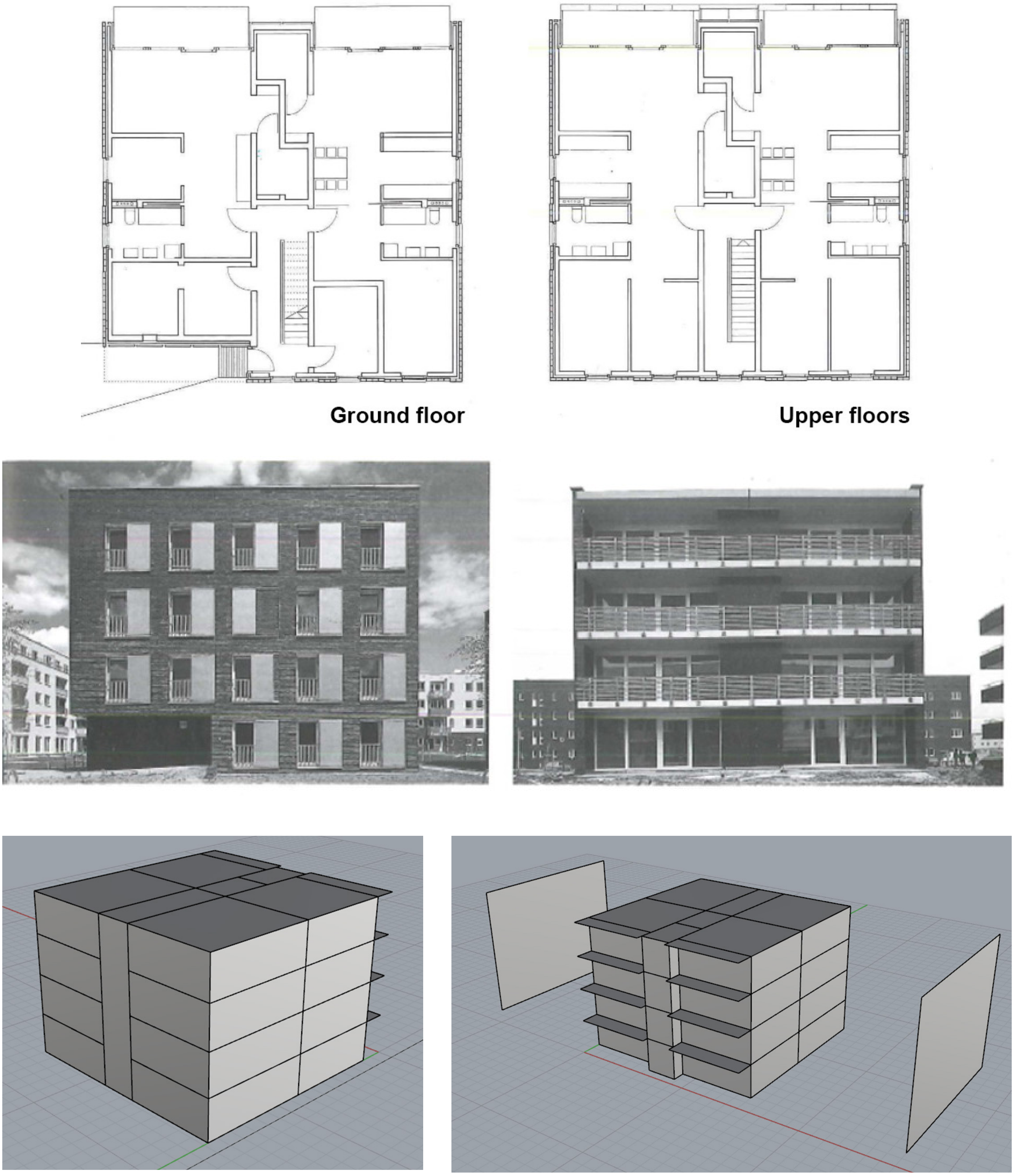


Figure 22 The case building: photos of the facades (top), the original floorplans (middle) and the rhino model (bottom)

5.2.2 Validation setup

Before using the Honeybee model in a study, a preliminary validation was set up to check the accuracy of the model method used in this study. Because the software itself is based on EnergyPlus, it is assumed to be reliable.

The output from the honeybee model is compared to the output from two alternative calculation methods:

1. Uniec2 an online calculation tool provided by the Dutch government for EPC calculations, which also gives yearly heat demand results based on the physical and thermal aspects of a room.
2. A basic heat balance calculation in Excel for February (the coldest month on average) based on the average temperature of that month. Due to low temperatures the heating be on throughout the month and an average temperature should give a representative figure of heating demand.

Two variations of the grasshopper model were made to match these alternative methods with the same input and calculation parameters.

5.2.3 Model setup and input

Both validation simulations focus on zone 2RB. See Figure 23 for a schematic floorplan of zone partitions. The floorplan is based on the re-design case building. The building has 4 floors 0-3 with zone 2RB being on floor 2. This zone was chosen to simplify the calculation and focus only on energy loss through the facade.

In Honeybee the schedules for the internal loads are set to a continuous amount (the daily average) and the total is 4.2 W/m^2(as in the excel file).

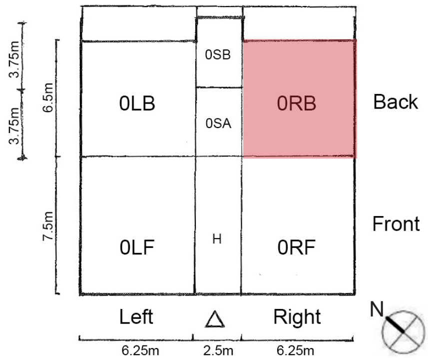


Figure 23 Original floorplan (top), zone partitions for the model (bottom).

Input for yearly	Honeybee	Uniec2	
Ti	19	19	°C
Te	EPW file	NEN	source
U value walls	0.21	0.21	W/m^{2}K
U value windows	1.6	1.6	W/m^{2}K
Ventilation	0.7	0.7	dm^3/s.m^2
Infiltration	0.2	0.2	dm^3/s.m^2
Sun	EPW file	NEN	source
g-value	0.6	0.6	factor
Q internal	4.2	4	W/m^2

Input for monthly	Honeybee	Excel	
Ti	19	19	°C
Te	EPW file	3.7	°C or source
U value walls	0.21	0.21	W/m^{2}K
U value windows	1.6	1.6	W/m^{2}K
Ventilation	0.7	0.7	dm^3/s.m^2
Infiltration	0.2	0.2	dm^3/s.m^2
Sun	(almost) none	none	
g-value	0.6	-	factor
Q internal	4.2	4.2	W/m^2

Ti - interior Temperature (setpoint)
Te - exterior Temperature
U walls - Heat transfer capacity of walls
U windows - Heat transfer capacity of windows
Ventilation - amount of air circulation (on purpose)
Infiltration - amount of air circulation (leakage)
Sun - Energy from sun
SHGC - Solar Heat Gain Coefficient
EPW - climate file used by Honeybee
NEN - official norms document Uniec2 bases it input on: NEN7120
Q internal - total internal heat load

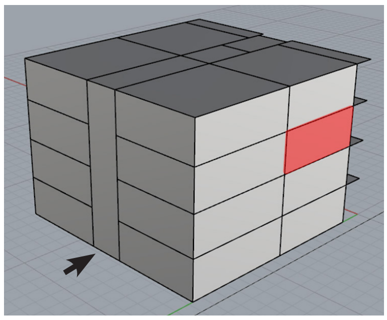


Figure 24 3D geometry in Rhino with position of 2RB highlighted

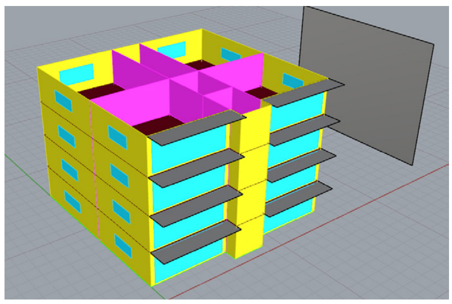


Figure 25 Honeybee Validation - Glazing visualized in Rhino.

5.2.4 Uniec2 valiation

A room was specificied in the input forms for Uniec2 that matched the geometry input for Honeybee, with the same adjoining surface characteristics and facade elements. The lack of transparancy in Uniec2 made matching the input problematic and required some digging through NEN norm documents. This resulted in discovering that the weather data used in Uniec2 slightly differs from the EPW file used by HB. Most critical is the slight difference in average dry bulb temperatures, most notably in the months of January, February and March (see Figure 26).

The results from Uniec2 show a yearly heat demand of 101 kWh/m^2 (see appendix A for full report).

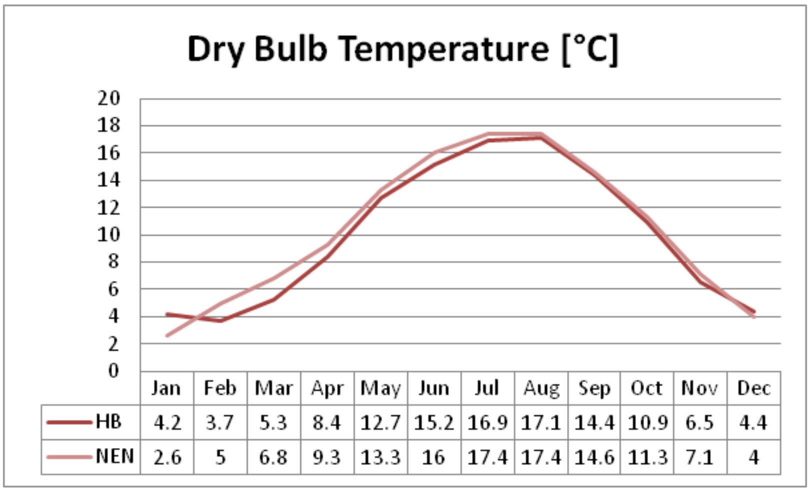


Figure 26 Average dry bulb temperatures as found in the HB (Honeybee) EPW file and NEN (Uniec2).

Heat flow type	Heat flow [W]
$Q_{transmission}$	-492
$Q_{ventilation}$	-585
$Q_{infiltration}$	-190
$Q_{internal}$	+191
Q_{total}	-1075

Table 1 Heat flows according to heat balance calculation for February

5.2.5 Excel validation

Based on the heat balance model a calculation was set up in excel for one room for the month of February (the on average coldest month according to the climate file used by HB). All in-going and out-going heat flows except for sun load were calculated. The same general input was used as with Uniec2 but the average outdoor temperature was based on the EPW climate file obtained through Honeybee.

The most important values are in Table 1 (full calculations in appendix ...). Taking the total monthly heat demand of 1075 W, multiplied with the number of hours in February (24 times 30) and dividing it by the floorspace of the zone (7.5 by 6.25 meters), the average heat demand for February is 17 kWh/m^2.

The transmission loss is mostly due to the loss through the glazed facade (384 W as opposed to 45 W through the closed facade with almost equal surface area). The high ventilation loss is due to the fact that it lacks a schedule (it's always on) and lacks any heat recovery. The loss to infiltration gives an indication of the importance of an air-tight house in winter.

5.2.6 Results and conclusions

The results from both validation methods:

- February heat demand :
  - Excel 17.0 kWh/m²
  - Honeybee 17.3 kWh/m²
- Annual heat demand:
  - Uniec2 101 kWh/m²
  - Honeybee 102 kWh/m²

After having made sure all the input is as equal as possible the results are quite promising for the HB model. With a roughly 2 percent deviation from the Excel calculation and 1 percent deviation from Uniec2, the model seems accurate enough to be valid for further reliance in this study.

Compared to the Dutch BENG limit of a maximum yearly energy demand of 25 kWh/ m² these results may seem high even though the insulation already meets minimal building code standards. As mentioned the ventilation is set to very high in this calculation and lacks heat recovery. By looking at the heat flows in Table 1 it is easy to recognize the impact a heat recovery of 80% would have and the significance of reduced infilatration. Further reduction would be due to use of heat from the sun which will play a prominent part in this study.

6 Impact studies

6.1 Introduction

6.1.1 Study goals

This series of studies is intended to quantify the impact of individual design choices on the heat demand of a small residential building in the Netherlands. These design choices relate to physical aspects that directly influence the annual heat demand of the building (see Figure 27).

6.1.2 Theoretical basis

The main building physics aspects in question here are the reduction of heat loss through the facade and the increase of solar heat gain (when advantageous) through glazed parts of the facade. The problem is that these two aspects often require opposite design directions:

- *Avoiding heat loss* through transmission translates to demands for well insulated facades and a compact building shape to reduce the ratio of facade area per internal volume.
- *Increasing solar heat gain* requires the opposite in the form of glazed facades (which typically have a lower insulation value) and a building shape that has increased 'sun surface' area, i.e. facade area facing the sun in winter (south in the Netherlands). This translates to a less compact, more elongated shape.

6.1.3 Study description and structure

The study focuses on several facade aspects:

- Insulation value of the facade.
- Orientation of a highly glazed facade (80% glass).
- Building shape compact vs. increased sun surface.
- A specific design application is studied, the 'sunspace': a zone that can act as both an interior and exterior space with a glazed facade. A balcony with a glazed facade for instance. This facade has a part that can open up in summer to allow for use as an exterior space and when closed can provide a comfortable interior space during periods of lower temperatures by making use of heat from the sun. It also provides a buffer zone function for the interior space behind it.
- Finally the sunspace is compared to a plain facade and a facade with open balconies (as found in the case study building) in an attempt to prove or disprove the potential advantage of the sunspace.

The rest of this chapter is subdivided by each individual study as follows:

6.2 Plain facade: Insulation
6.3 Plain facade: Orientation
6.4 Plain facade: Building Shape
6.5 Sunspace: Insulation
6.6 Sunspace: Orientation
6.7 Sunspace: Building Shape
6.8 Comparison: Shape A (Compact)
6.9 Comparison: Shape B (Elongated)
6.10 General discussion and conclusions

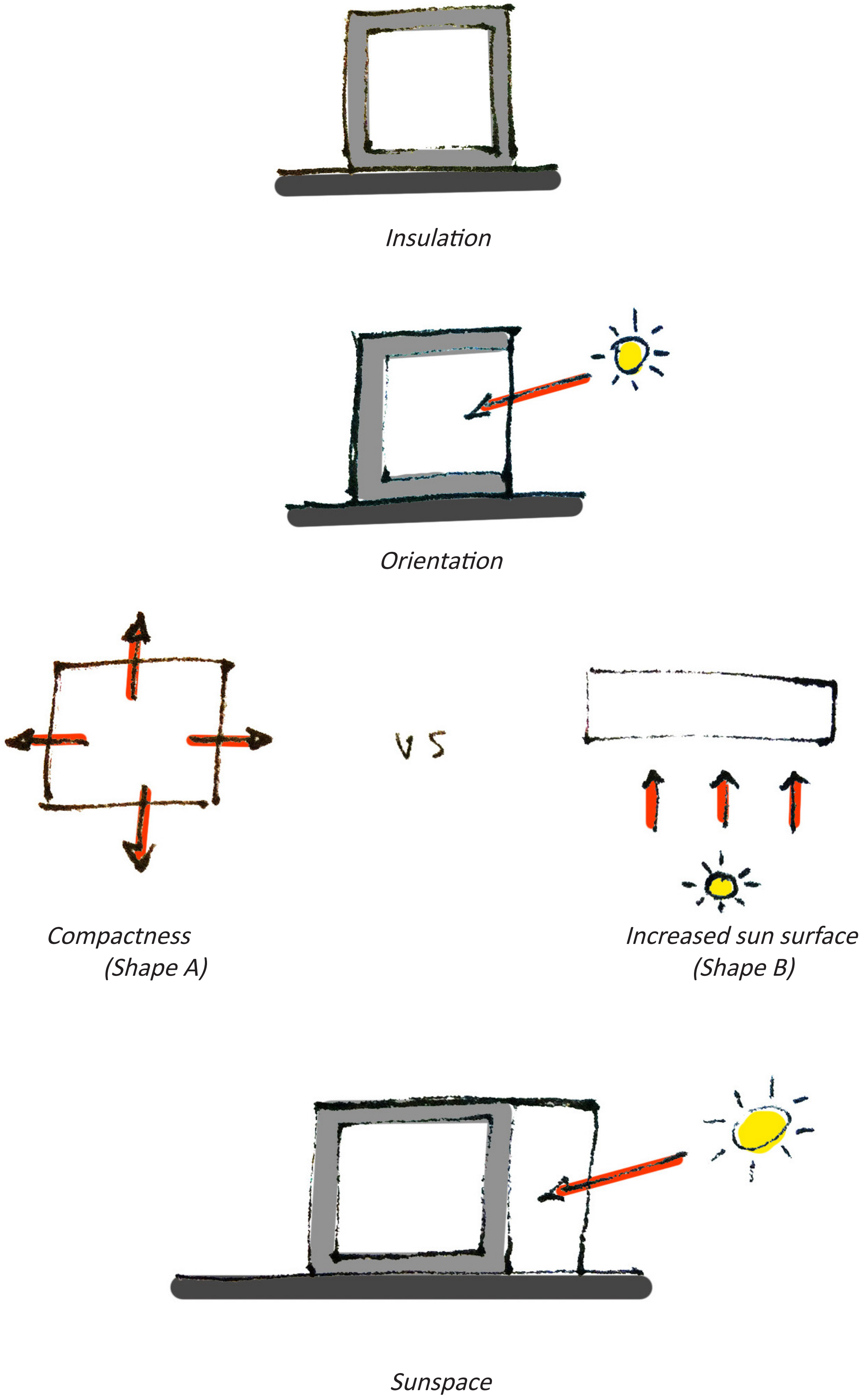
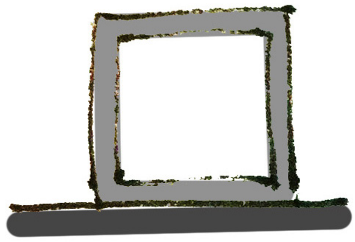


Figure 27 Schematic overview of the design choices discussed in this chapter.

6.2 Plain facade: insulation

6.2.1 Introduction

The first impact study is about different levels of insulation in the facade and their impact on heat demand. Insulation is one of the most straightforward variables in reducing heat demand. A higher insulation value means less heat loss due to transmission. Due to the cost usually associated with higher facade insulation values it is generally preferrable to insulate up to a point where it is most effective or necessary. The temperate Dutch climate requires all buildings designed for regular occupance to have a decent level of insulation. Although winters are mild, many days of the year see outside temperatures drop well below the minimum comfort temperature of 18 degrees Celsius.



The value used for insulation is Rc which is the inverse of the U-value plus general air transmission resistance ($Rc = 1/U + R_{air}$) which is the heat transmission value of a partition. So the minimum Rc value for facades as defined by the Dutch building codes, Rc = 4.5, equals a U value of about 0.22 W/m^2K. Compare this to the building code maximum for glass U= 1.6 W/m^2K and it's clear that windows are expected to be far less insulating than the facade.

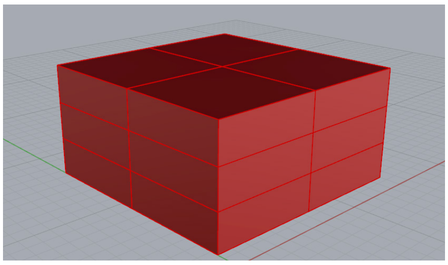


Figure 28 Basic geometry for impact studies with four identical zones of 7.5 by 7.5 meters and 2.5 meters high per floor.

6.2.2 Case description

The geometry used in the simulations is a simplified version of the case study building (see Figure 28). Each floor is divided into four equal zones. This dramatically reduces the simulation times and still suffices for the purpose of this study, which is to show the general impact of individual design decisions.

In this particular study the facades are identical and consist of 20% glazing. The rest of the facade consists of a basic buildup of limestone blocks and insulation material.

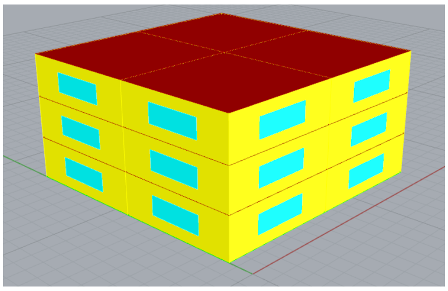


Figure 29 Geometry with glazing visualized in Honeybee

6.2.3 Honeybee model input

- Wall Rc= 4.5 and roof/floor Rc= 6.
- Window U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5
- Heating setpoint is 19° C.
- Ventilation is 0.7 or 0.14 (simulating 80% heat recovery) dm^3/s per m^2.
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

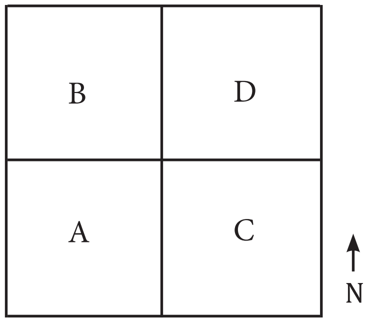


Figure 30 Zone partitions. In this study all zones have mostly opaque facades with only 20% glass. This is assumed to be the bare minimum for habitability in this study.

6.2.4 Variables

Main variable is the insulation value of the opaque facade surface. Several sets are simulated for different values of window U value (1.6 or 0.7) and Heat Recovery (none or 80%).

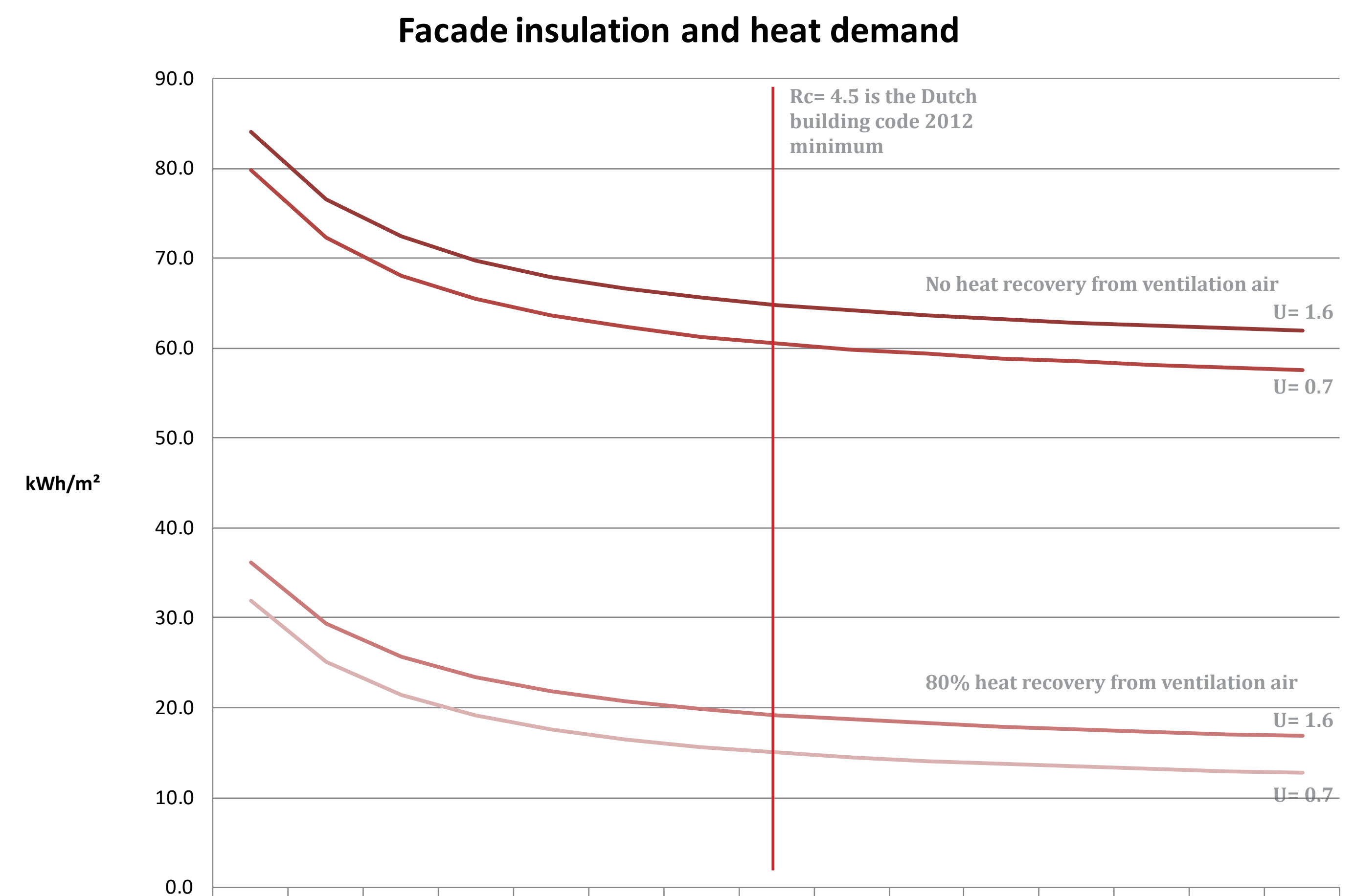
6.2.5 Discussion

Simulations of the building with an increase in value for insulation of the facade show a decrease in impact as the insulation level rises (see Figure 31). The greatest impact, measured in drop in annual heat demand, is from an Rc value of 1 to about 2.5 after that the impact gradually levels off. The heat demand reduction from Rc=1 to Rc= 4.5 ranges from 25% to 50% for the different variants. But the impact of increasing Rc from 4.5 to 8 barely reaches a decrease of 10% in annual heat demand.

It is also important to note the immensely significant impact of heat recovery when you have a well ventilated building. Heat demand for a building with Rc value of 4.5 and heat recovery of 80% is well under 30% that of the heat demand of the same building without heat recovery.

6.2.6 Conclusions

The impact of insulation decreases as the Rc value rises. The difference between an Rc of 1 and 2.5 is very significant. But an increase from 4.5 to 8 has much less impact. Insulation is important but only up to a point. The building code minimum of 4.5 is already quite decent. In a standard concrete facade with an average performing insulation material (0.03 W/m-K) on the outside this can already be achieved with an insulation layer of 125 mm thickness. To achieve an insulation value of 8 in the facade,



	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
U=1.6, no HR	84.0	76.5	72.4	69.8	68.0	66.7	65.6	64.9	64.2	63.7	63.3	62.9	62.5	62.3	62.0
U=0.7 no HR	79.9	72.3	68.1	65.5	63.7	62.3	61.3	60.5	59.9	59.3	58.9	58.5	58.2	57.9	57.6
U=1.6 with HR	36.1	29.3	25.6	23.4	21.8	20.7	19.9	19.2	18.7	18.2	17.9	17.6	17.3	17.1	16.9
U=0.7 with HR	31.9	25.0	21.4	19.1	17.6	16.5	15.7	15.0	14.5	14.1	13.7	13.4	13.2	12.9	12.7

Figure 31 Heat demand (in kWh per m²) of the middle floor of the study building at different levels of facade insulation (Rc 1 - 8 with 0.5 intervals). Line 1 for windows with U= 1.6 and no Heat Recovery. Line 2 for windows with U= 0.7 and no Heat Recover. Line 3 for windows with U=1.6 and 80% Heat Recovery. Line 4 for windows with U= 0.7 and 80% Heat Recovery.

Context: connecting Rc to insulation thickness

Insulation thickness for a material with conductivity of 0.03 W/m-K (fairly average insulation material):

Rc 1 = 20 mm

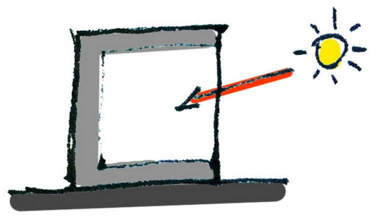
Rc 4.5 = 125mm

Rc 8 = 230 mm

6.3 Plain facade: orientation

6.3.1 Introduction

Solar heat gain is the only positive heat flow as defined by building heat balance theory that is directly influenced by the building (shape) design. The position and amount of glass in the facade is relevant to the heat demand of a building because it allows sunlight to enter the interior of the building. This does not only provide natural lighting but also positive heat flow that can reduce the heat demand. A well insulated building that still lets in a lot of sun can potentially capture a lot of heat this way and benefit from it well after the sun has gone down.



When designing a facade for sunlight entry it is important to note the changing angle of sunlight throughout the year. The angle of sunlight entry depends on location and time. It is an extremely variable aspect. Glazing is usually not very variable. In standard buildings a single fixed position is chosen for glazing. To benefit from solar heat and the resulting lower heat demand several aspects have to be considered:

- the angle of the sunlight: in the Netherlands the midday sun comes in at a 15 degree angle in winter (December), a 35 degree angle in March/September and a 65 degree angle in summer (June);
- when solar heating is favorable and when it is not: overheating can become a serious issue in summer if proper measures such as sunshading and capacity for natural ventilation are not taken;
- glass windows have a poor insulation value compared to opaque insulation material: a glass facade that barely 'catches' sun, will likely lose more heat than it will allow the building to gain.

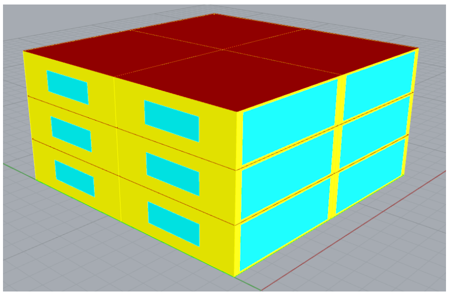


Figure 32 A visualization fo the geometry with glazing for study 2 with the 80% glazed facade on the right.

6.3.2 Case description

The simulated building is similar to the one in 6.2 except for one facade now having 80% glazing (see Figure 32).

6.3.3 Honeybee model input

- Orientation of main glass facade: variable
- Wall Rc= 4.5 and roof/floor Rc= 6
- Window U= 1.6 with g-value of 0.6
- Heating setpoint is 19° C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

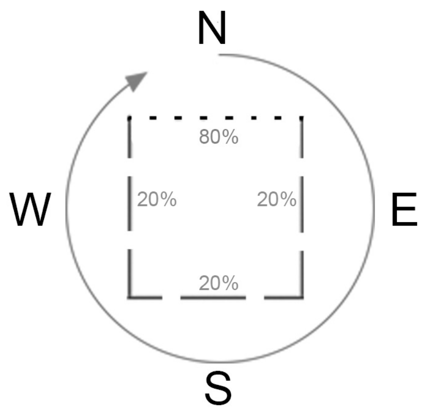


Figure 33 Diagram of the orientation study and the direction of rotation.

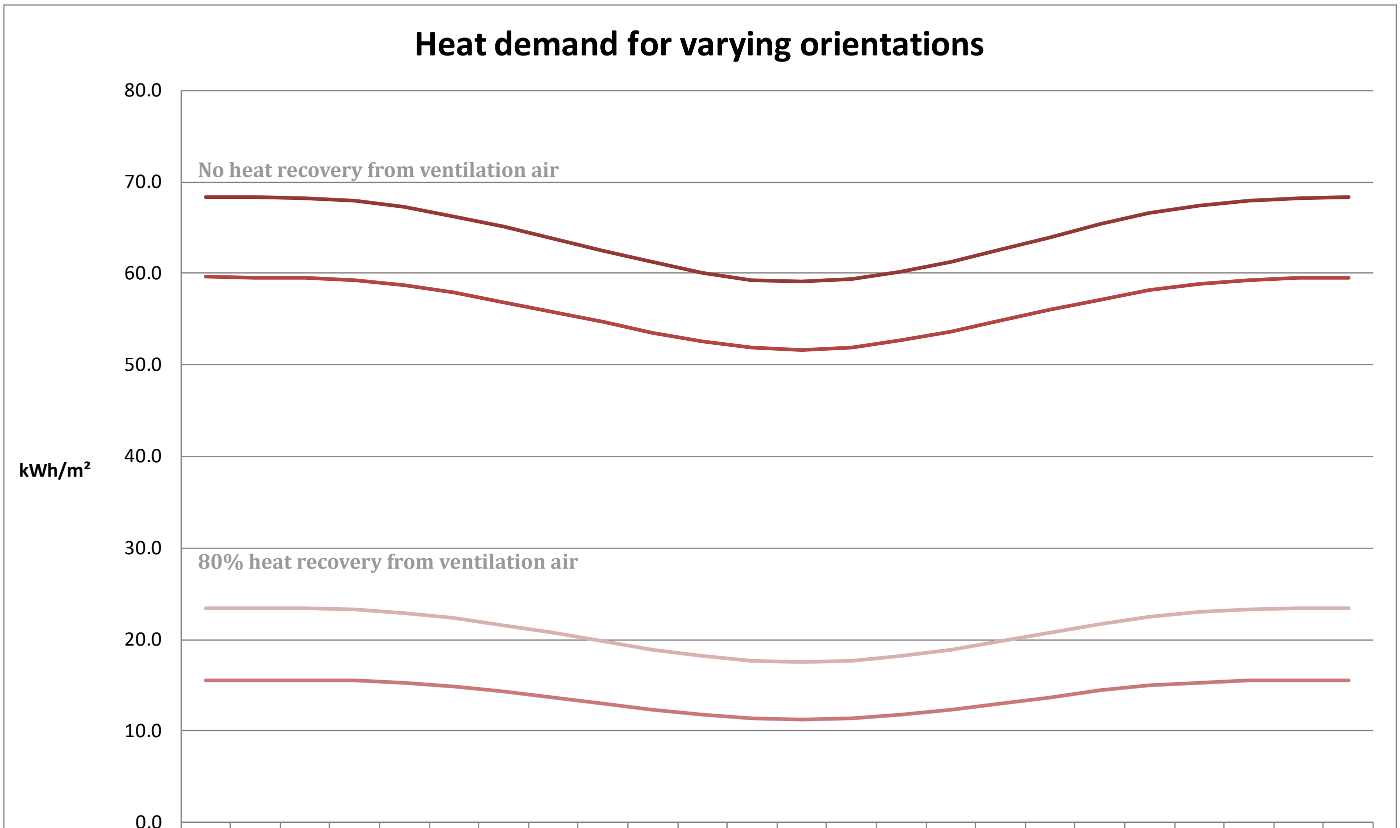
6.3.4 Variables

The study building is simulated at differing orientations (see Figure 33) to find the impact of orientation on the heat demand of the building. The orientation change has an interval of 15 degrees.

6.3.5 Discussion

The direction the 80% glazed part of the building faces significantly impacts the heat demand of the building (see Figure 34). With heat recovery this building can easily meet the maximum heat demand set for a passive house ($15kWh/m^2$) at the right orientation.

With glass that has a U value of 1.6 the facade only performs better when close to facing directly south. A well insulated version (U= 0.7) performs better even when facing east or west and has a 30% heat demand reduction potential when facing straight south.



	N			NE			E			SE			S			SW			W			NW		
U=1.6	68.4	68.4	68.3	67.9	67.2	66.3	65.1	63.8	62.5	61.2	60.0	59.3	59.1	59.4	60.2	61.3	62.6	64.0	65.4	66.6	67.5	68.0	68.2	68.4
U=0.7	59.6	59.6	59.5	59.2	58.7	57.9	56.9	55.8	54.7	53.5	52.5	51.8	51.6	51.9	52.6	53.6	54.8	56.0	57.2	58.1	58.8	59.3	59.5	59.6
U=1.6 +HR	23.4	23.4	23.4	23.3	22.9	22.3	21.6	20.7	19.8	18.9	18.1	17.6	17.5	17.7	18.2	18.9	19.8	20.7	21.7	22.4	23.0	23.3	23.4	23.4
U=0.7 +HR	15.5	15.5	15.5	15.5	15.3	14.9	14.4	13.7	13.0	12.3	11.8	11.4	11.3	11.4	11.7	12.3	13.0	13.7	14.4	15.0	15.3	15.5	15.5	15.5

Figure 34 Heat demand (in kWh per m²) of the middle floor of the study building at varying orientations (starting at North with 15 degree intervals). Line 1 for windows with U= 1.6 and no Heat Recovery. Line 2 for windows with U= 0.7 and no Heat Recover. Line 3 for windows with U=0.7 and 80% Heat Recovery.

6.3.6 Conclusions

Solar heat can play a significant role in reducing heat demand in a building that is well insulated. Any facade with a roughly southern orientation in between SW and SE can benefit from this.

It is however important to note that overheating is taken into account when designing glass facades. Measures against overheating include sunshading in summer and enabling ample natural ventilation during times of excessive heat gain.

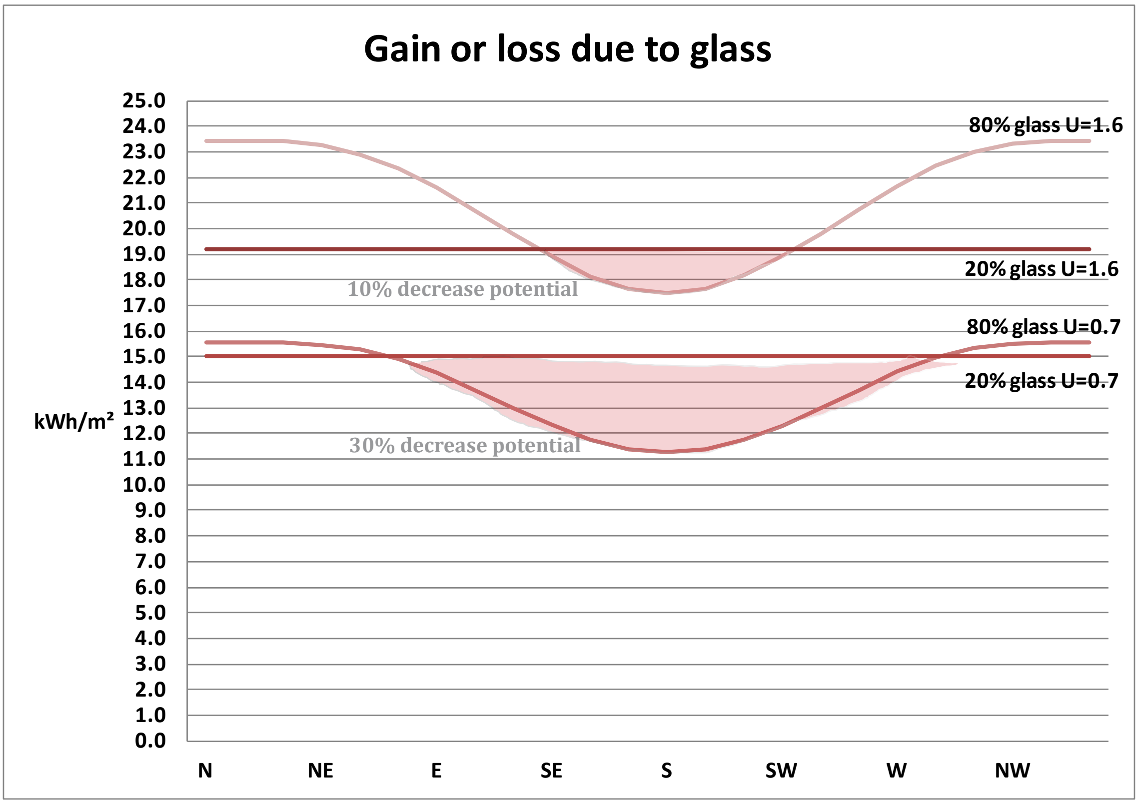


Figure 35 Heat demand comparison between a 80% and 20% glass version showing the potential heat demand reduction for different orientations. Note that glass facades will lose more heat than they gain when they aren't orientated towards the south. The lines for the 20% glass facade represent the value of the previous study and not of a version that was simulated for different orientations.

6.4 Plain facade: building shape

6.4.1 Introduction

Building shape has two aspects that influence heat demand: compactness and the amount of surface facing the sun (see Figure 36). Compactness is advantageous because it reduces loss through transmission. A compact building has low surface area facade compared to internal volume. Sun surface is advantageous because it allows more heat from the sun to enter the building as long as the facade is designed to allow for it.

To investigate the difference between a compact building and a building with a higher sun surface both will be simulated with an increasing percentage of window area on the facade facing the south.

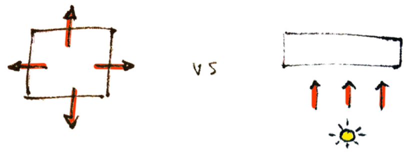


Figure 36 Compactness vs. Sun surface

6.4.2 Case description

This case includes two different geometries (see Figure 37): the geometry of the previous studies, shape A, and an adjusted geometry that has all zones arranged in a line from west to east, shape B.

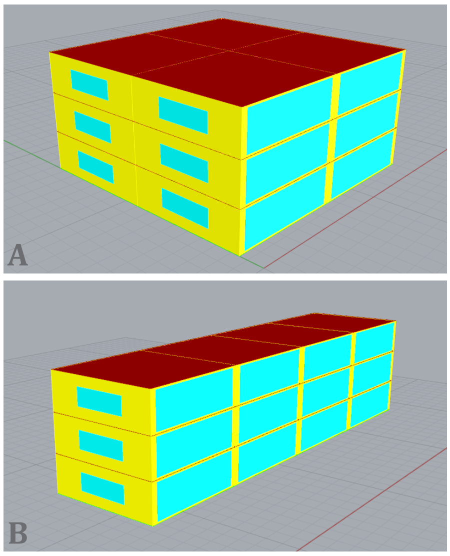


Figure 37 Honeybee visualization of compact shape A (top) and 'sun surface' shape B (bottom). Both glass facades face south in this study to show the maximum potential.

6.4.3 Honeybee model input

- Orientation of main glass facade: South facing
- Wall Rc= 4.5 and roof/floor Rc= 6.
- Window U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5.
- Heating setpoint is 19˚ C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

6.4.4 Variables

The simulations are run for both building shape variants A and B. In these variants the percentage of glass in the facade is varied from 20% - 80. This was done for two types of glass, with insulation U= 1.6 and U= 0.7.

6.4.5 Discussion

With high insulation values version A has a higher heat demand than version B even at 20% glass surface and it only gets worse from there (see Figure 38). Version B has a steeper increase in cooling load as the glass percentage rises.

A downside of glass facades is that they can easily lead to overheating of a building. Operative temperature for zone 2A (western side zone on middle floor) shows that this is the case for the study building for a majority of the year (see Figure 40).

6.4.6 Conclusion

With a high insulation value, making use of solar heat by increasing the surface area of the building facing the south is very advantageous in terms of reducing heating demand.

It should again be noted that this study only looks at the heat demand side. Using heat from the sun always goes hand in hand with the risk of overheating in summer. It is important to keep in mind when solar heat gain will be advantageous and when it will not be.

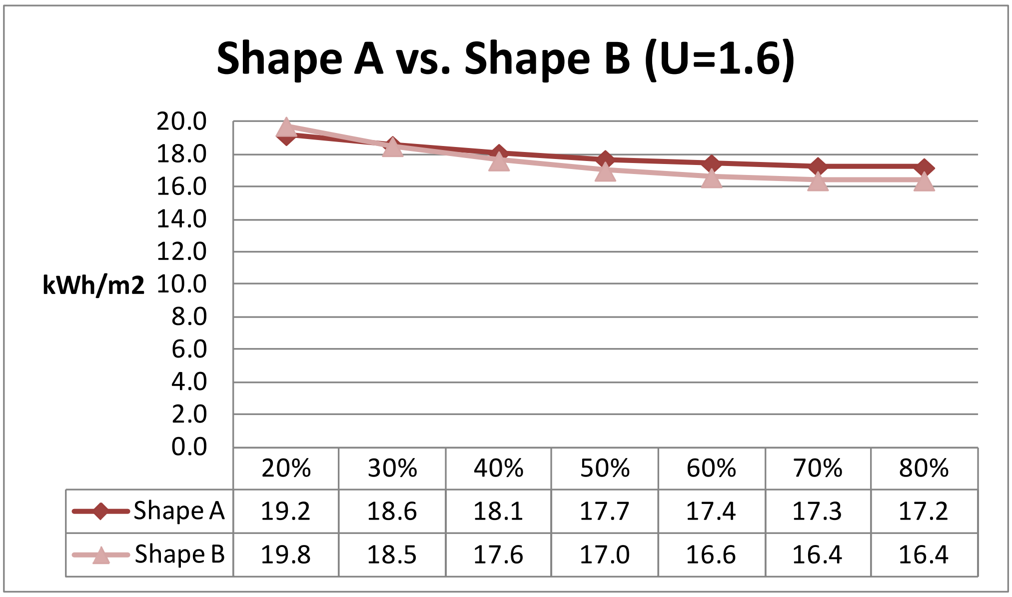


Figure 38 Heating demand and cooling demand for version A and version B. Glass percentage of the south facade varies from 20% to 80%.

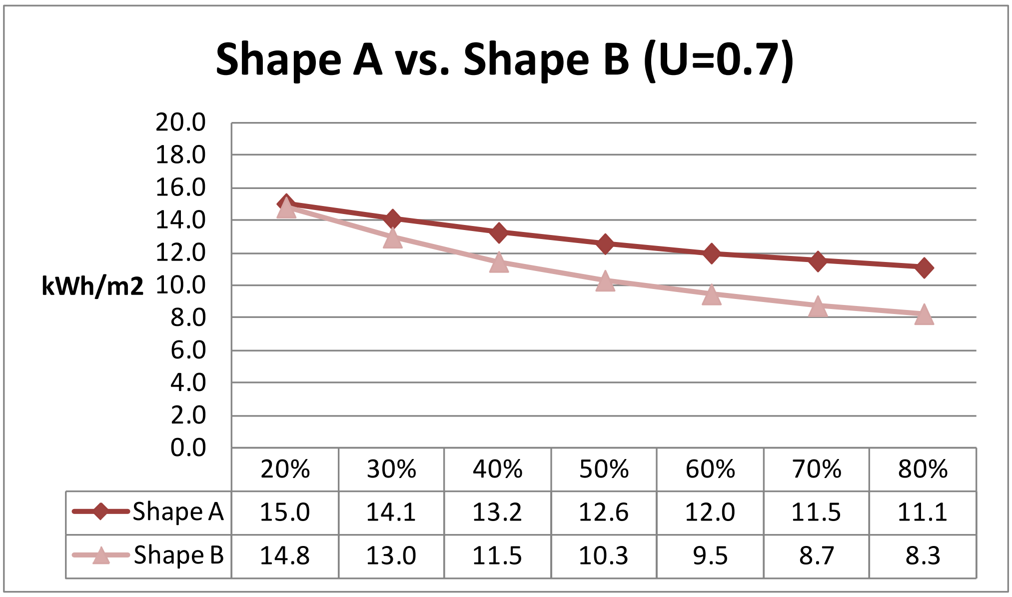


Figure 39 Heating demand and cooling demand for version A and version B. Glass percentage of the south facade varies from 20% to 80%

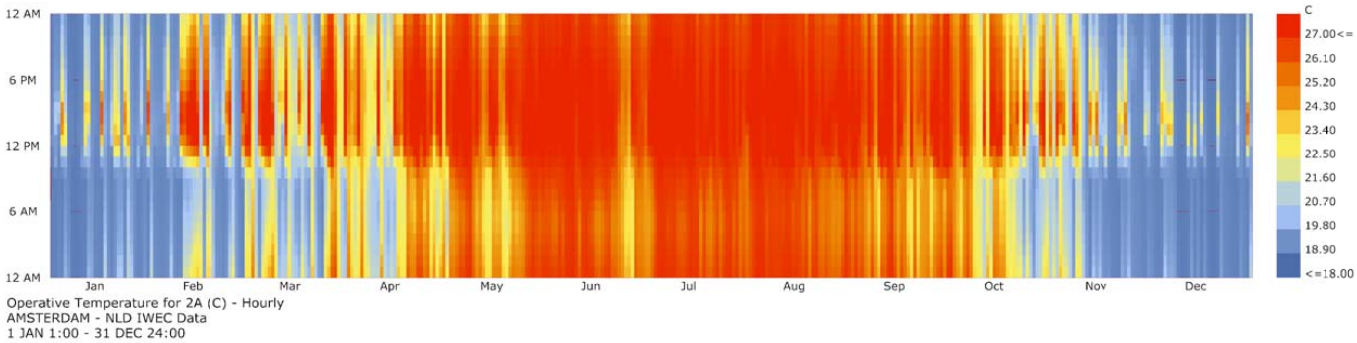
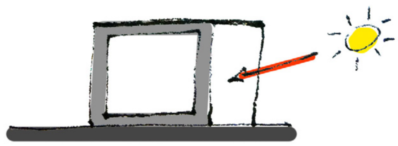


Figure 40 Visualization of the operative temperature per hour over the whole year for the southern facing variant. Hours at which op. temp. is 27 degrees or higher are in red. In general it is assumed that comfortable indoor temperature range is 18 - 26.

6.5 Sunspace: insulation

6.5.1 Introduction

Sunspaces are spaces with a glass skin intended to maximize the solar heat gain. In this case we are talking about balconies with a glass skin. This allows for more comfortable use of this space in winter as it retains heat from the sun when oriented correctly. To avoid overheating in summer it should be shaded from the summer sun and include a method of (natural) ventilation.



Although the application of sunspace like additions is gaining popularity among designers it is not necessarily well understood. This study and following ones will show the impact a sunspace can have on heat demand and what factors are influential.

6.5.2 Case description

The main geometry remains the same as the first study building, but now it has added sunspace volumes on the south facade. These volumes have a glass facade facing the exterior as well as on the interior side.

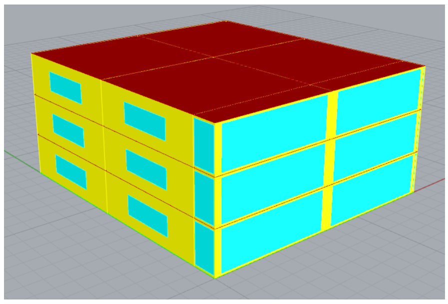


Figure 41 Visualization of study building with Sunspace addition.

6.5.3 Honeybee model input

- Orientation of sunspaces: South facing
- Wall Rc= 4.5 and roof/floor Rc= 6
- Windows: U= 5.8 with g-value of 0.7; U= 2.8 with g-value of 0.7; U= 1.6 with g-value of 0.6; U= 0.7 with g-value of 0.5
- Heating setpoint is 19˚ C and sunspace cooling setpoint is 30˚ C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

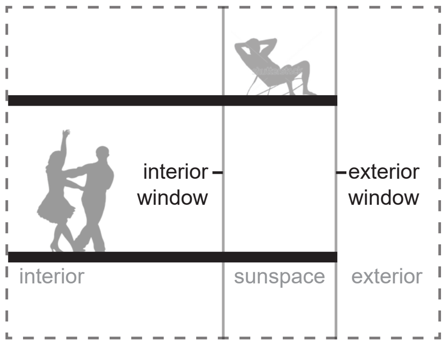


Figure 42 Schematic representation

6.5.4 Variables

Two sets are simulated: one with an interior window U value of 1.6 and one with 0.7. In both sets the exterior window goes through the U values of 5.8, 3.8, 1.6, and 0.7. These values approximate the insulation values of respectively a single pane window, a (simple) double pane window, a window meeting building code minimum standards and an extreme high performance window. It should be noted that the value of 0.7 is that of the glass itself and that in such high performance windows it is often the window frame that is less insulating and therefore causes more heat loss than can be expected when only taking the 0.7 U value into account.

6.5.5 Discussion

The results show that lowering the U value of the outer facade decreases heat demand (See Figure 43). Heat demand goes down for both the set with an interior window with U= 1.6 as well as for the one with U= 0.7.

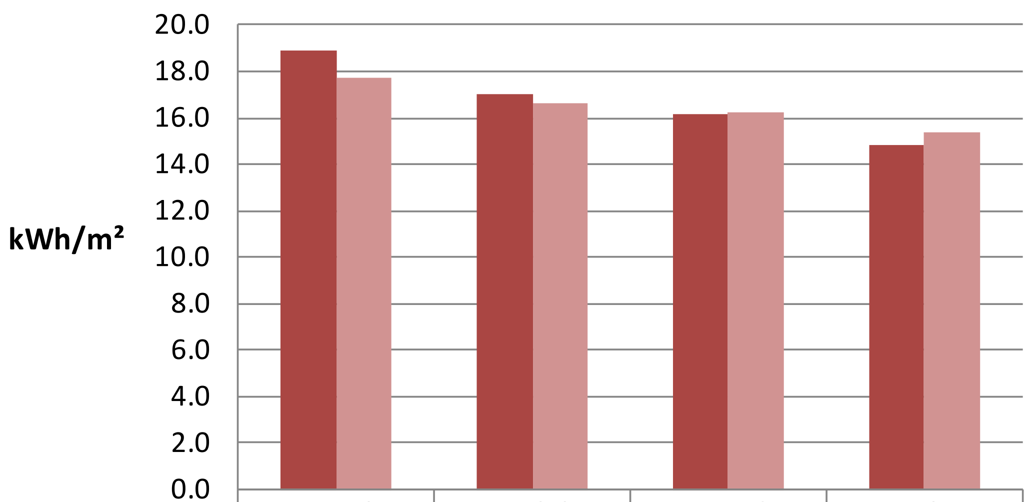
What is interesting is that with an interior window with U= 1.6 the decline is steeper and although it starts out with a higher heat demand at U= 5.8 for the outer window, it ends up with a lower heat demand at U= 0.7 for the outer window compared to the version with a interior U= 0.7.

These results are for a middle floor so heat loss through floor and ceiling are significantly reduced.

6.5.6 Conclusions

Based on these results it could be argued that reducing heat demand with a sunspace is best achieved with a very low U value (below 1.6) for the exterior window. At the same time it is not advisable to invest in a lower U value for the interior facade compared to that of the exterior window since this seems to work counterproductively. This result makes sense since U value is an indicator of heat flow and in this case we want heat to flow from the sunspace into the interior space more rapidly than it flows to the outside.

So a relatively lower U value on the interior side seems advisable when the exterior side is well insulated (U= 1.6 or below). This only applies if the sunspace is kept relatively airtight so there is no significant heat loss due to air flow.



	U= 5.8	U= 3.8	U= 1.6	U= 0.7
U interior= 1.6	18.9	17.0	16.2	14.9
U interior= 0.7	17.7	16.6	16.3	15.4

Figure 43 Heat demand for the study building with a Sunspace. Two different U values of glass for the thermal skin are set against a variation of U values for the glass of the exterior facade of the Sunspace.

6.6 Sunspace: orientation

6.6.1 Introduction
As with the simple glazed facade the sunspace's performance should be influenced by orientation. In this case however there will be less direct solar heat gain into the interior space. Instead the sunspace will act as a buffer. This should lead to reduced heat loss overall and reduced peak solar heat gain.

6.6.2 Case description
The building is the same as described in 6.5: the compact building shape variant with sunspaces on one facade.

6.6.3 Honeybee model input
- Orientation of sunspaces: variable
- Wall Rc= 4.5 and roof/floor Rc= 6
- Window U values and solar transmittance: U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5
- Heating setpoint is 19˚ C and cooling setpoint is 26˚ C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

6.6.4 Variables
As in 6.2 the study building's orientation is varied from N to S at 15 degree intervals.

6.6.5 Discussion
The results show that the South facing sunspace has about a 10% decrease in heat demand compared to the north facing one (see Figure 46). The 'plain' version without a sunspace, also shown in this graph. had a 25% decrease in heat demand.

6.6.6 Conclusions
These results seem to indicate that a sunspace actually has less potential for heat demand reduction than a plain facade with 80% glass. In 6.8 a further study into comparing sunspaces to other types of facade is done to determine if this is truly the case.

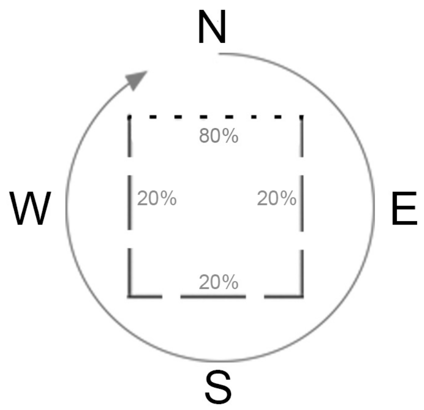


Figure 44 Diagram of the orientation study and the direction of rotation.

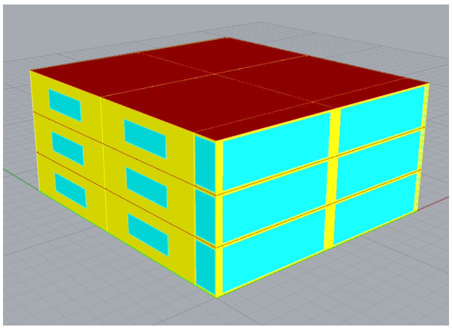
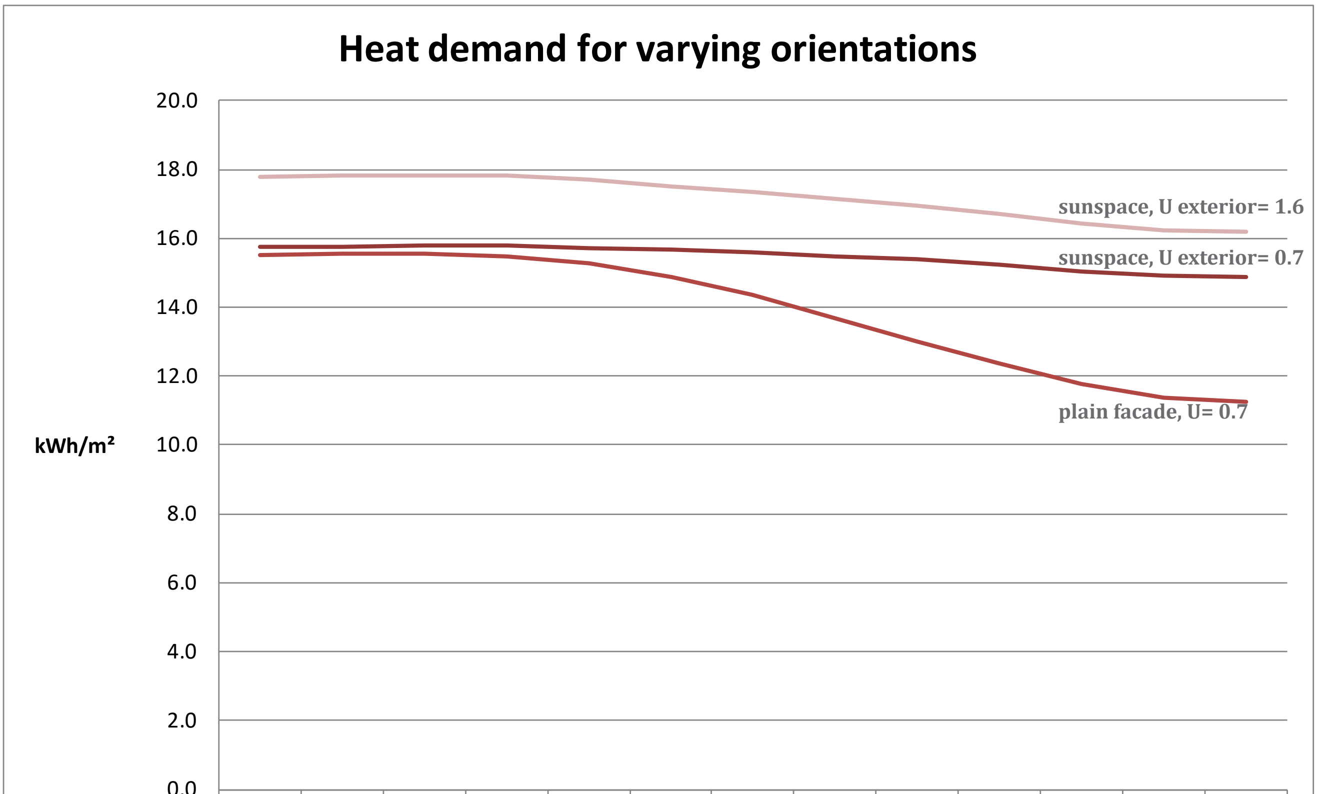


Figure 45 Visualization of study building with sunspace additions.



	N			NE			E			SE			S
U ext=1.6	17.8	17.8	17.8	17.8	17.7	17.5	17.3	17.1	16.9	16.7	16.4	16.2	16.2
U ext=0.7	15.7	15.8	15.8	15.8	15.7	15.7	15.6	15.5	15.4	15.2	15.1	14.9	14.9
no sunspace	15.5	15.5	15.5	15.5	15.3	14.9	14.4	13.7	13.0	12.3	11.8	11.4	11.3

Figure 46 Graph showing the heat demand in 3 variations of the study building at varying orientations.

6.7 Sunspace: building shape

6.7.1 Introduction

Again a comparison is made between the compact building (A) and the elongated version (B) but his time with sunspaces on the south facade (see Figure 47 and Figure 48).

6.7.2 Case description

Since the number of zones with a south facade is doubled in shape B, the number of sunspaces is also doubled.

6.7.3 Honeybee model input

- Orientation of sunspaces: South
- Wall Rc= 4.5 and roof/floor Rc= 6
- Windows: U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5
- Heating setpoint is 19° C and cooling setpoint is 26° C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

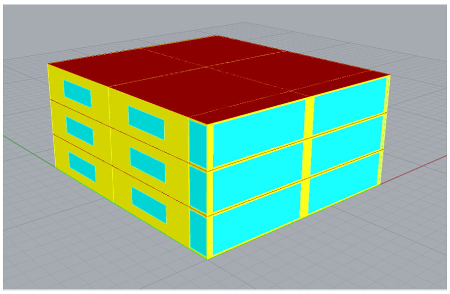


Figure 47 Visualization of shape A with sunspaces.

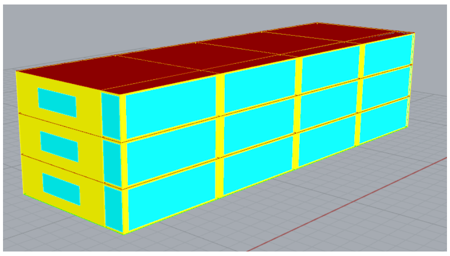


Figure 48 Visualization of shape B with sunspaces.

6.7.4 Variables

For both shapes A and B two sets are run for window U= 1.6 and window U= 0.7. In these sets the percentage of glass on the interior side of the sunspace is varied from 20% to 80%.

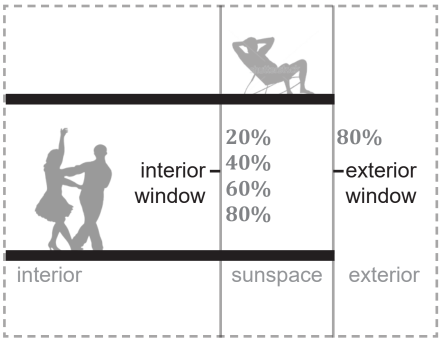


Figure 49 Schematic of sunspace. The interior window percentage varies from 20% to 80% in this study.

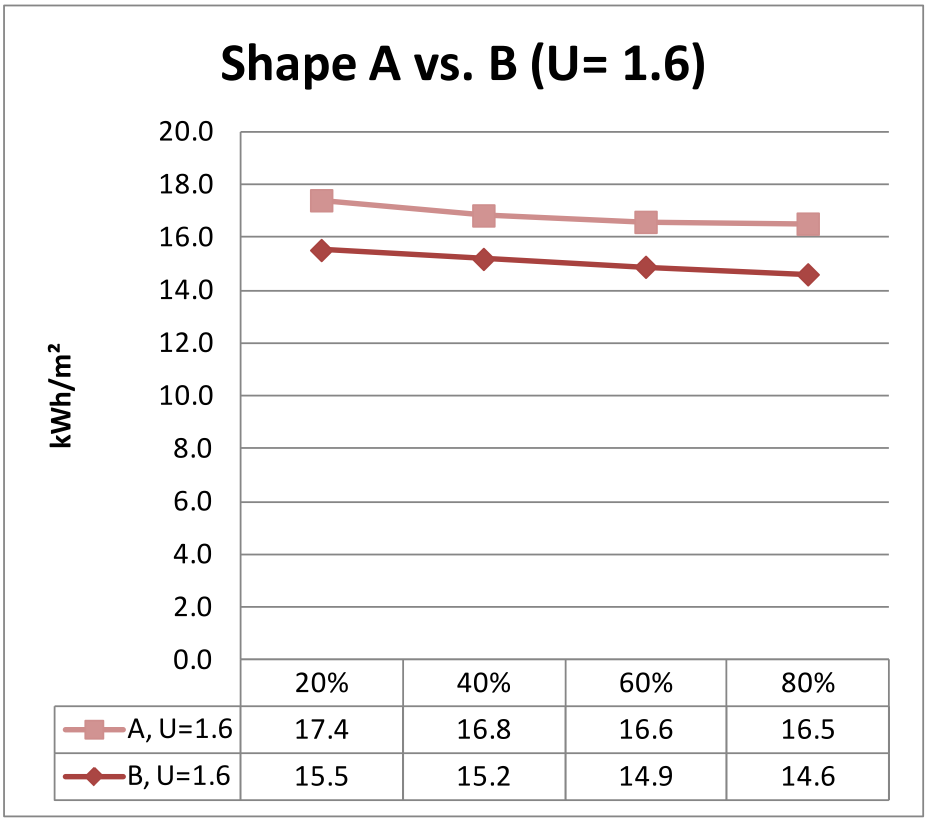
6.7.5 Discussion

The results (see Figure 50 and Figure 51) again show that the elongated shape (B) performs better in terms of heat demand especially if the U value for the exterior windows is low (U= 0.7).

Higher percentage of glass translates to lower heat demand in all sets.

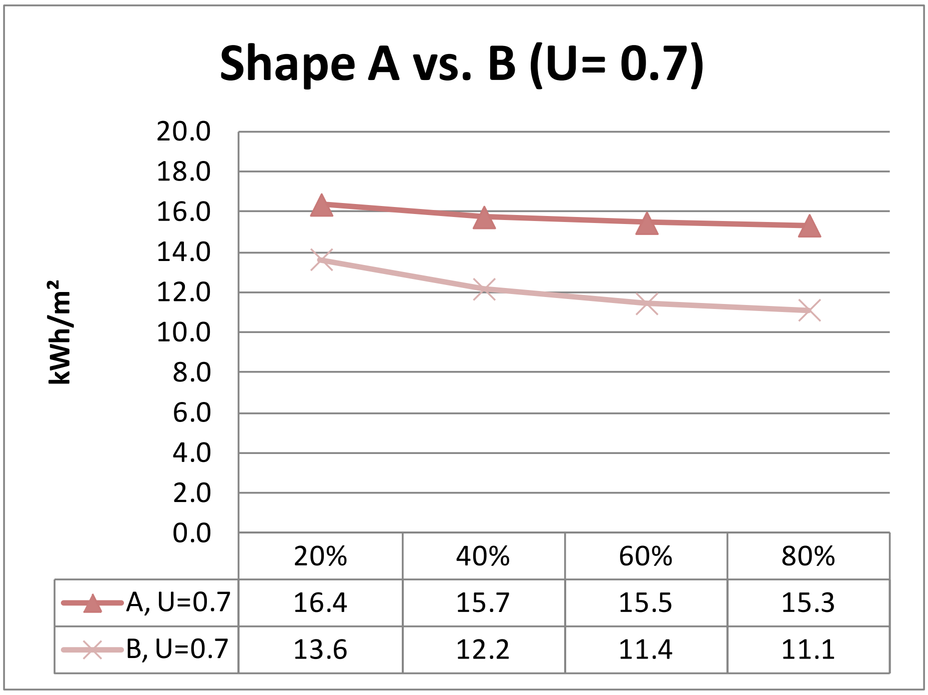
6.7.6 Conclusions

The percentage of glass on the interior side of the sunspace directly relates to the heat demand. A higher percentage of glass leads to lower heat demand. This was expected since more glass means both more direct sunlight entry and more heat transmittance through the interior facade.



	20%	40%	60%	80%
A, U=1.6	17.4	16.8	16.6	16.5
B, U=1.6	15.5	15.2	14.9	14.6

Figure 50 Graph showing heat demand for shape A and B buildings with sunspaces for varying percentage of glass on interior side of sunspace.



	20%	40%	60%	80%
A, U=0.7	16.4	15.7	15.5	15.3
B, U=0.7	13.6	12.2	11.4	11.1

Figure 51 Graph showing heat demand for shape A and B buildings with sunspaces for varying percentage of glass on interior side of sunspace.

6.8 Comparison: shape A

6.8.1 Introduction

This study focuses on the difference between facade exteriors and their impact on heat demand. The three exteriors are 'plain' , 'balcony' and 'sunspace'. The 'balcony' variant is based on the case study building so it would be very relevant to see how this option compares to the other two that have been studied so far.

6.8.2 Case description

This case consists of three variations of a middle floor with either a plain facade, a balcony or a sunspace. In this model, the floors and ceilings are set to adiabetic which means they will not transfer heat. The plain facade (see Figure 39) and sunspace facade (see Figure 41) variants are as modelled before with 80% glass in the facade facing south. The balcony facade variant (see Figure 40) is the same as the plain facade variant but has horizontal shading elements added (1.5 m in depth), representing the balconies of the floor above.

6.8.3 Model input

- Orientation: South
- Wall Rc= 4.5 and roof/floor is adiabetic.
- Window types: U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5.
- Heating setpoint is 19˚ C and cooling setpoint is 26˚ C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

The sunspace variant has a cooling setpoint of 30 degrees set for the sunspace zone to simulate the effect of occupants opening the sunspace to the outside when it gets too hot.

For a description of the honeybee model for this case see Appendix B.

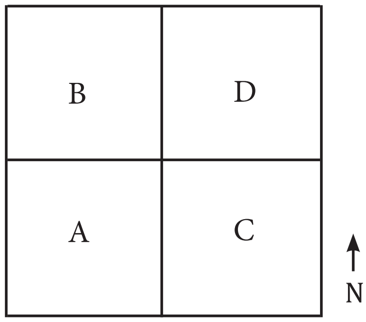


Figure 52 Zone partitions. A and C are the default southern zones. B and D the northern zones.

6.8.4 Variables

In this study the three facade variants are compared in two sets with differing window types U= 1.6 and U= 0.7.

6.8.5 Discussion

The results for the plain facade variant (see Figure 53) show that the southern zones A and C have lower heat demand, as expected. This decrease in heat demand is amplified by better insulation of the window.

The results for the balcony facade variant (see Figure 54) show a similar situation as in the plain facade variant but with slightly increased heat demand, especially for the southern zones A and C. This is most likely due to the shading element reducing sun exposure during spring and autumn, when the sun's angle isn't as low as in the winter, but heating is still required. The slightly reduced sun exposure is causing slightly increased heat demand.

Looking at the overall average of each variation (see Figure 56) it seems the plain facade variant wins out in reduced heat demand. It should however be noted that the plain facade variant also suffers from overheating issues in summer while the balcony variant does not (see

Looking at the operative temperatures for each variant (see Figure 57) it is possible to get an idea of how comfortable each version might be. The plain

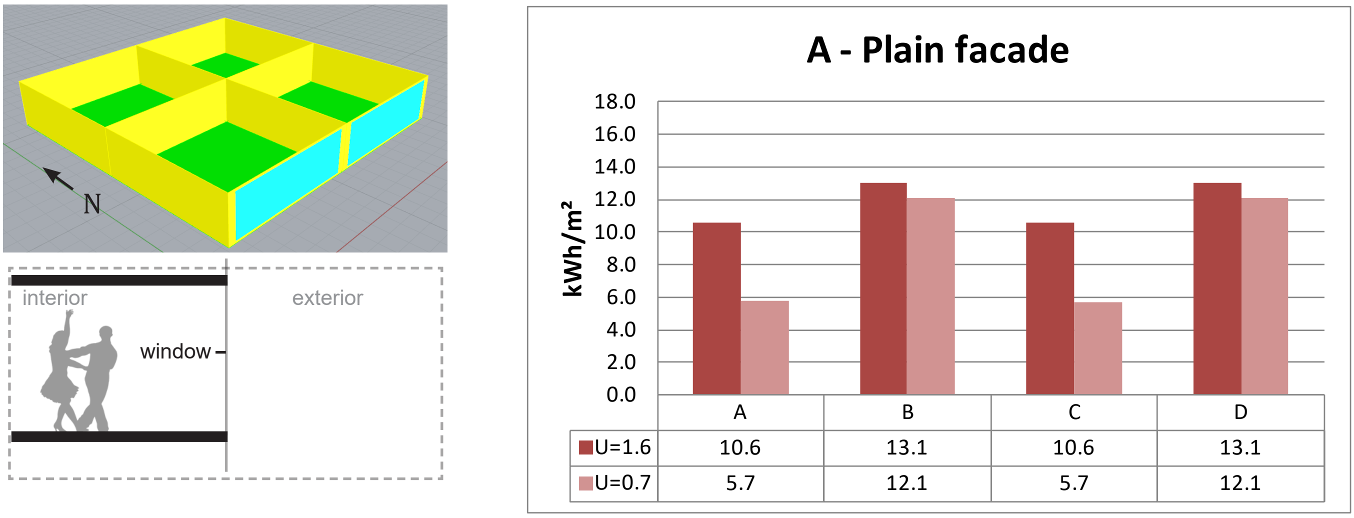


Figure 53 Visualization and schematic section of plain facade (left). Results foir the plain facade variant (right) are shown per zone and for two window types, designated by their insulation values: U= 1.6 and U= 0.7.

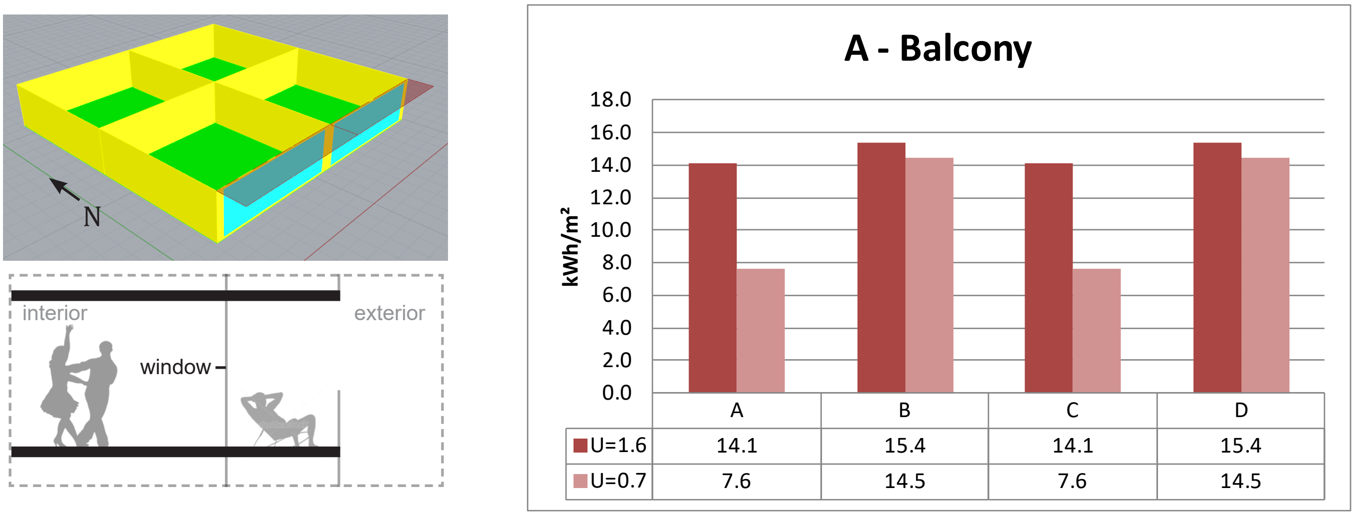


Figure 54 Visualization and schematic section of balcony facade (left). Results for the balcony facade variant (right) are shown per zone and for two window types, designated by their insulation values: U= 1.6 and U= 0.7.

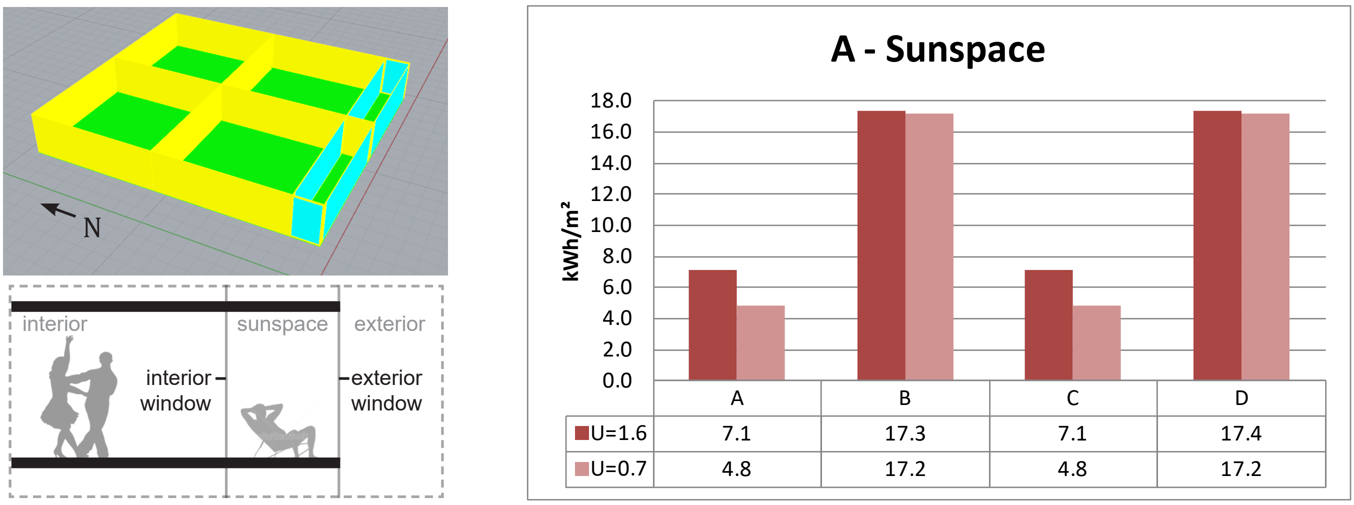


Figure 55 Visualization and schematic section of sunspace (left). Results foir the sunspace facade variant (right) are shown per zone and for two window types, designated by their insulation values: U= 1.6 and U= 0.7.

facade version is prone to overheating as shown by the large red areas even in February. The balcony facade already reduces this effect considerably by shading the glass facade in the warmer periods. The sunspace variant even further reduces peak temperatures. The overheating in summer could be reduced if the user simply opens the sunspace to the outside.

The operative temperature of the sunspace shows that even though it isn't heated itself it is often quite comfortable (above 18 degrees) in the afternoons and evenings of the colder months (see Figure 58).

It is important to note that the scope of this study is limited to heating demand and not cooling. The simulation is not set up to realistically deal with the summer situation in which occupants would likely be opening windows. Of course for a designer these things will be important and when thinking about designing for low heat demand, the summer situation should never be overlooked.

6.8.6 Conclusions

Purely in terms of heat demand reduction the plain facade seems to have most potential while the sunspace might not seem worth the material cost. This study might however suffer from a poor setup. In the sunspace variant the northern zones actually require more heat, even though the heat demand in the southern zones goes down. This can only be explained by the lower peak heat of the southern zones due to the buffer effect of the sunspaces. Apparently this leads to less heat transmitting to the northern zones, which in turn increases their heat demand. In a more realistic scenario these zones would have more air flow between them and also the sunspace can be opened up to the interior when it gets warm. This would mean the interior zones get more direct heat.

In terms of comfortable use the sunspace facade could already be considered the preferred candidate since it serves as an effective buffer reducing peak heat in the interior zone and can be used comfortably on many days of the colder seasons.

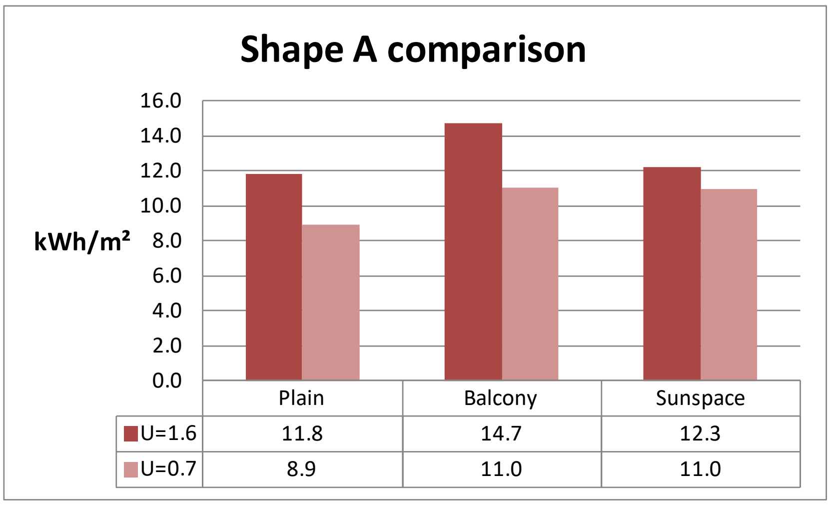


Figure 56 Comparison graph of shape A showing average heat demand for each variant (plain, balcony and sunspace) in kWh/m².

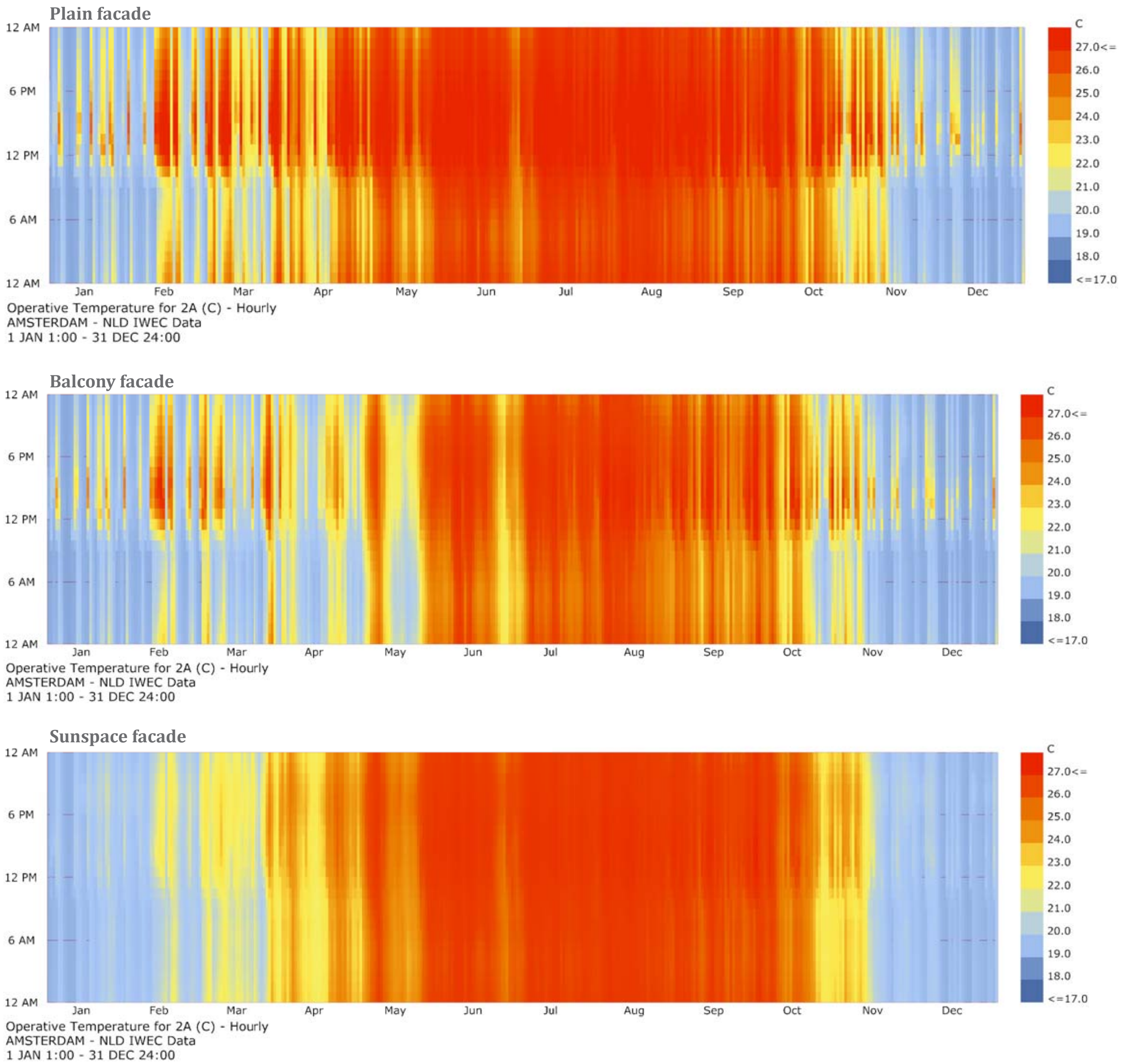


Figure 57 Hourly operative temperature charts of zone A for each variant in degrees Celsius.

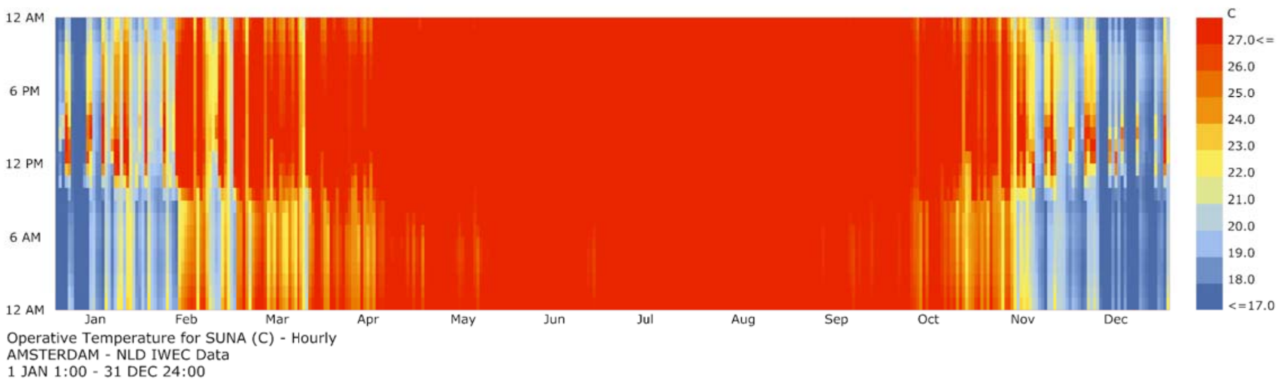


Figure 58 Hourly operative temperature chart for the sunspace of zone A.

6.9 Comparison: Shape B

6.9.1 Introduction

The same comparison as in 6.7 is done for shape B. In shape B all zones have a southern facade and are therefore more directly influenced by the variation in exterior.

6.9.2 Case description

Three variations of a middle floor with either a simple glazed facade, a balcony or a sunspace. As it is shape B all zones have a southern facade. The zones at the ends also have a an extra opaque facade. Zone names are A to D from west to east. Meaning A and D are on either ends and B and C are in the middle.

6.9.3 Honeybee model input

- Wall Rc= 4.5 and roof/floor Rc= 6
- Window types: U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5.
- Heating setpoint is 19° C and cooling setpoint is 26° C.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

Again the sunspace zones are set to cool at 30 degrees to account for occupants enabling more natural ventilation if it gets too hot.

For the honeybee model see Appendix B.

6.9.4 Variables

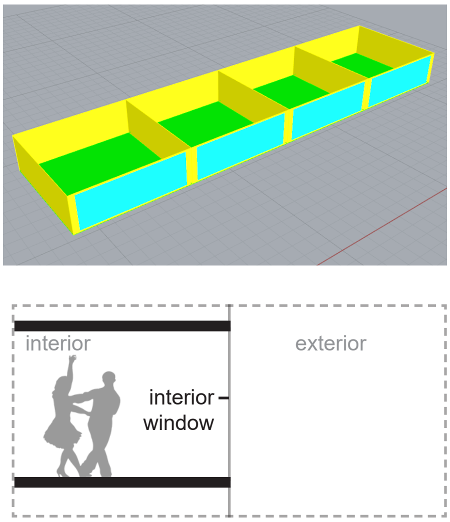
In this study the three facade variants are compared in two sets with window types U= 1.6 and U= 0.7.

6.9.5 Discussion

For this shape the results (see Figure 59, Figure 60 and Figure 61) show a more uniform picture across the zones compared to shape A. Only the A and D zones have a slightly higher heat demand which can easily be explained by the extra opaque facade that borders their zone, causing more transmission loss.

The average results (see Figure 62) show a much clearer picture in favor of the sunspace compared to the shape A study. With an annual heat demand of 5.7 kWh/m^2 at U= 0.7 for the windows, it clearly performs better than the balcony version (7.6 kWh/m^2) and equal to the plain facade.

The operative heat maps (see Figure 63) show a very similar image to the ones from shape A: The balcony version has less overheating than the plain facade version and the sunspace version has even less overheating in the interior zone with significantly reduced peak temperatures. The heat map for the sunspace itself (see Figure 64) shows it does overheat quite often but in reality this could easily be countered by opening it up to the outside, enabling ample natural ventilation.



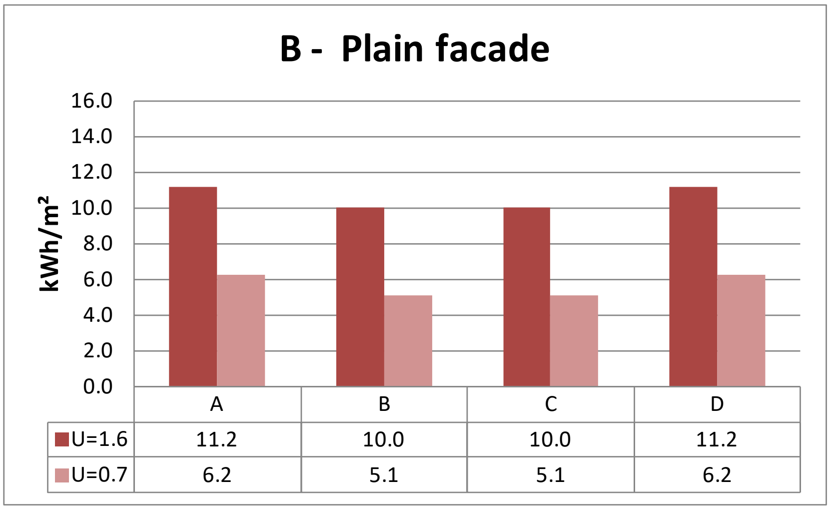
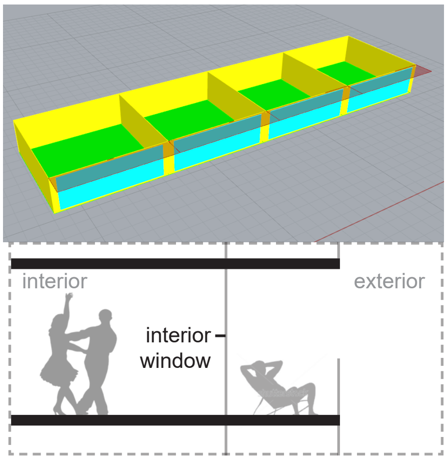


Figure 59 Visualization and schematic section of plain facade (left). Results from the simulation (right).



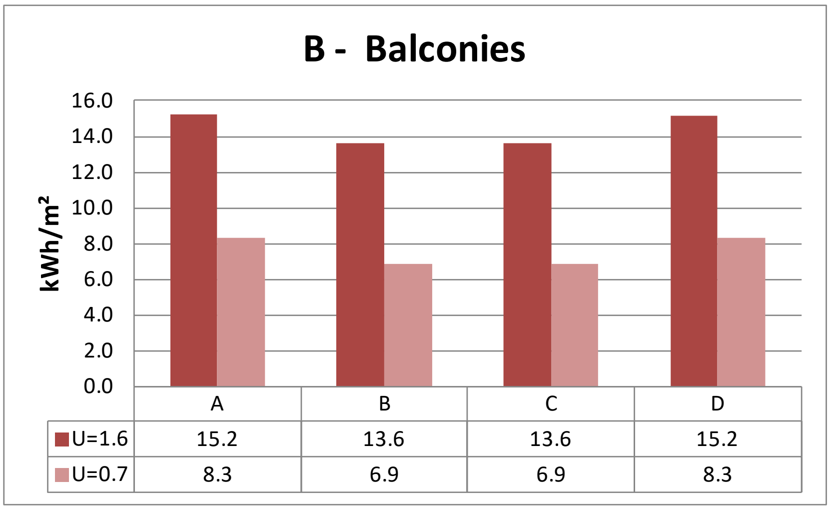
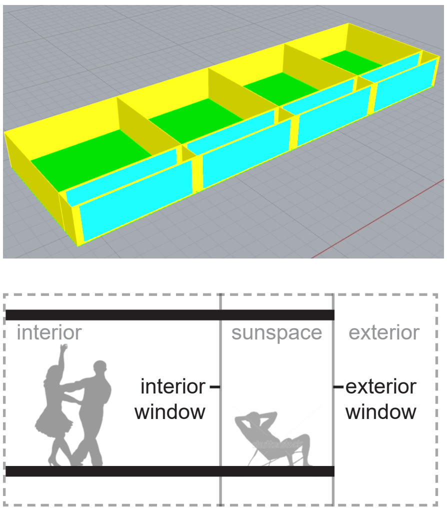


Figure 60 Visualization and schematic section of balconies (left). Results from the simulation (right).



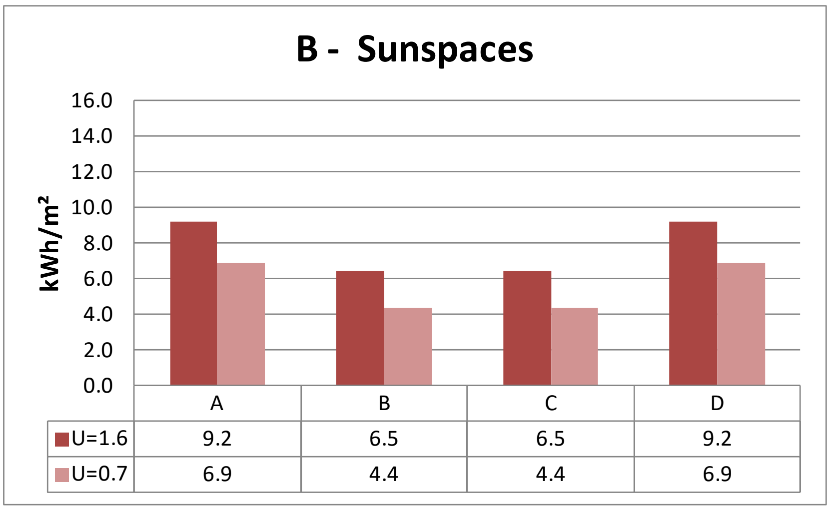


Figure 61 Visualization and schematic section of sunspace (left). Results from the simulation (right).

6.9.6 Conclusions

Based on these results it could be argued that the sunspace is truly the better version. It has at least as good a heat gain potential as the plain facade version and furthermore it adds a flexible zone that can often be used comfortably in winter and can be used as a balcony in summer (with the same sun shading benefits).

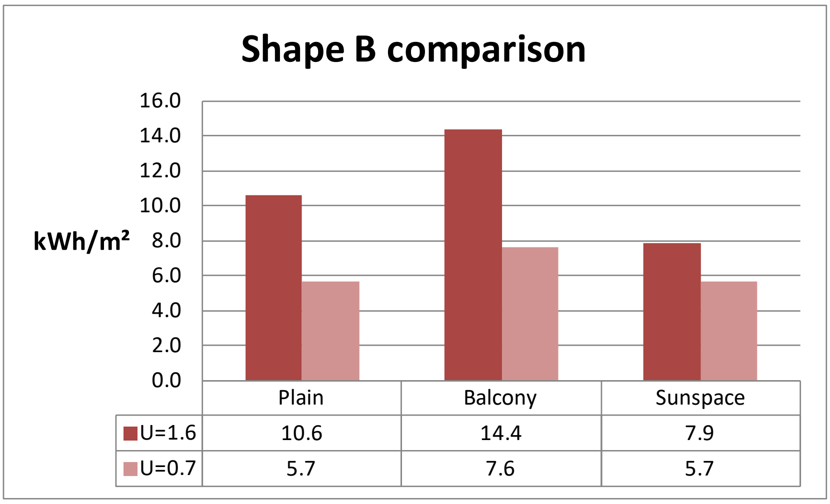


Figure 62 Comparison graph showing the average heat demand in each version.

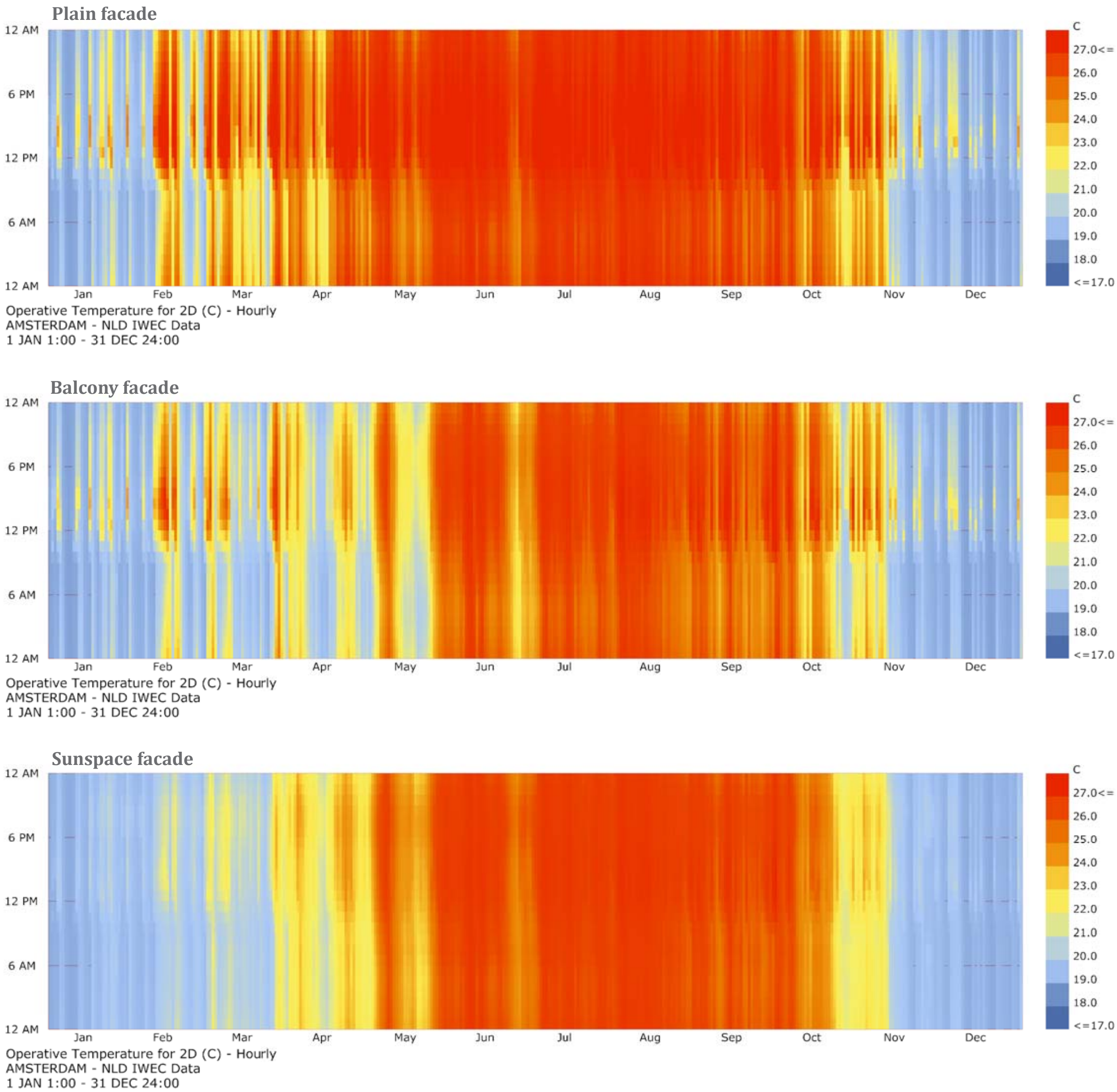


Figure 63 Hourly operative temperature charts of zone A for each variant in degrees Celsius.

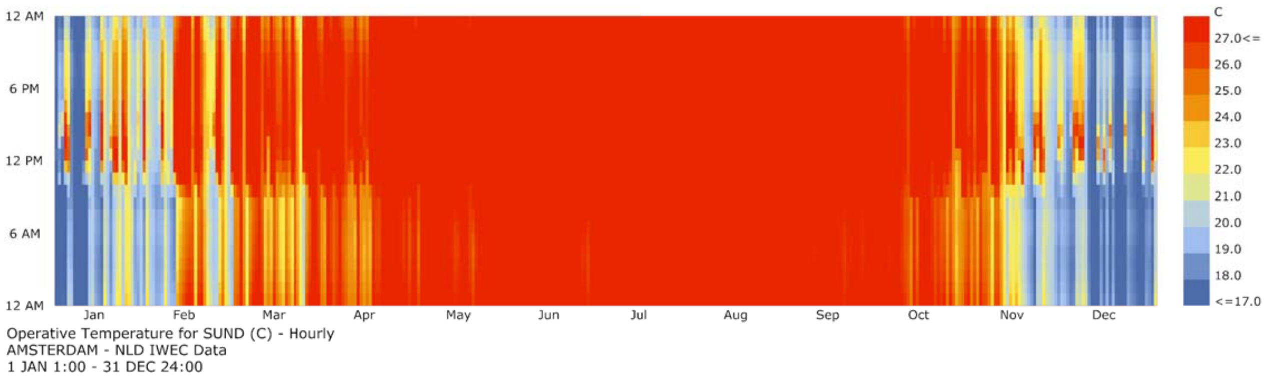


Figure 64 Hourly operative temperature chart for the sunspace of zone A.

6.10 General discussion and conclusions

6.10.1 Methodology

The many factors involved in heat demand and building design make it a complicated subject. In this series of impact studies an attempt was made to simplify things by focusing on a limited set of design aspects (insulation, orientation of glazed facade, building shape). By including the facade aspects of the case study building (glazed facadde with balconies) and variations on it, an attempt was made to make the link between the studies and the case study building more clear.

Heat balance is complicated and a lot of factors are involved. This study is only showing the heat potential in limited scenarios. In reality (among other things) the user is an added factor that can seriously impact the actual heat demand in many ways. They might want a higher heating setpoint, they might open windows for fresh air on cold days, they might open the sunspace zone to the interior zone at appropriate or inappropriate moments. It can not be emphasized enough that this study simply shows the potential benefit to heat demand of certain design aspects. In an actual design these benefits might not translate 1 to 1, and serious consideration of the behavior of the user would be necessary.

6.10.2 Sunspace

Initial results on sunspaces were conflicting, with an early test study showing reduced heat demand when a sunspace was added and then the first impact study showing differently. Although the shape A studies show some abiguity as to the advantage to heat demand reduction as compared to a plain facade, the shape B studies show a much clearer image. Sunspaces basically combine the advantages of both the plain facade (maximum heat capture) and the balcony (shading during summer). Although it is not investigated in this simulation study, it seems reasonable that this performance would only improve by occupants making proper use of the flexibility of the sunspace. Opening it to the interior to allow heat in during sunny cold days and opening it to the exterior to lose heat on warmer days.

6.10.3 Conclusions

1. Facade insulation (of opaque parts) is only part of the solution. The building code minimum of Rc= 4.5 is already quite decent and an improvement to Rc= 8 is only a minor improvement.
2. Orientation is an important aspect of employing solar heat gain to reduce heat demand. Southern orientations have significant heat demand reduction potential that can result in annual heat demand reduction even with the building code max. value of U= 1.6 for the windows.
3. Building shape isn’t just about compactness. With modern well insulated buildings creating sun surface to increase solar heat gain can significantly reduce heat demand, well outweighing the slightly increased transmission losses.
4. Sunspaces are a an improvement on the balconies (as defined in this study) in two ways in terms of heat demand: they allow more use of solar heat gain and reduce heat loss due to creating a buffer zone.
5. Sunspaces also allow for comfortable midday to evening use during sunny cold days.
6. In all studies the importance of well insulated windows (U= 0.7) became evident. They allow for maximizing use of solar heat gain whilst limiting heat loss through transmission.

7. Re-design Case

7.1 Re-design introduction and goals

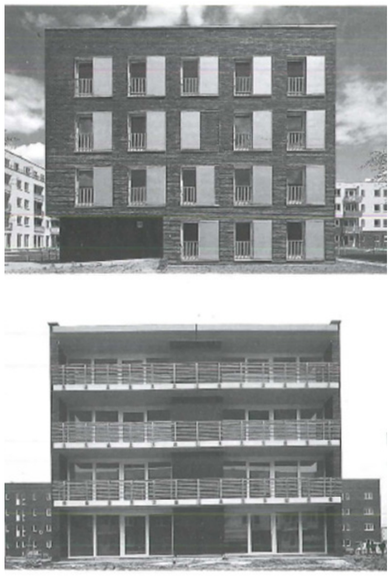


Figure 65 Pictures of he case building (front and back)

7.1.1 Introduction

To put theory closer to practice the lessons learned from the impact studies will be applied to a re-design case.

The re-design case building is a design of a small residential building that was built in Berlin (see Figure 65) and is described in chapter 5.2.

The urban context and placement of the building put the glass and balcony facade on a north facing orientation.

7.1.2 Re-design goals

The goal of the re-design will be to effectively apply the lessons from the impact studies and decrease the heat demand of the resulting re-design building to as low a level as possible. At the same time the surface area of individual rooms should remain equal and the overall lay-out should function the same in terms of public-private area and the way the rooms connect. Finally the exterior aesthetic elements will remain the same. This includes the shape of the windows.

Based on the impact studies several steps are defined for reducing the heat demand of the case building (also see Figure 66):

- <u>Step 1: Orientation change</u>

Even the original case building would already perform significantly better at a different orientation that allows more sunlight entry through the existing glass facade. A southern orientation should be optimal for heat demand reduction.

- <u>Step 2: Shape change</u>

The actual re-design part comes as the case building is transformed from a shape A type building to a shape B type building. To maintain the same kind of functionality and interior spaces the floorplan will have to be carefully re-assembled. To maximize the effect the south facade will have to make maximum use of sunlight by allowing it to enter the building.

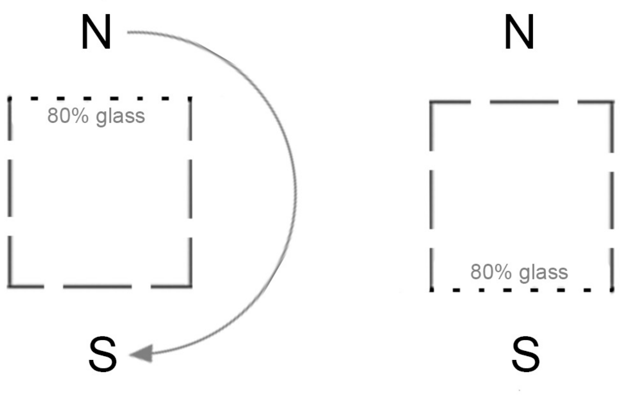
- <u>Step 3: Sunspace and sunshade</u>

The balcony space of the original design will be converted into sunspaces (one for each apartment) The remaining glass facade of the living space will receive a horizontal sunshading element to keep out summer heat. Alternatively the whole south facade could become a sunspace, but one of the demands in this case was to stick to the original amount of floorspace. So the sunspace will have the same surface area as the balcony.

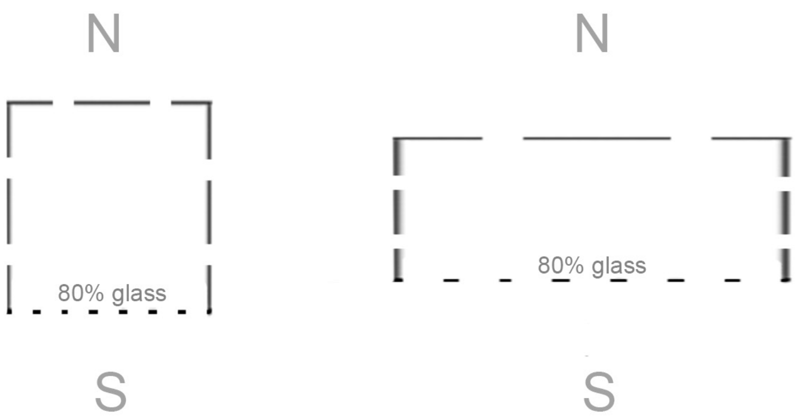
- <u>Step 4: Facade Insulation 4.5 to 8</u>

At this stage the only thing remaining is an increase of insulation of the facade from Rc=4.5 to Rc=8. As the studies showed this impact isn't very large in the big picture, but is relevant again when heat demand is to be as low as it can be.

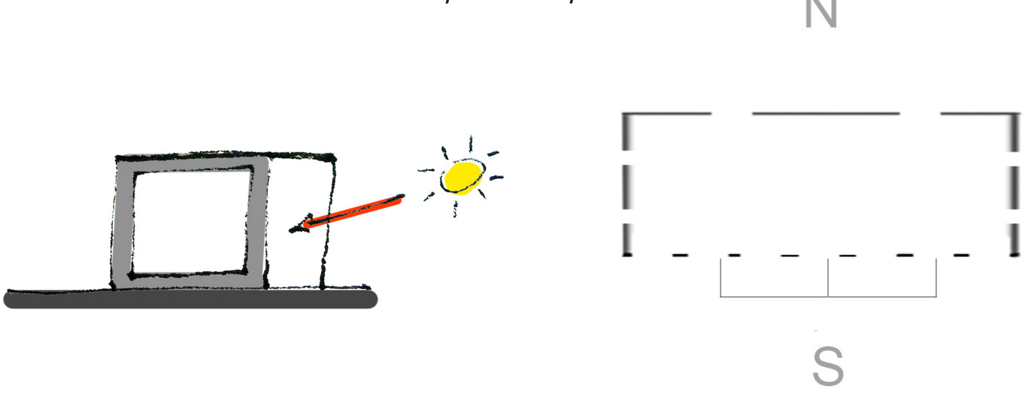
Step 1: Orientation change



Step 2: Shape change (A to B)



Step 3: Sunspace and sunshade



Step 4: Improve Insulation

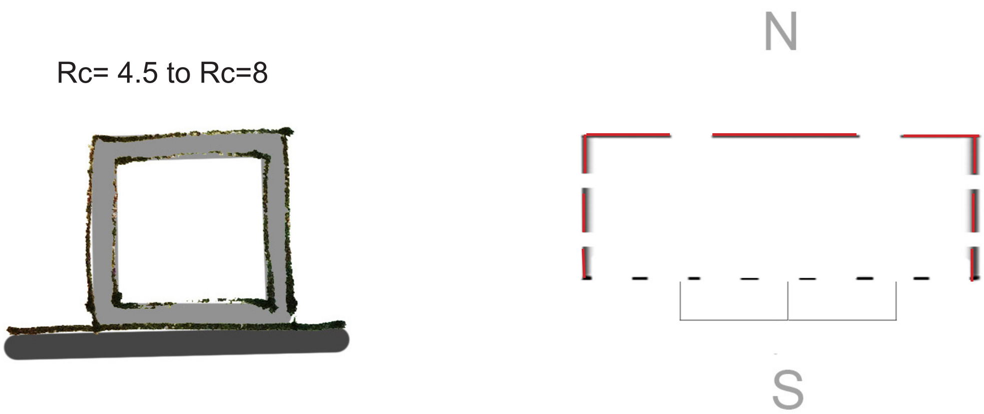


Figure 66 Re-design steps

7.2 Re-design modelling

7.2.1 Introduction

Re-design 1 is a variation on the original design, that is true to the original floorplan but adjusted so that the shape of the building approaches that of a shape B (elongated rectangle) instead of a square (see Figure 69). This way there is a larger glazed facade on one side that can be oriented towards the south (and the winter sun) and the balconies have become sunspaces (see Figure 68).

7.2.2 Model description

To estimate the impact of the re-design on the heat demand of the building another simulation is done. Similar to the setup of the comparison studies (see 6.8 and 6.9), only a middle floor is simulated with ceiling and floors set to adiabetic.

In this study the model of the case building (condition zero) is a middle floor divided into two apartment zones and the staircase (see Figure 67). Shading elements represent the shading effect of the balconies. Because the studies in chapter 6 with a similar shape building divided into two zones per apartment showed results that don't necessarily seem realistic, it was decided that this model would have only one climate zone per apartment.

The redesign is similarly divided into one zone per appartment and stairs with the addition of two sunspace zones (see Figure 68). It also has sunshading elements above the plain facade parts of the glazed facade.

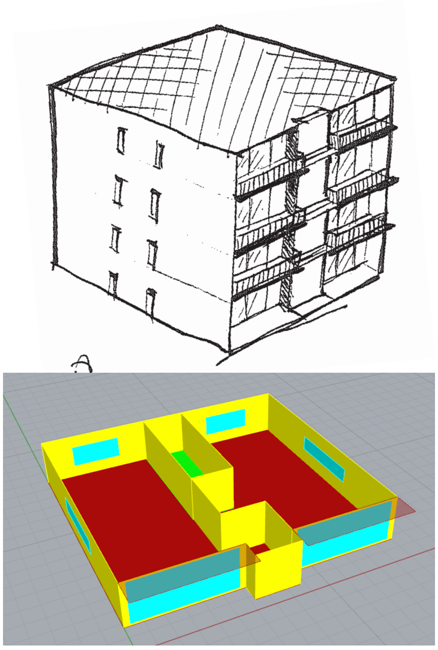


Figure 67 Sketch and honeybee visualization of CZ (condition zero).

7.2.3 Simulation input

The simulation input is mostly similar to most of the standard input of the impact studies. The most important calculation input is as follows:

- Wall Rc= 4.5 or Rc= 8 (in final step) and roof/floor is set to adiabetic.
- Window types: U= 1.6 with g-value of 0.6 or U= 0.7 with g-value of 0.5.
- Heating setpoint is 19˚ C and cooling setpoint is 26˚ C for all zones.
- Ventilation is 0.14 dm^3/s per m^2 (simulating 80% heat recovery).
- Infiltration is 0.2 dm^3/s per m^2.
- $Q_{interior}$= 4.2 W/m^2
- Weather file downloaded from:

https://www.energyplus.net/weather-download/europe_wmo_region_6/NLD//NLD_Amsterdam.062400_IWEC/all

7.2.4 Variables

The steps as described in the re-design guidelines will be the variables in this application study. North orientation changed to south orientation. A change from shape A to shape B. Insulation values of windows U=1.6 or U=0.7 and finally the facade insulation is increased from Rc=4.5 to Rc=8.

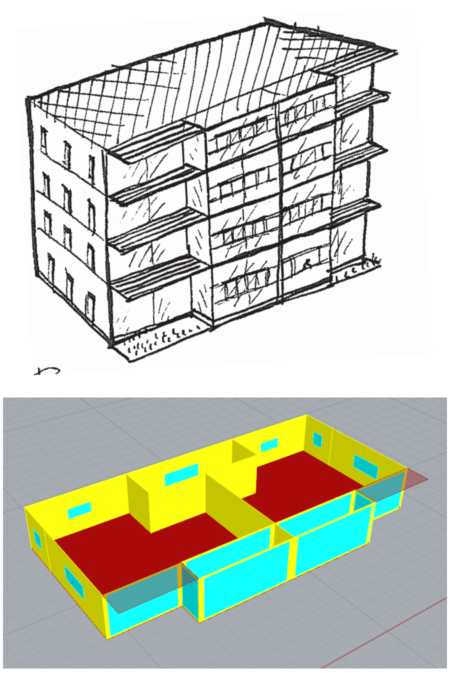


Figure 68 Sketch and honeybee visualization of RD1 (Re-Design 1).

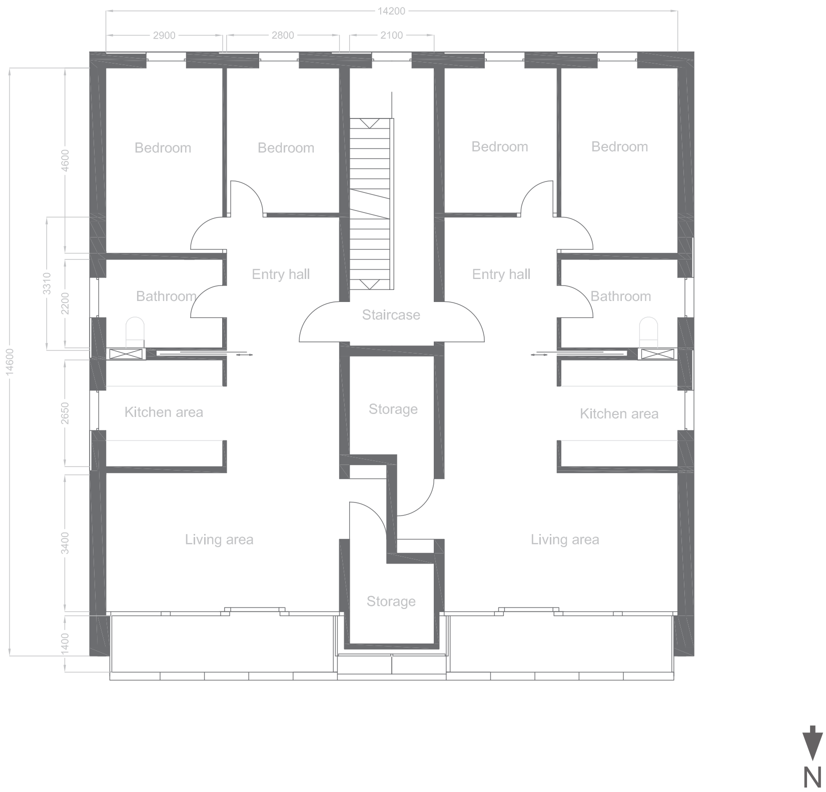
7.2.5 Results

The first big step, changing the orientation of the glass facade from North to South, results in an estimated annual heat demand drop of about 30%. Combine that with improving window insulation from U=1.6 to U=0,7 and the total drop is over 50% from 25.4 to 12.3 kWh/m^2.

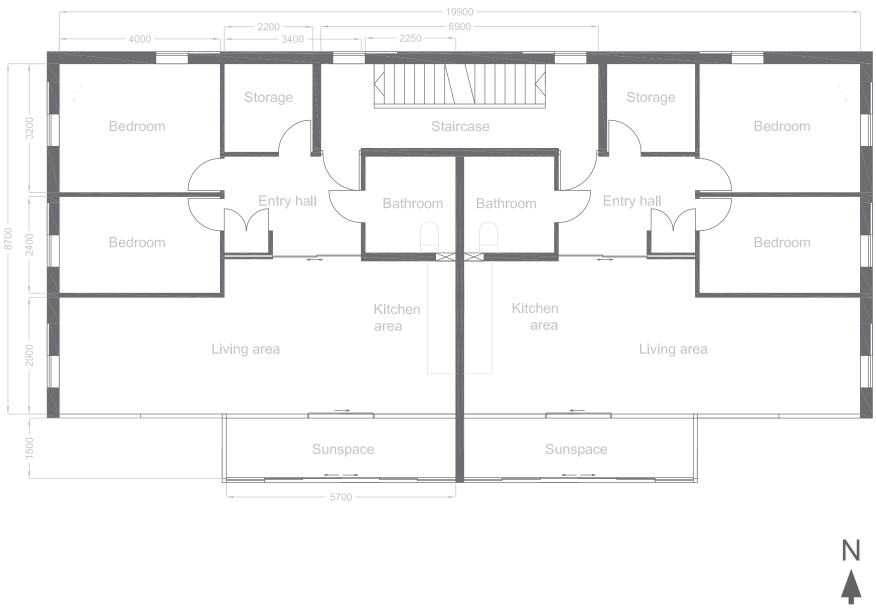
The re-design further decreases the amount to 8.4 kWh/m^2.

Finally the increase in facade insulation results in 6.4 kWh/m^2.

Case building (1:200)



Re-design 1 (1:200)



7.3 Impact of improvement steps and conclusions

7.3.1 Glass insulation

Improving the glass insulation value from U= 1.6 to U= 0.7 in the original case building decreases heat demand from 25.4 to 17.7 kWh/m^2. For the south facing variant and the re-design similar impact can be seen (see Figure 69 and Figure 70).

7.3.2 Orientation

The original design had the glazed facade facing in a northern direction. By changing this orientation from north to south reduces heat demand from 25.4 down to 18.6 kWh/m^2. Almost as good as improving the glass insulation. Combined the resulting heat demand is only 12.3 kWh/m^2, less than half the original heat demand.

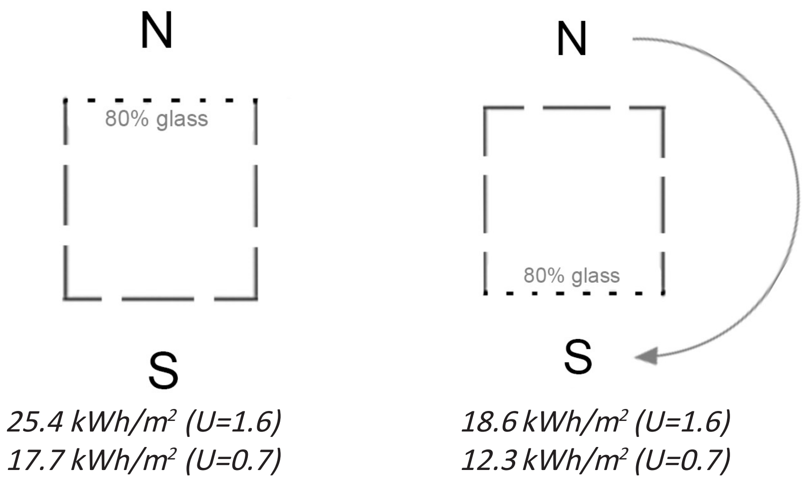


Figure 69 Heat demand figures for the original building facing north (left) and south (right). Annual heat demand is given for variants with either a window U value of 1.6 or 0.7,

7.3.3 Shape change

The re-design of the building further decreases the demand, proving that solar heat gain can outweigh the slightly increased transmission loss due to increased facade surface area.

7.3.4 Facade insulation

The impact of an increase in facade insulation is limited as expected. The heat demand goes down by 2 kWh/m^2 from 8.4 to 6.4. But at this stage any decrease is still significant. A reduction of 2 kWh/m^2 becomes a 25% reduction in this case.

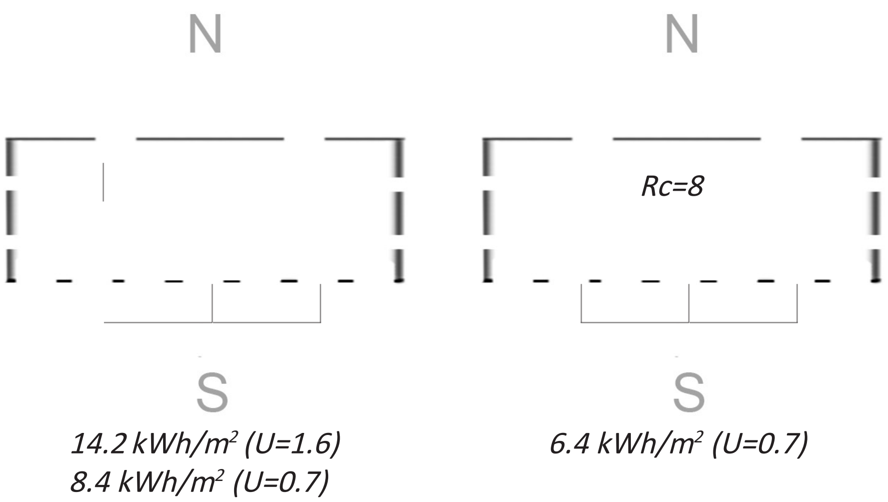


Figure 70 Heat demand figures for the re-design building for variants with either a window U value of 1.6 or 0.7,

Absolute reduction [kWh/m²]
1. -U glass = 7.7
2. S glass = 5.4
3. Shape B = 3.9
4. Rc = 2

Relative reduction
1. -U glass = 30%
2. S glass = 31%
3. Shape B = 31%
4. Rc = 24%

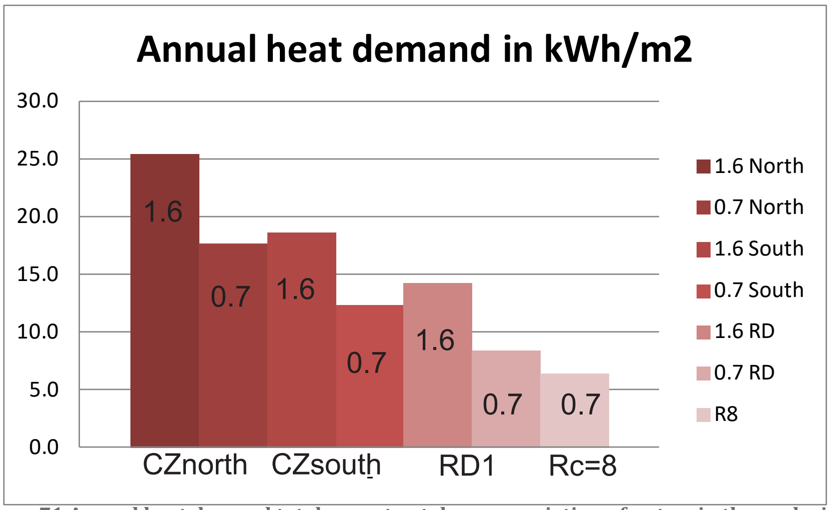


Figure 71 Annual heat demand totals per step taken, or variation of a step, in the re-design.

7.3.5 Conclusions

Both orientation and insulation are important when it comes to using glass for solar heat gain. Optimizing the building shape to maximize the benefit of solar heat gain is also a good way to go.

8. Design Guidelines

8.1 Introduction & application

8.1.1 Introduction
These guidelines are the answer to the main research question formulated for this study: *What is the impact of early design decisions on the heat demand of a residential building in the Netherlands and what heat demand reduction guidelines can be established for designers?*

The guidelines are based on the results from a range of studies into the impact of several design variables on the heat demand of a representative study building. These results were gained by simulating the study building in EnergyPlus related software and should be seen as only generally representative of the situation in a Dutch (or similar) climate setting.

To make the information gained from the studies more insightful to designers an attempt was made at translating a technical story into a design story.

8.1.2 Application
These guidelines are intended for designers that want to design residential buildings in the Netherlands with low heat demand. They do not give specific instructions on how to design a building. Instead they give an idea of what design variables have a strong impact on heat demand and which ones should be prioritized.

8.2 Guidelines per aspect

8.2.1 Insulation
In the Netherlands facade insulation needs to be at a minimum Rc value of 4.5 already due to building code requirements. As shown in figure Figure 31, the impact of increasing insulation above 4.5 is limited.

Increasing window insulation beyond the building code requirement of U=1.6 is definitely worth it when making use of large glass surfaces for solar heat gain. Looking at Figure 11 and Figure 35 it becomes clear that both the literature and this study support the application of well insulated glass as it increases solar heat gain potential.

8.2.2 Orientation of glazed facade
Apart from this study confirming the effectiveness of well insulated glass this study also supports the use of glazed facades for solar heat gain. The results from this study show that favourable results with well insulated glass can even be achieved beyond the range as described in the literature. The optimum is still confined to the purely south facing facade.

8.2.3 Building shape
The impact studies clearly show the potential of decreased compactness in favor of a south favoring shape factor with a longer facade facing south. Since the advantage here is in solar heat gain a high glass percentage in this facade and an improved insulation value (below U=1.6) are crucial.

8.2.4 Sunspaces
In a static model as used in this study the heat demand reduction potential

of a sunspace is not necessarily better than of a plain facade with the same glass percentage. In a flexible model it is likely to perform better though and it is definitely a better alternative to a balcony in both heat demand reduction potential and in offering a comfortable use zone even in winter (on sunny days).

8.3 Priority infographic

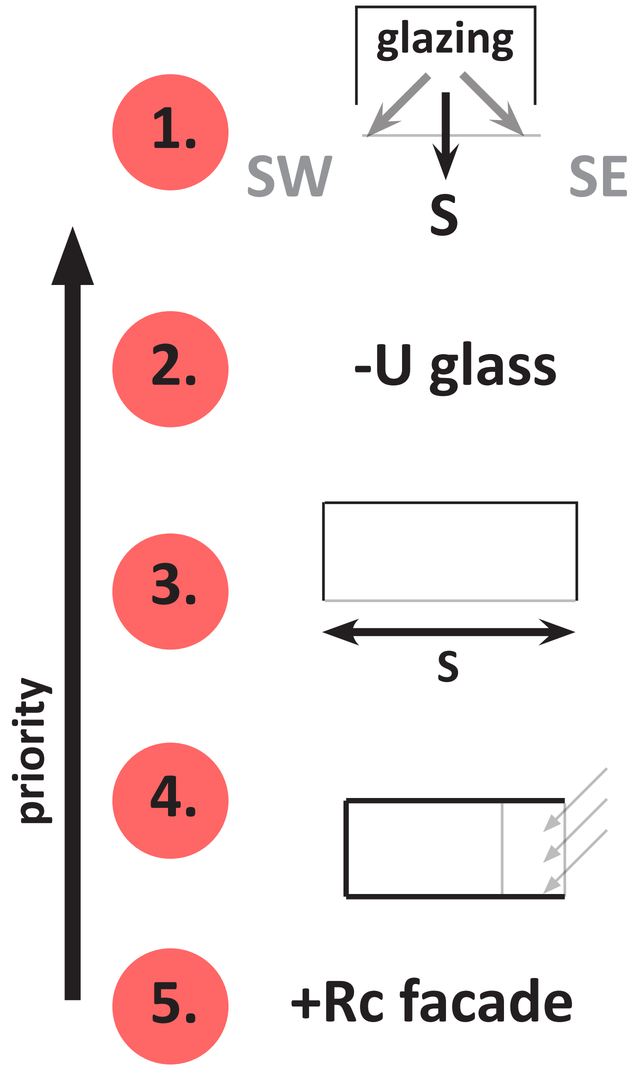
1. Have as much glazing face (roughly) South.

2. Increase insulation of glazing.

3. Maximize sun surface.

4. Sunspaces if applicable.

5. Increase insulation value of facade.



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Appendices

Appendix A - Validation input and output
Appendix B - Impact study output

APPENDIX A - Validation

Honeybee model for validation

Geometry

The validation model uses a geometry based on the re-design case. First the geometry was modelled in Rhino. Each block represents a zone for the heat simulation. The surfaces on the back of the building are the balconies and the large surfaces to the sides are context are the sides of context buildings.

Once finished the geometry was selected and imported into grasshopper using a ‘ B-rep’ block, adding all the zones of the building.

This B-rep block is connected to a honeybee modification block that makes sure all surfaces facing eachother are the same size (EnergyPlus requires this) and then to the honeybee block that translates geometry into zones. In this case they are also given default program characteristics and ‘isConditioned’ is true by default.

Using the Zone Adjacencies module, Honeybee can figure out for itself which surfaces are interior walls and which are exterior walls.

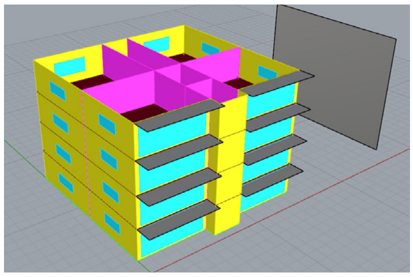


Figure 74 Honeybee Validation - Glazing visualized in Rhino.

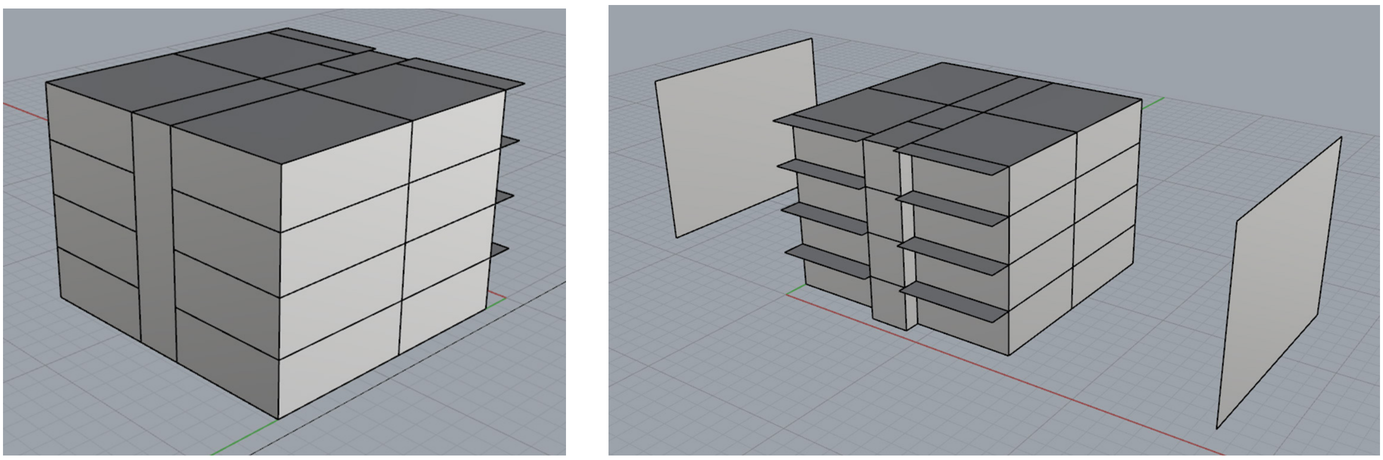


Figure 72 Honeybee Validation - Geometry modelled in Rhino.

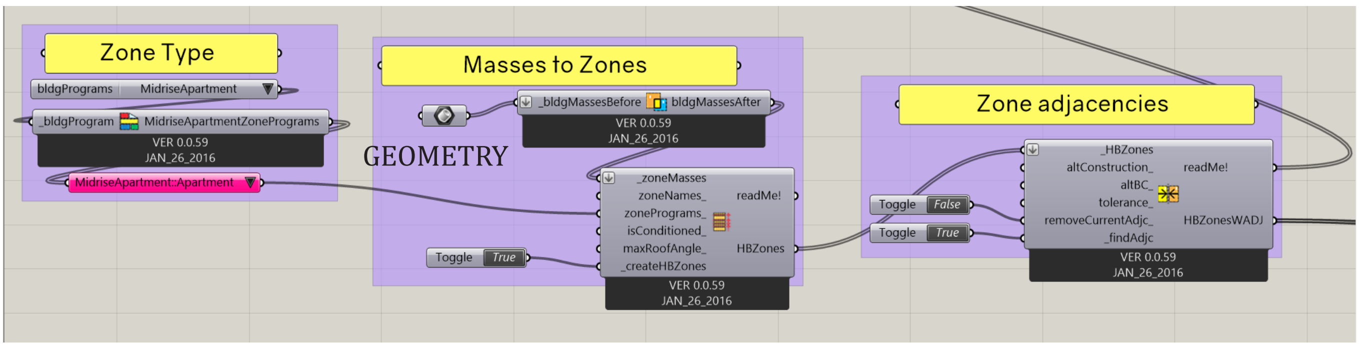


Figure 73 Honeybee Validation - Input of geometry into Grasshopper

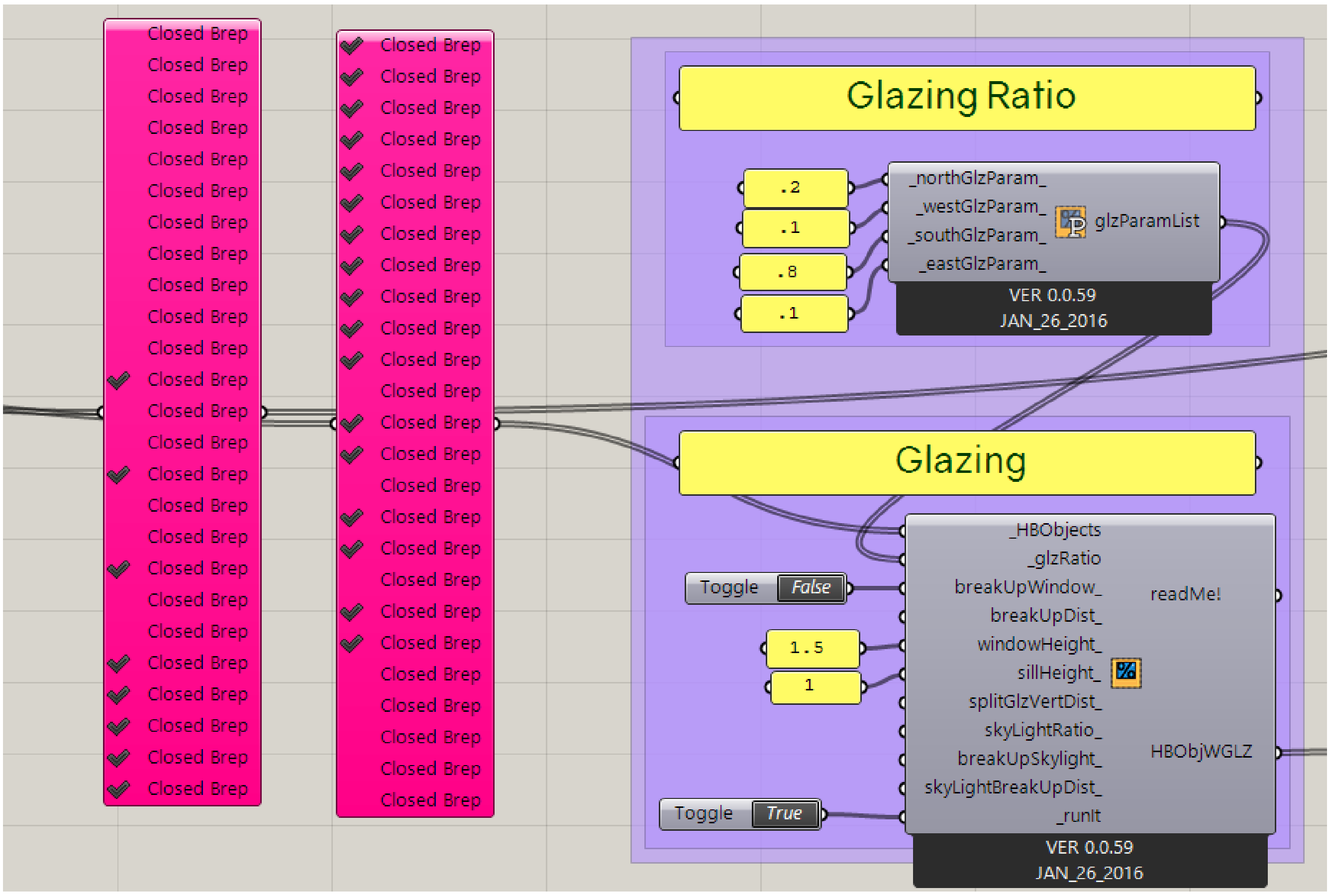


Figure 75 Honeybee Validation - Glazing in grasshopper

Materials

A wall material is defined with the appropriate U value and mass (See Figure 75). The windows are simply defined by U value and SHGC.

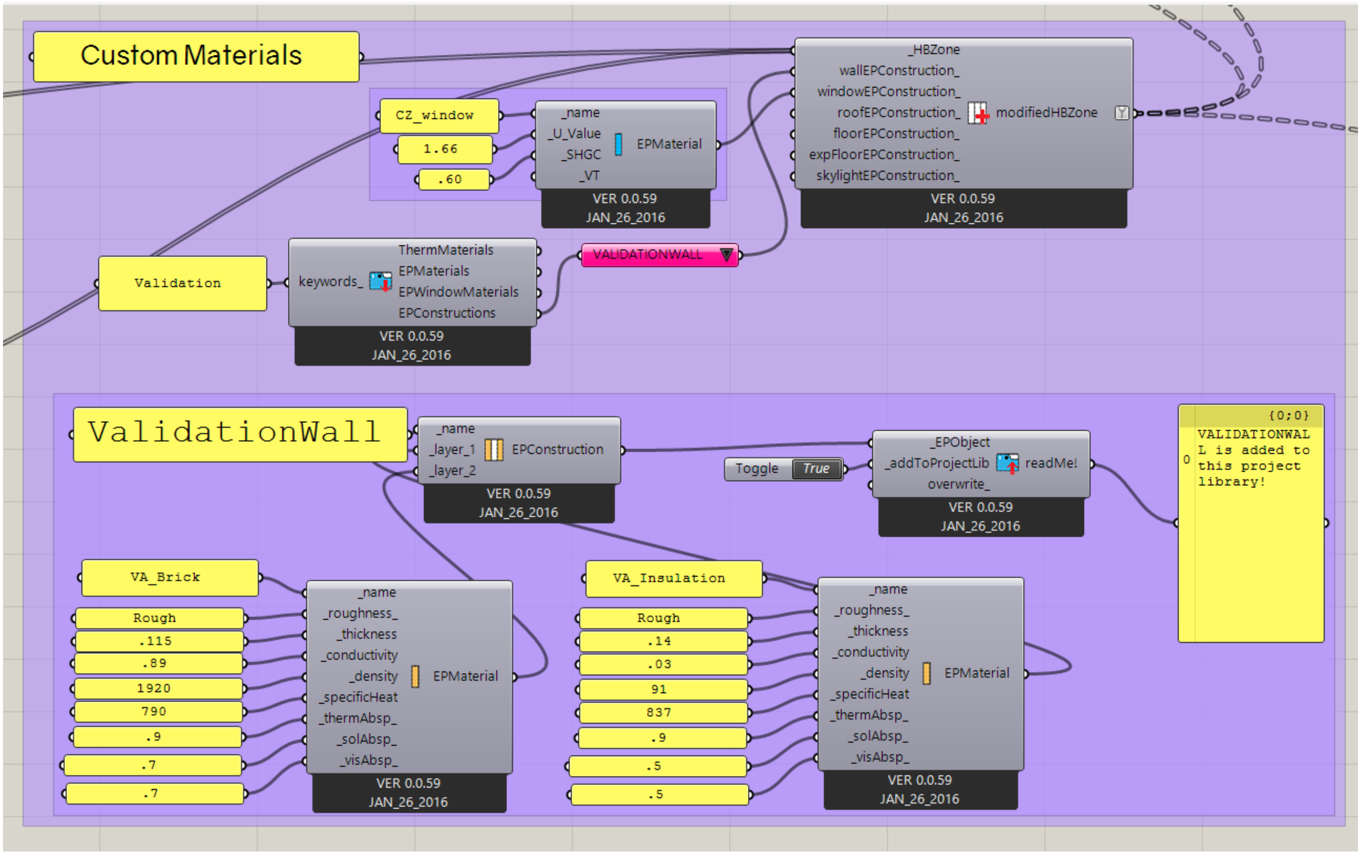


Figure 76 Honeybee Validation - Materials in grasshopper

Loads & Schedules

The correct loads and schedules are added. In this case they are simple averages.

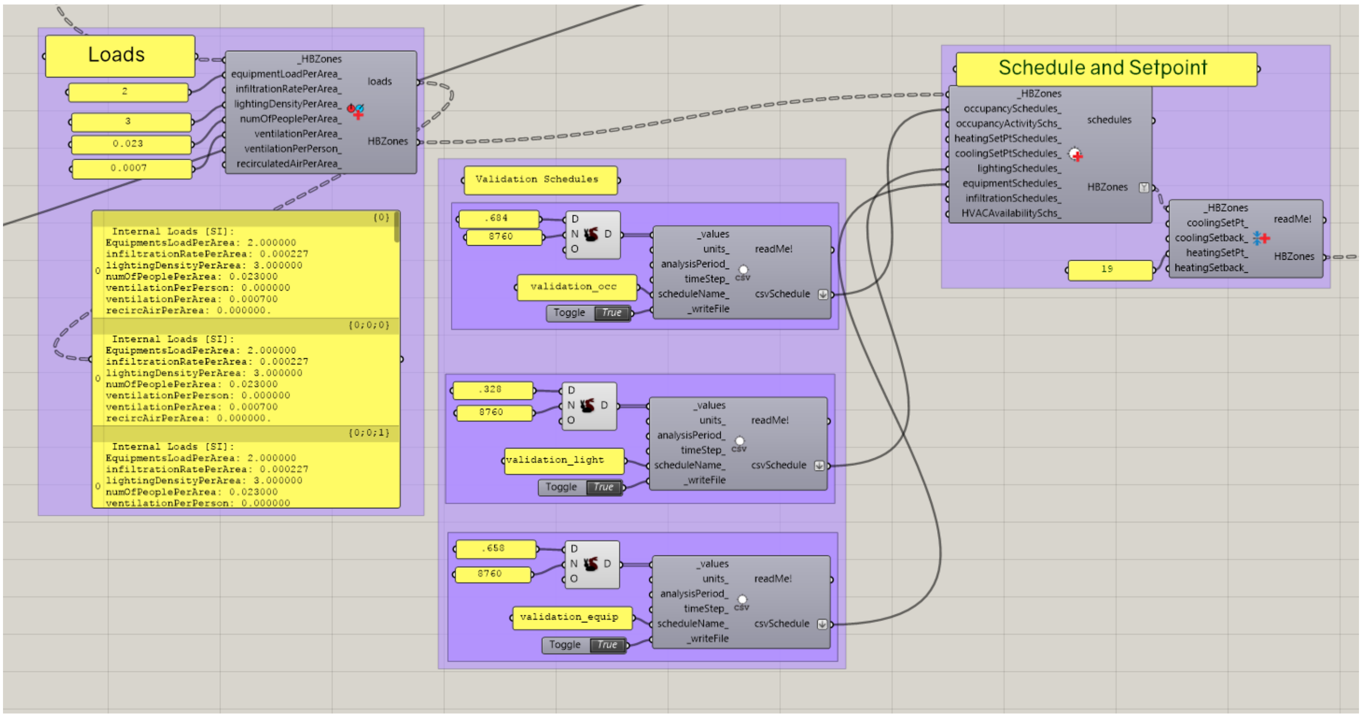


Figure 77 Honeybee Validation - Loads and schedules in grashopper

EnergyPlus Simulation

Finally the simulation parameters and output are defined and all input is connected to the EnergyPlus module. The Sun Block surface is added as a context element. The results consist of lists of hourly values that can be added up or averaged per zone or for the whole.

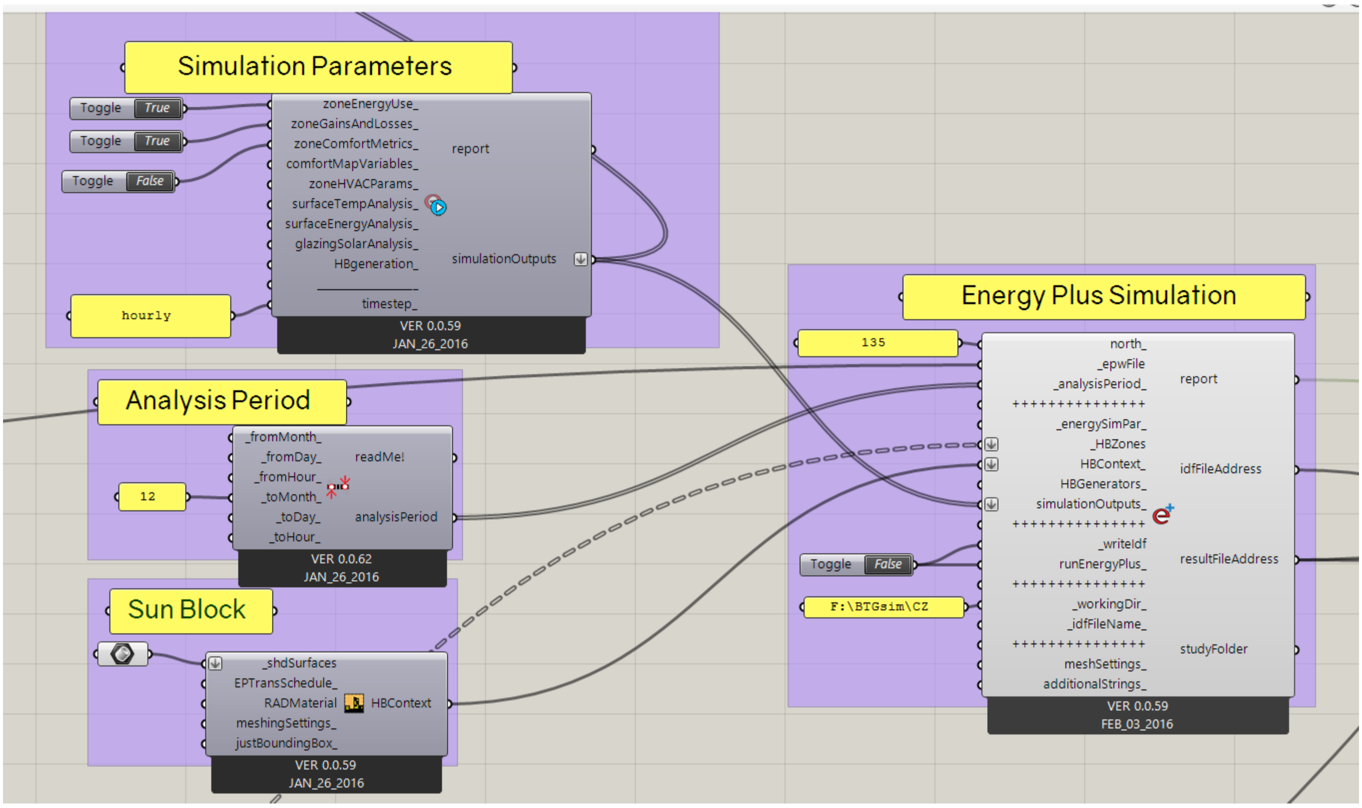


Figure 78 Honeybee Validation - EnergyPlus Simulation in grasshopper

Excel input and output

General Information								
Q total	**Zone**	**Area**	**T inside**		**Feb av. Temp.**			**Heat Demand**
[W]		[m²]	[°C]		[°C]			kWh/m²
-1075.34	2RB	45.5	19		3.7			**17.0**

Q transmission	**-491.5 W**							
Surf Total	**Surfaces**	**A closed**	**U**	**Qtrans**	**Windows**	**A windows**	**U**	**Qtrans**
[m2]		[m²]	[W/m²K]	[W]	[ratio]	[m²]	[W/m²K]	[W]
18.9	Back facade	3.78	0.21	-12.1451	0.8	15.12	1.66	-384.02
17.55	Side facade	15.80	0.21	-50.7493	0.1	1.76	1.66	-44.57
18.9	interior wall	18.9	0.3	0				0
17.55	interior wall	17.55	0.3	0				0
45.5	floor above	45.5	0.3	0				0
45.5	floor below	45.5	0.3	0				0

Q ventilation	**-584.8**	**W**
Ventilation av.	0.0007	m3/m2.s
Vvent	0.03185	m3/s
ρ	1.2	kg/m3
cp	1000	J/kg.K

Name	**Equation**	**Unit**	**Type**
Q trans	U*A*(Te-Ti)	[W]	loss
Q vent	Vvent * ρ * cp * (Te-Ti)	[W]	loss
Q inf	Vinf * 1.2 * 1000 * (Te-Ti)	[W]	loss
Q int	Qocc + Q equip + Q light	[W]	load

Q infiltration	**-189.6**	**W**
Infiltration av.	0.000227	m3/m2.s
Vinf	0.0103285	m3/s
ρ	1.2	kg/m3
cp	1000	J/kg.K

Q interior	**190.5 W**						
	type	**max W**	**ratio**	**schedule av.**	**W/m²**	**W**	**kWh/m²**
	occupancy	120	0.023	0.684	1.89	85.9	4.65
	lighting	3	1	0.328	0.98	44.8	1.16
	equipment	2	1	0.658	1.32	59.9	3.12
					4.19		

Uniec 2.2

Condition Zero - Validation
onbekend

0,94

Algemene gegevens

projectomschrijving	*Validation*
variant	*onbekend*
straat / huisnummer / toevoeging	
postcode / plaats	
bouwjaar	
categorie	*Energieprestatie Woningbouw*
aantal woningbouw-eenheden in berekening	*1*
gebruiksfunctie	*woonfunctie*
datum	*03-10-2016*
opmerkingen	

Indeling gebouw

Eigenschappen rekenzones			
type rekenzone	omschrijving	interne warmtecapaciteit	A_g [m²]
verwarmde zone	R2B	traditioneel, gemengd zwaar	45,50

Infiltratie

meetwaarde voor infiltratie $q_{v;10;spec}$	*ja*
lengte van het gebouw	*13,50 m*
breedte van het gebouw	*16,40 m*
hoogte van het gebouw	*10,80 m*

Eigenschappen infiltratie		
rekenzone	gebouwtype	$q_{v;10;spec}$ [dm³/s per m²]
R2B	meerlaags gebouw, tussengelegen laag (standaard geveltype)	2,00

Open verbrandingstoestellen

Het gebouw bevat geen open verbrandingstoestellen.

Bouwkundige transmissiegegevens

Transmissiegegevens rekenzone R2B							
constructie	A [m²]	R_c [m²K/W]	U [W/m²K]	g_{gl} [-]	zonwering	beschaduwing	toelichting
Achtergevel (balkon) - buitenlucht, NO - 18,9 m² - 90°							
Facade	1,90	4,50				constante overstek ho ≥ 1,0	

Transmissiegegevens rekenzone R2B							
constructie	A [m²]	R_c [m²K/W]	U [W/m²K]	g_{gl} [-]	zonwering	beschaduwing	toelichting
Raam	17,00		1,66	0,60	nee	constante overstek ho ≥ 1,0	
Rechtergevel - buitenlucht, ZO - 17,6 m² - 90°							
Facade	15,55	4,50				minimale belem.	
Raam	2,00		1,66	0,60	nee	minimale belem.	
Binnenwand NW - AVR - 17,6 m²							
Binnenwand	17,55	1,00					
Binnenwand ZW - AVR - 18,9 m²							
Binnenwand	18,90	1,00					
bovenvloer - AVR - 45,5 m²							
Vloer	45,50	3,00					
ondervloer - AVR - 45,5 m²							
Vloer	45,50	3,00					

Lineaire transmissiegegevens rekenzone R2B					
constructie	l [m]	ψ [W/m¹K]	beschrijving	+25%	toelichting
Achtergevel (balkon) - buitenlucht, NO - 18,9 m² - 90°					
Baksteen	0,12	0,890	n.v.t.	n.v.t.	
Isolatie	0,14	0,030	n.v.t.	n.v.t.	
Rechtergevel - buitenlucht, ZO - 17,6 m² - 90°					
Baksteen	0,12	0,890	n.v.t.	n.v.t.	
Isolatie	0,14	0,030	n.v.t.	n.v.t.	

Verwarming- en warmtapwatersystemen

verwarming/warmtapwater 1

Opwekking

type opwekker	*HR-combiketel*
positie HR-ketel	*binnen EPC begrenzing*
indeling LT/HT voor opwekker	*hoge temperatuur*
toepassingsklasse (CW-klasse)	*4 (CW 4)*
toestel - HR-ketel	*ATAG A244EC (HP)*
aantal HR-ketels	*1*
transmissieverlies verwarmingssysteem - januari (H_T)	*36 W/K*
warmtebehoefte verwarmingssysteem ($Q_{H;nd;an}$)	*12.263 MJ*
hoeveelheid energie t.b.v. verwarming per toestel ($Q_{H;dis;nren;an}$)	*12.908 MJ*
hoeveelheid energie t.b.v. warmtapwater per toestel ($Q_{W;dis;nren;an}$)	*7.200 MJ*
opwekkingsrendement verwarming - HR ketel ($\eta_{H;gen}$)	*0,950*
opwekkingsrendement warmtapwater - HR ketel ($\eta_{W;gen}$)	*0,900*

Kenmerken afgiftesysteem verwarming

Type warmteafgifte (in woonkamer)					
type warmteafgifte	positie	hoogte	R_c	$\theta_{em;avg}$	$\eta_{H;em}$
radiator- en/of convectorverwarming	buitenwand	< 8 m	≥ 2,5 m²K/W	> 50 °	0,95

regeling warmteafgifte aanwezig	*ja*
afgifterendement ($\eta_{H;em}$)	*0,950*

Kenmerken distributiesysteem verwarming

ongeïsoleerde verdeler / verzamelaar aanwezig	*nee*
buffervat buiten verwarmde ruimte aanwezig	*nee*
verwarmingsleidingen in onverwarmde ruimten en/of kruipruimte	*nee*
distributierendement ($\eta_{H;dis}$)	*1,000*

Kenmerken tapwatersysteem

aantal woningbouw-eenheden aangesloten op systeem	*1*
warmtapwatersysteem ten behoeve van	*keuken en badruimte*
gemiddelde leidinglengte naar badruimte	*forfaitair*
gemiddelde leidinglengte naar aanrecht	*forfaitair*
inwendige diameter leiding naar aanrecht	*[illegible] 10 mm*
afgifterendement warmtapwater ($\eta_{W;em}$)	*0,[illegible]2*

Douchewarmteterugwinning

douchewarmteterugwinning	*nee*

Zonneboiler

zonneboiler	*nee*

Hulpenergie verwarming

hoofdcirculatiepomp aanwezig	*ja*
hoofdcirculatiepomp voorzien van pompregeling	*ja*
aanvullende circulatiepomp aanwezig	*nee*

Aangesloten rekenzones

R2B

Ventilatie

ventilatie 1

Ventilatiesysteem

ventilatiesysteem	*C. natuurlijke toevoer en mechanische afvoer*
systeemvariant	*C1 standaard*
luchtvolumestroomfactor voor warmte- en koudebehoefte (f_{sys})	*1,09*
correctiefactor regelsysteem voor warmte- en koudebehoefte (f_{reg})	*1,00*

Kenmerken ventilatiesysteem

werkelijk geïnstalleerde ventilatiecapaciteit bekend	*ja*
natuurlijke toevoer ($q_{vinst;1a}$ / $q_{ve;sys;nat;e}$)	*7 dm³/s*
warmtepompboiler(s) in gebouw	*nee*

luchtdichtheidsklasse ventilatiekanalen	*onbekend*

Passieve koeling

max. benutting geïnstal. ventilatiecapaciteit voor koudebehoefte	*nee*
max. benutting geïnstal. spuicapaciteit voor koudebehoefte	*nee*

Kenmerken ventilatoren

nominaal vermogen ventilator(en) forfaitair	*ja*
type ventilatoren (vermogen forfaitair)	*gelijkstroom*
extra circulatie op ruimteniveau	*nee*

Aangesloten rekenzones

R2B

Resultaten

Jaarlijkse hoeveelheid primaire energie voor de energiefunctie		
verwarming (excl. hulpenergie)	$E_{H;P}$	13.588 MJ
hulpenergie		396 MJ
warmtapwater (excl. hulpenergie)	$E_{W;P}$	8.000 MJ
hulpenergie		0 MJ
koeling (excl. hulpenergie)	$E_{C;P}$	0 MJ
hulpenergie		0 MJ
zomercomfort	$E_{SC;P}$	3.641 MJ
ventilatoren	$E_{V;P}$	2.981 MJ
verlichting	$E_{L;P}$	2.097 MJ
geëxporteerde elektriciteit	$E_{P;exp;el}$	0 MJ
op eigen perceel opgewekte & verbruikte elektriciteit	$E_{P;pr;us;el}$	0 MJ
in het gebied opgewekte elektriciteit	$E_{P;pr;dei;el}$	0 MJ

Oppervlakten		
totale gebruiksoppervlakte	A	45,50 m²
totale verliesoppervlakte	A_{ls}	36,45 m²

Aardgasgebruik (exclusief koken)		
gebouwgebonden installaties		614 m³aeq

Elektriciteitsgebruik		
gebouwgebonden installaties		989 kWh
niet-gebouwgebonden apparatuur (stelpost)		1.275 kWh
op eigen perceel opgewekte & verbruikte elektriciteit		0 kWh
geëxporteerde electriciteit		0 kWh
TOTAAL		2.265 kWh

CO_2-emissie		
CO_2-emissie	m_{co2}	1.651 kg

Energieprestatie		
specifieke energieprestatie	EP	675 MJ/m²
karakteristiek energiegebruik	E_{Ptot}	30.703 MJ
toelaatbaar karakteristiek energiegebruik	$E_{P;adm;tot;nb}$	13.146 MJ
energieprestatiecoëfficiënt	EPC	0,935 -
energieprestatiecoëfficiënt	EPC	0,94 -

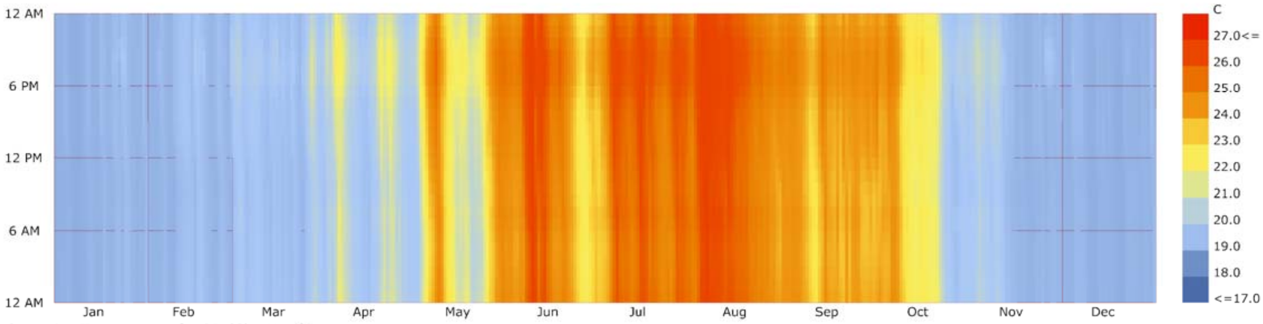
BENG indicatoren		
energiebehoefte		100,9 kWh/m²
primair energiegebruik		174,6 kWh/m²
aandeel hernieuwbare energie		0 %

Het gebouw voldoet niet aan de eisen inzake energieprestatie uit het Bouwbesluit 2012.

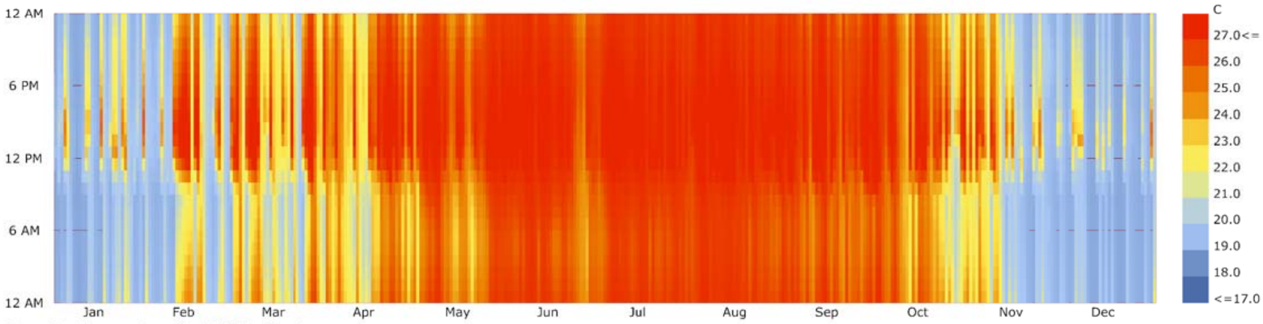
Uniec 2.2 is gebaseerd op NEN7120;2011 “Energieprestatie van gebouwen” (inclusief het Nader Voorschrift) en NEN 8088-1 “Ventilatie en luchtdoorlatendheid van gebouwen” inclusief alle wettelijk van kracht zijnde correctiebladen.

Alle bovenstaande energiegebruiken zijn genormeerde energiegebruiken gebaseerd op een standaard klimaatjaar en een standaard gebruikersgedrag. Het werkelijke energiebruik zal afwijken van het genormeerde energieverbruik. Aan de berekende energiegebruiken kunnen geen rechten ontleend worden.

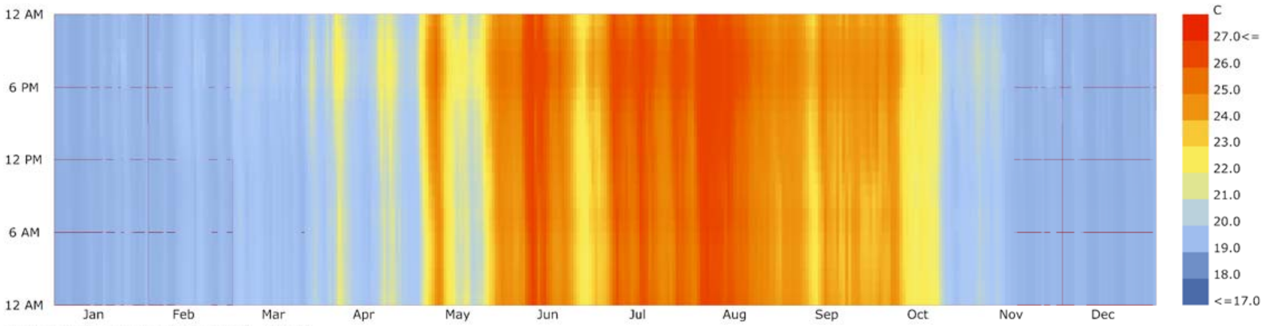
APPENDIX B - Output



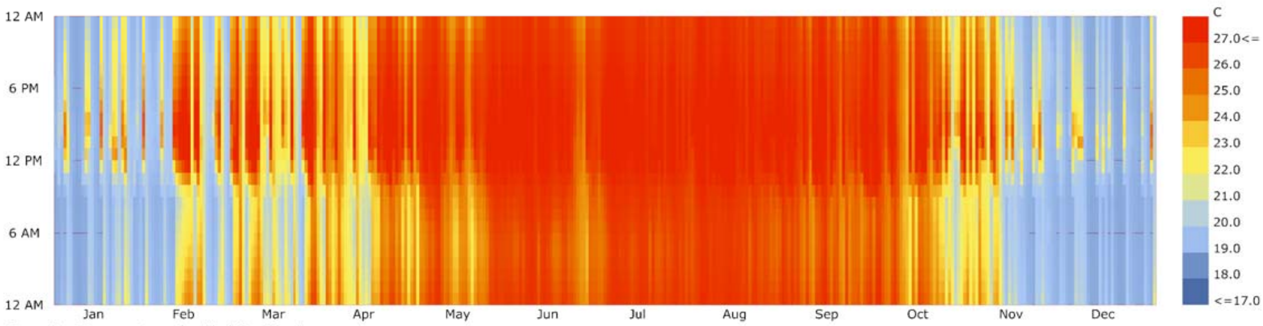
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

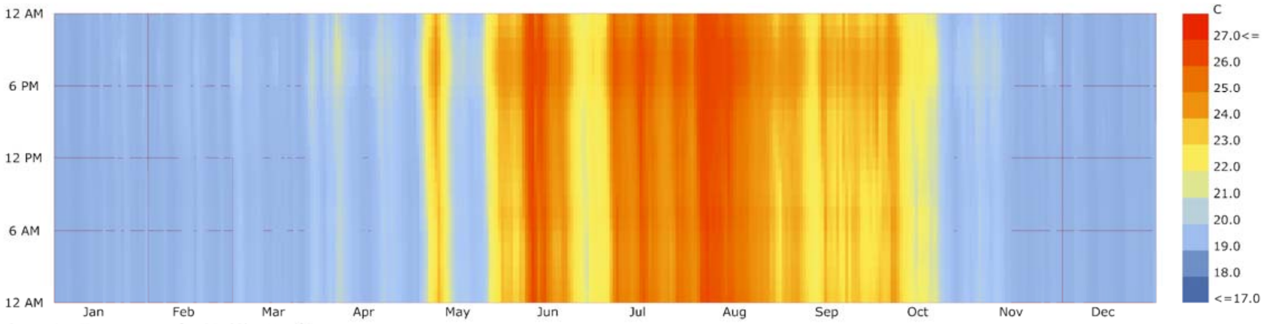


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

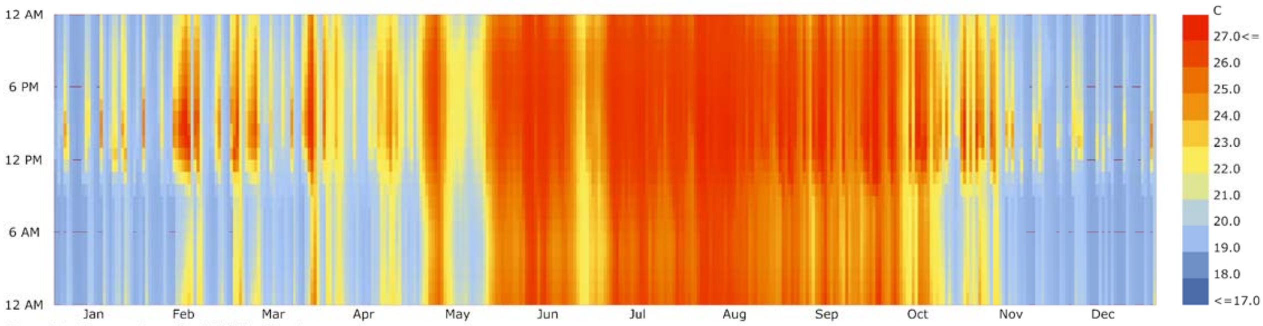


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

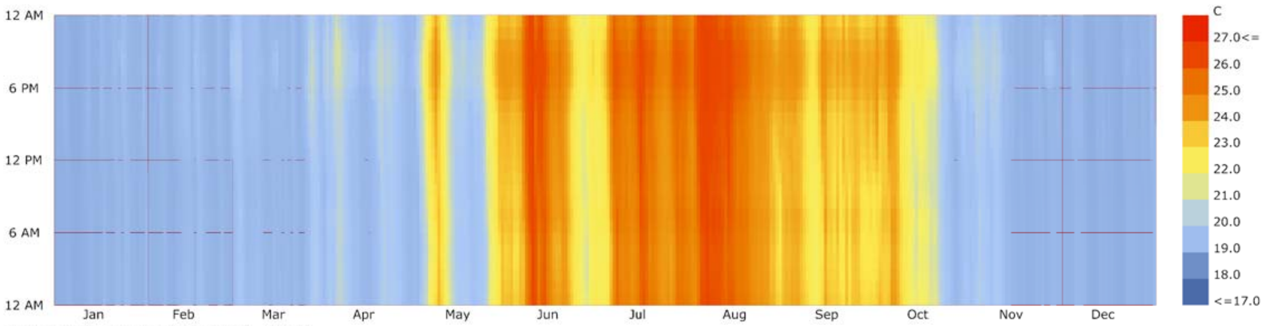
Hourly Operative Temperature
Shape A - Balcony - zones A to D



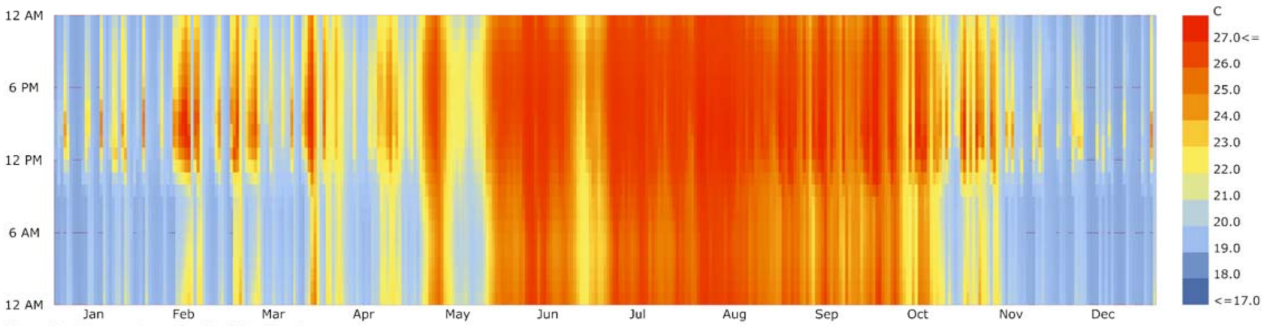
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

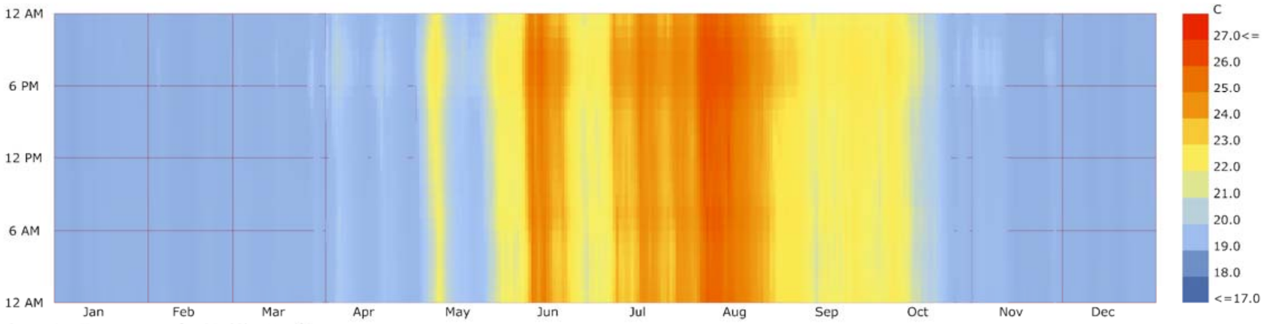


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

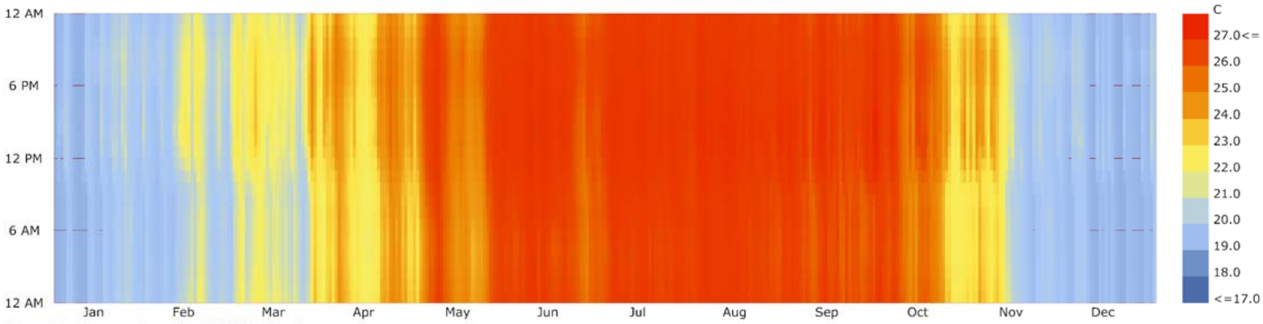


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

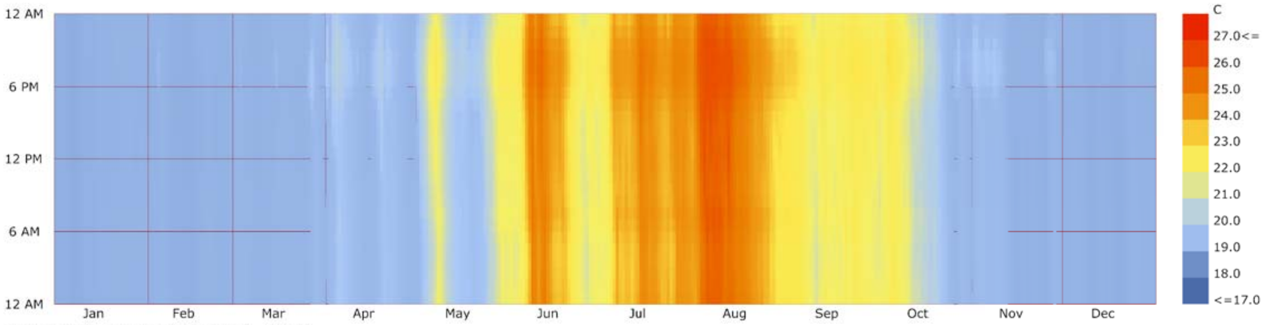
Hourly Operative Temperature
Shape A - Sunspace - Zones A to D



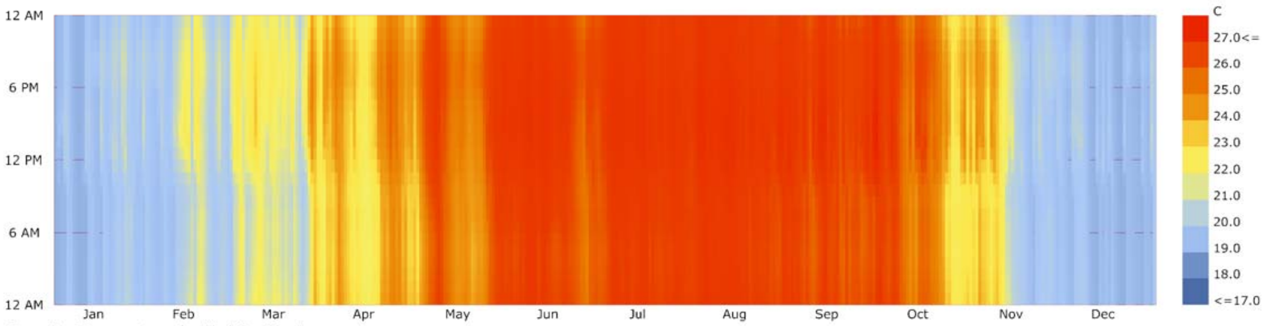
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

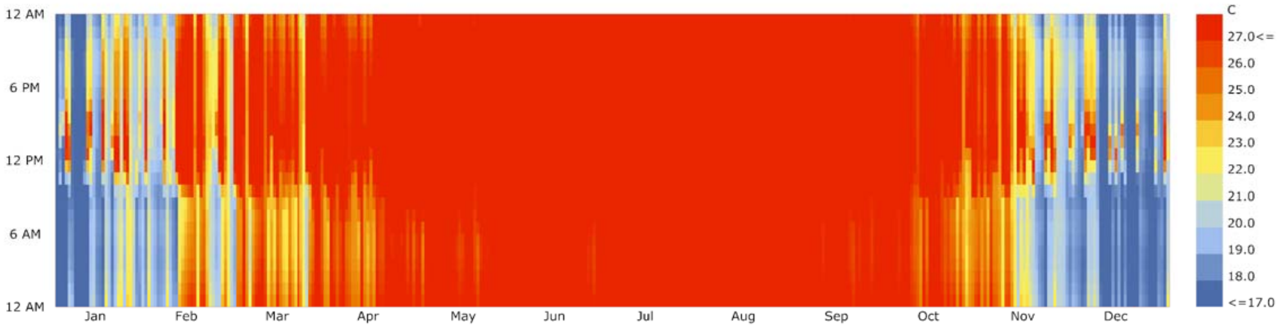


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

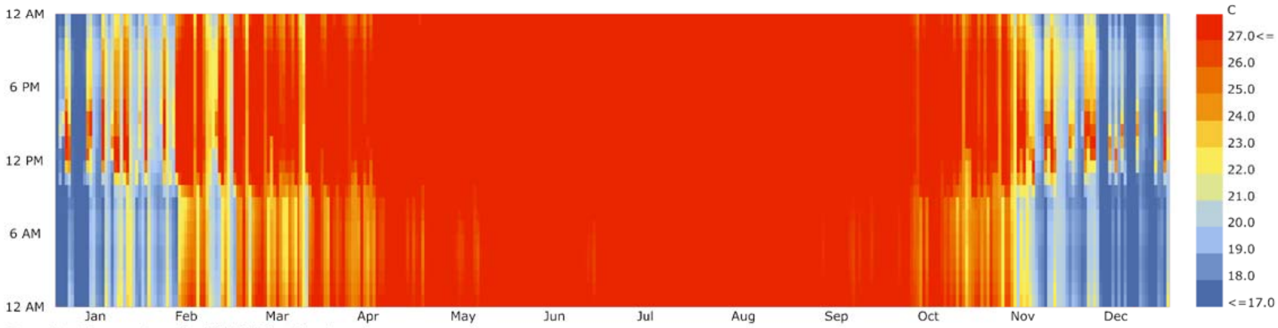


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

Hourly Operative Temperature
Shape A - Sunspace - Sunspace zones

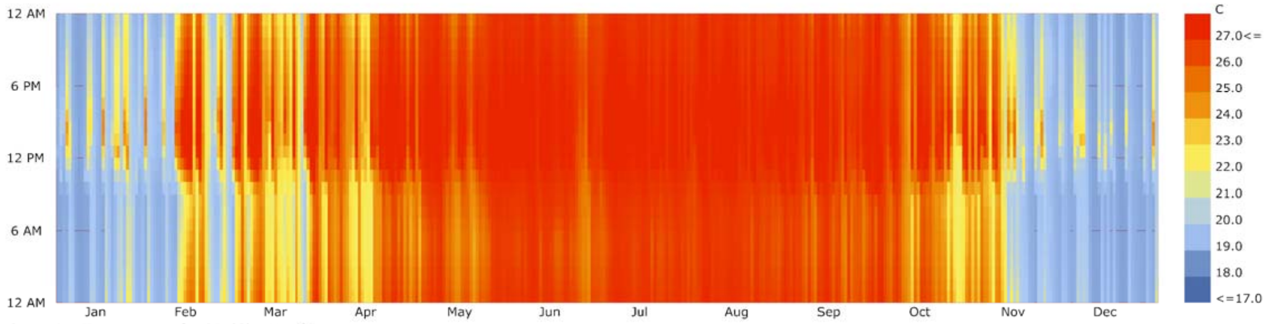


Operative Temperature for SUNA (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

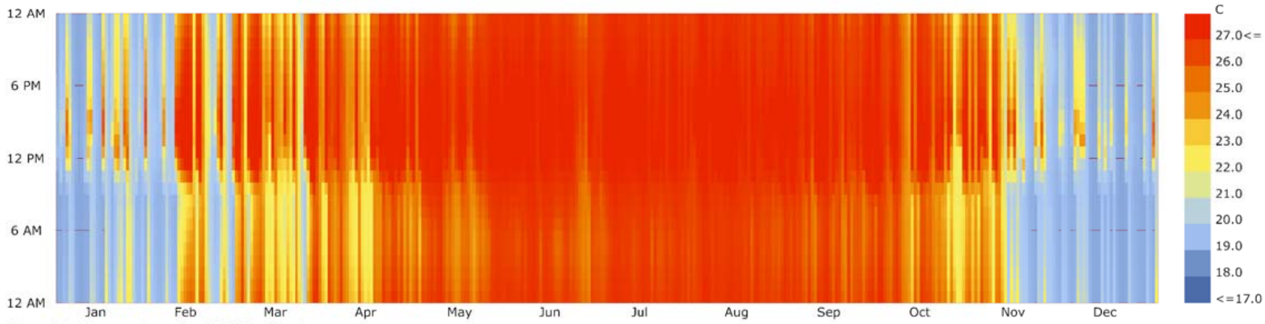


Operative Temperature for SUNC (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

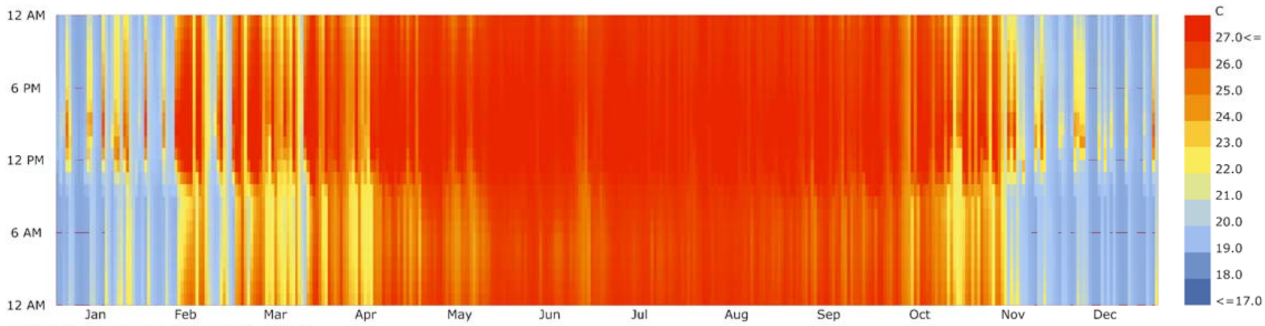
Hourly Operative Temperature
Shape B - Plain facade - zones A to D



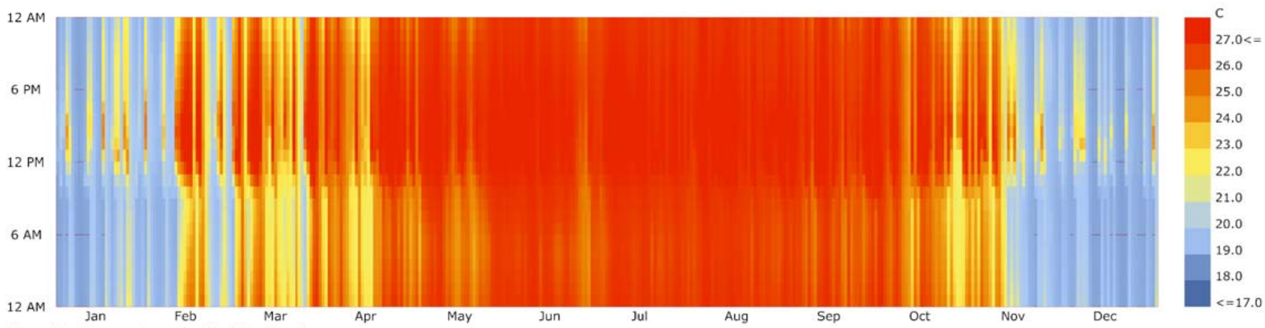
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

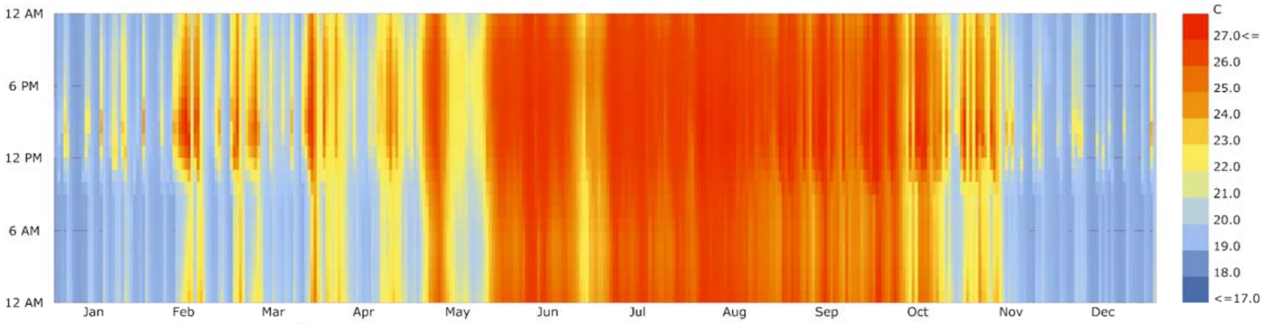


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

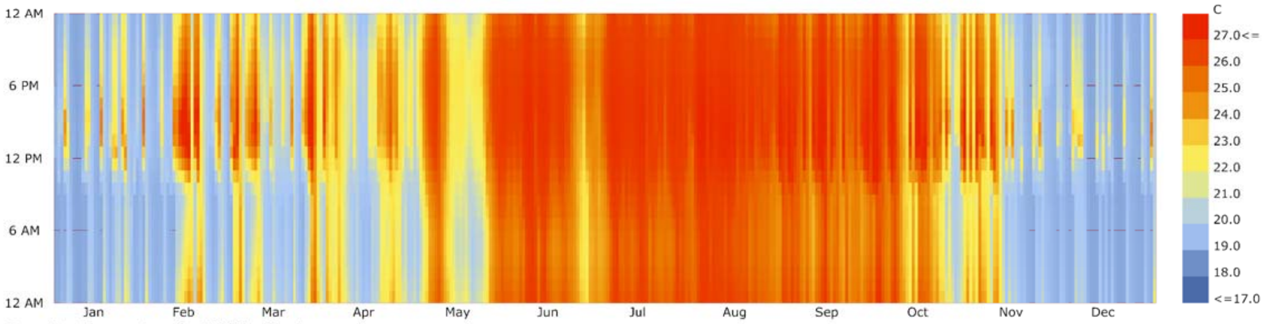


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

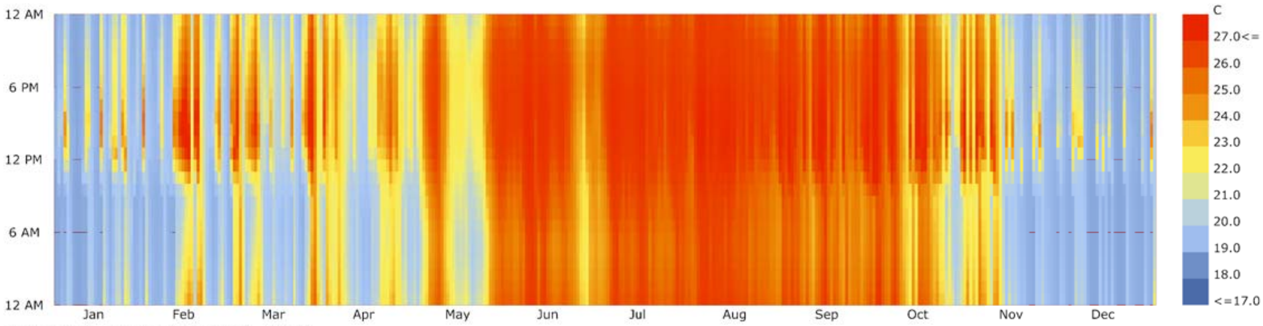
Hourly Operative Temperature
Shape B - Balcony - Zones A to D



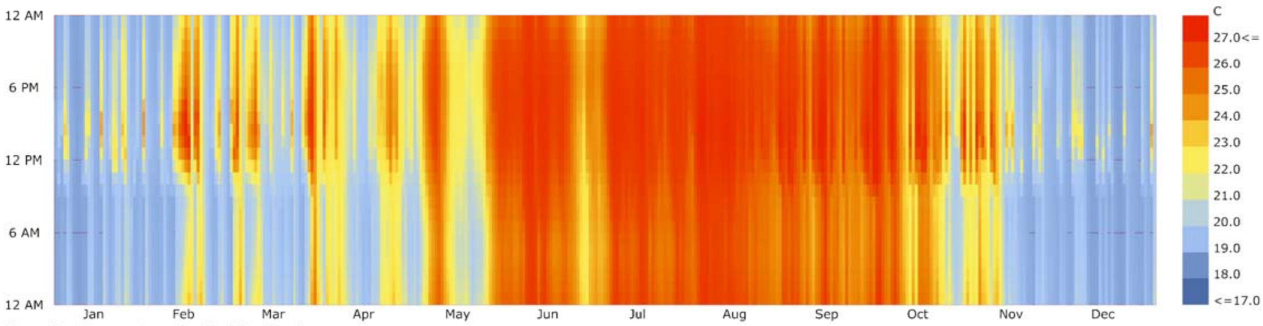
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

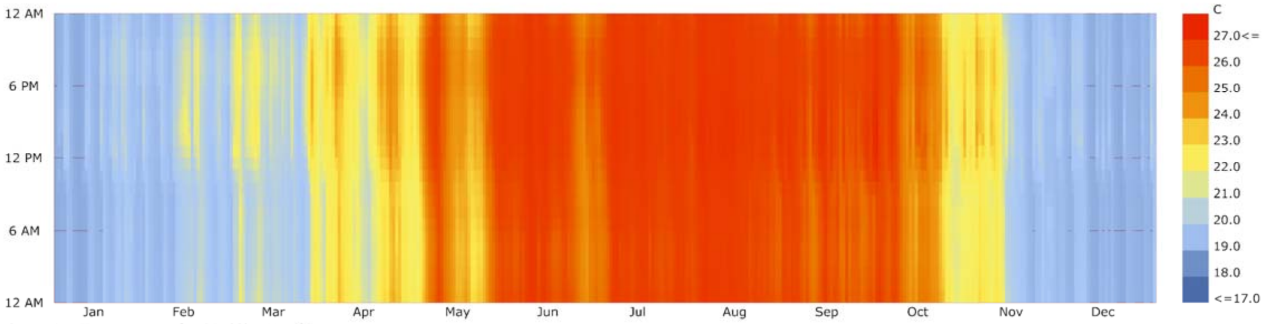


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

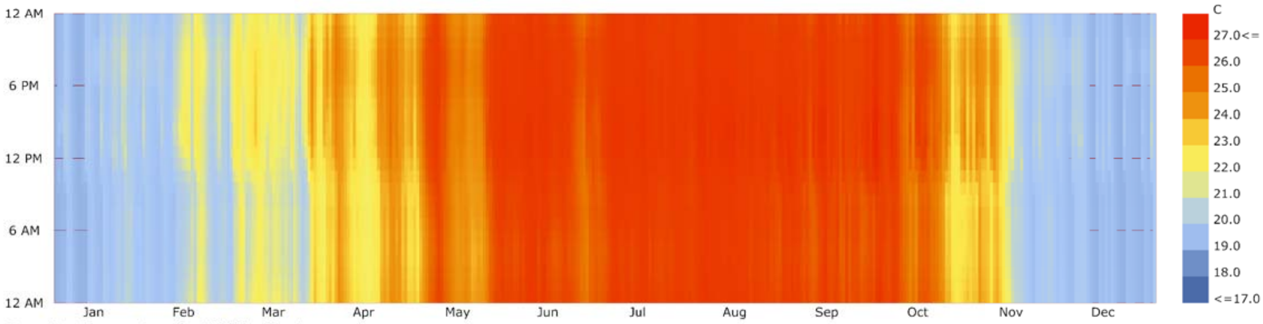


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

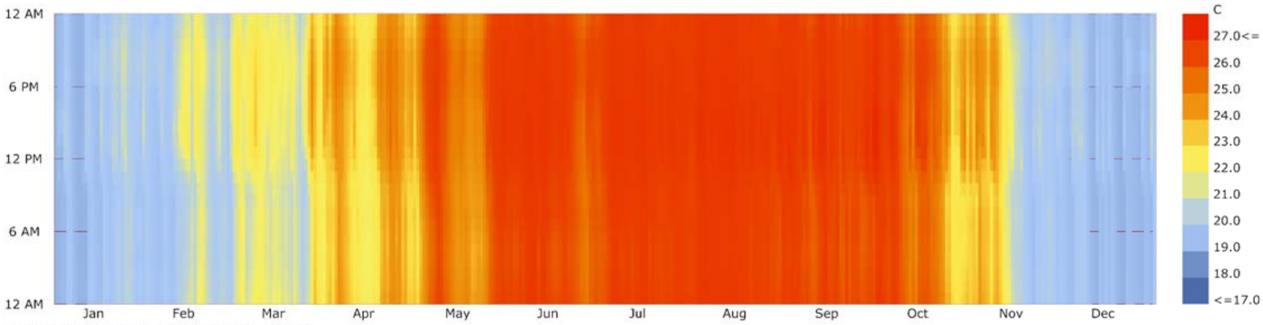
Hourly Operative Temperature
Shape B - Sunspace - Zones A to D



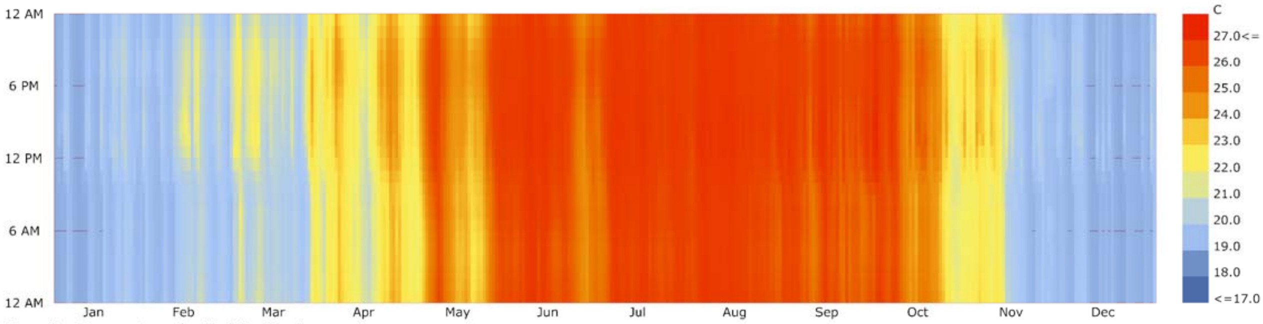
Operative Temperature for 2D (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for 2C (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

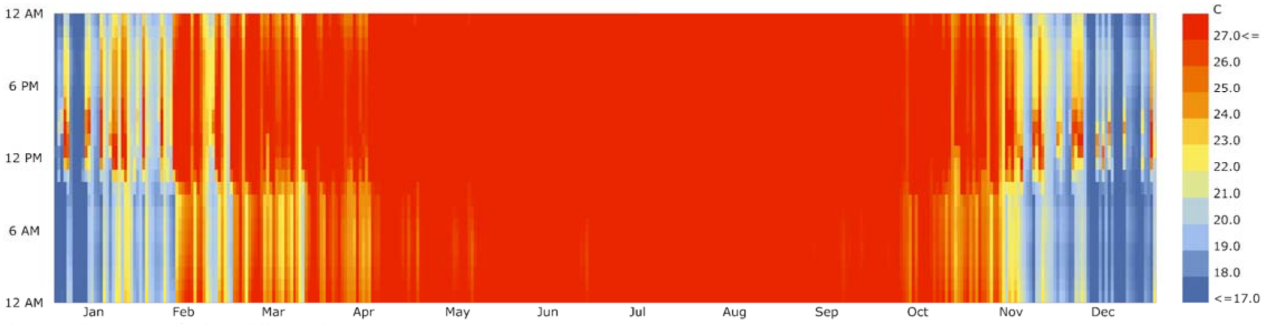


Operative Temperature for 2B (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

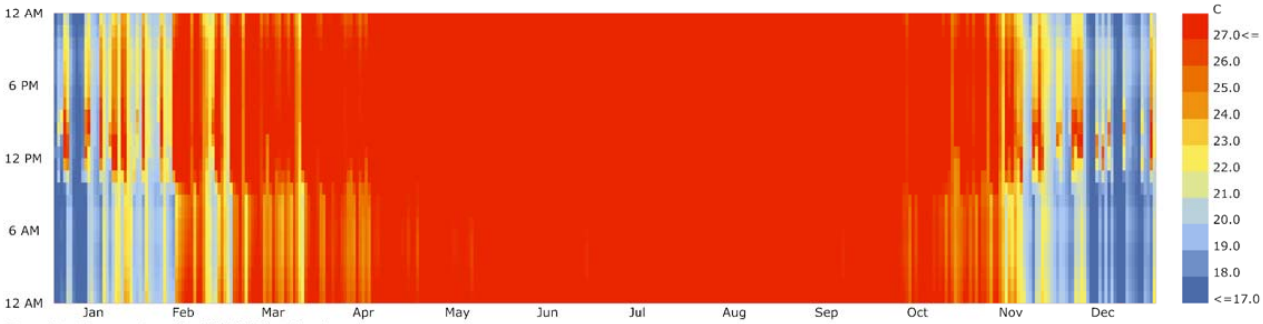


Operative Temperature for 2A (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00

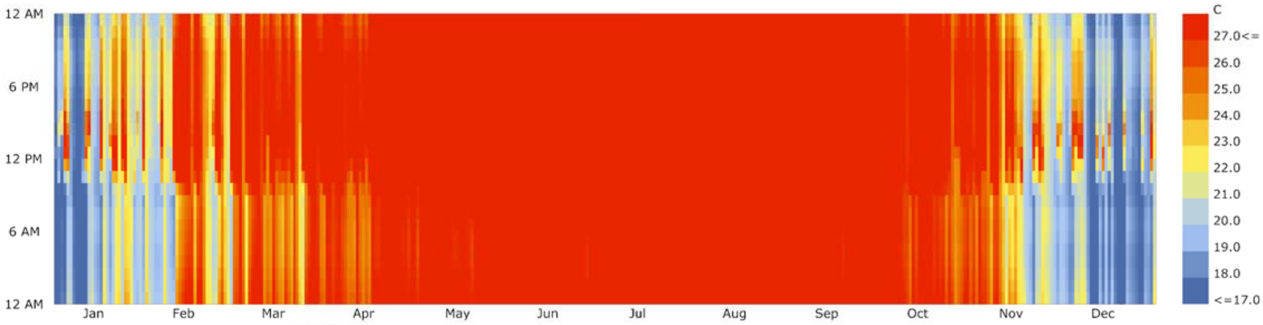
Hourly Operative Temperature
Shape B - Sunspace - Sunspace zones



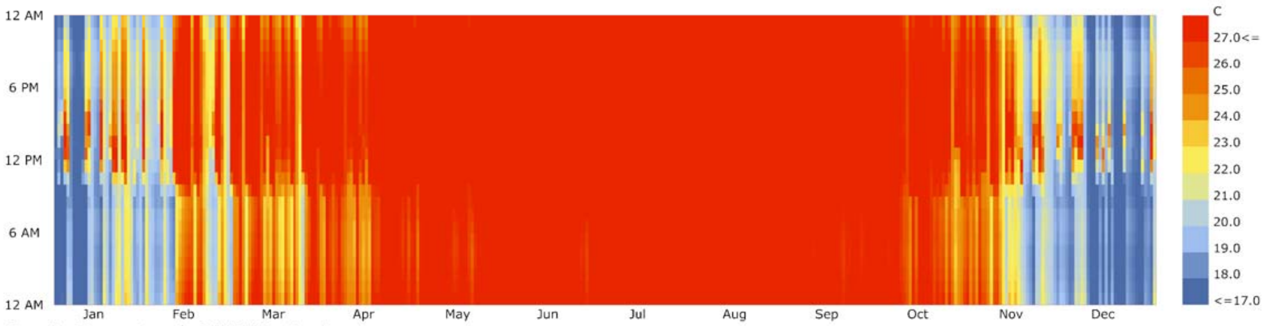
Operative Temperature for SUND (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for SUNC (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for SUNB (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Operative Temperature for SUNA (C) - Hourly
AMSTERDAM - NLD IWEC Data
1 JAN 1:00 - 31 DEC 24:00