Energy-flat housing - Vincent Höfte

Graduation presentation, January, 2018

ENERGY-FLAT DESIGN

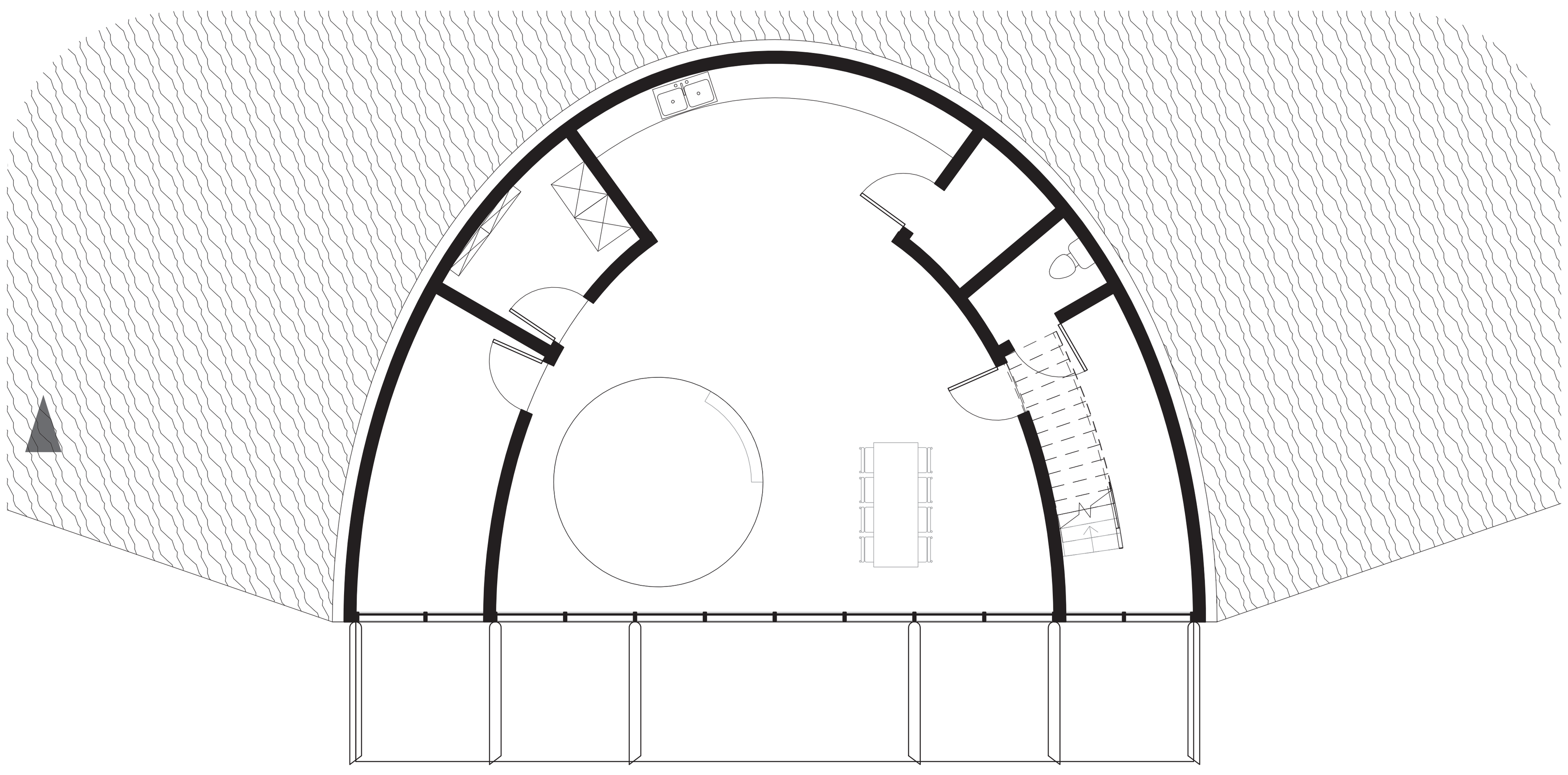
Architecture

The final design is a non-typical kind of architecture, which is the result of design by research.

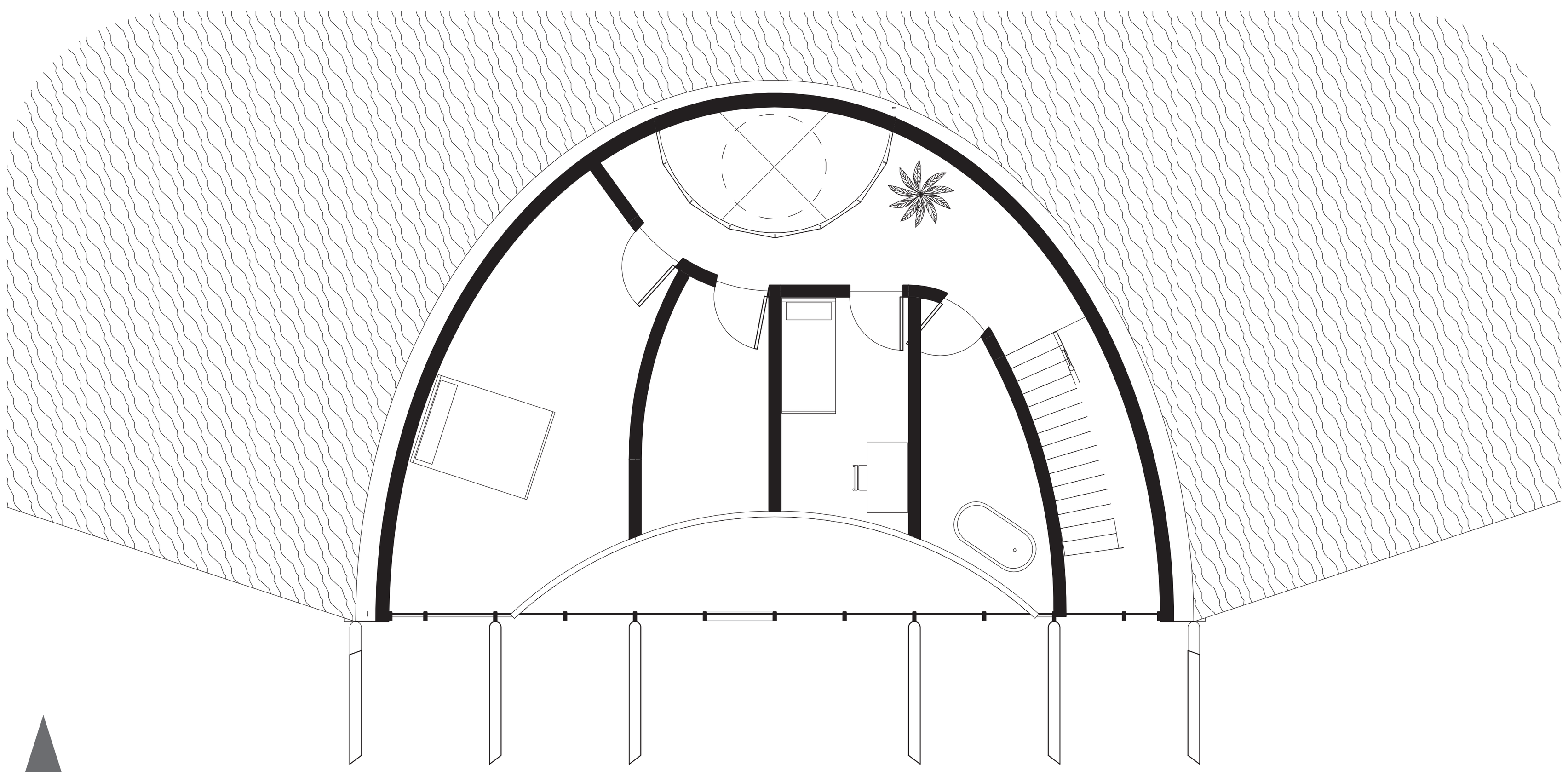
The aim of the final design is to be energy-flat in the heat-balance. The floor space of the building (176 m2) is equal to that of the reference design, to allow for a fair comparison with the reference design.

The design is a quarter elliptical sphere which is covered by a layer of earth. The south façade consist for 80 % of glazed surfaces. In front of the façade, there is an array of six rotating insulated solar blinds. In the back of the house, there is one shaft going through the layer of earth, providing light in the back of the house and ventilation possibilities. The house has two levels and almost all rooms oriented themselves to light of the south façade.

Floor plans

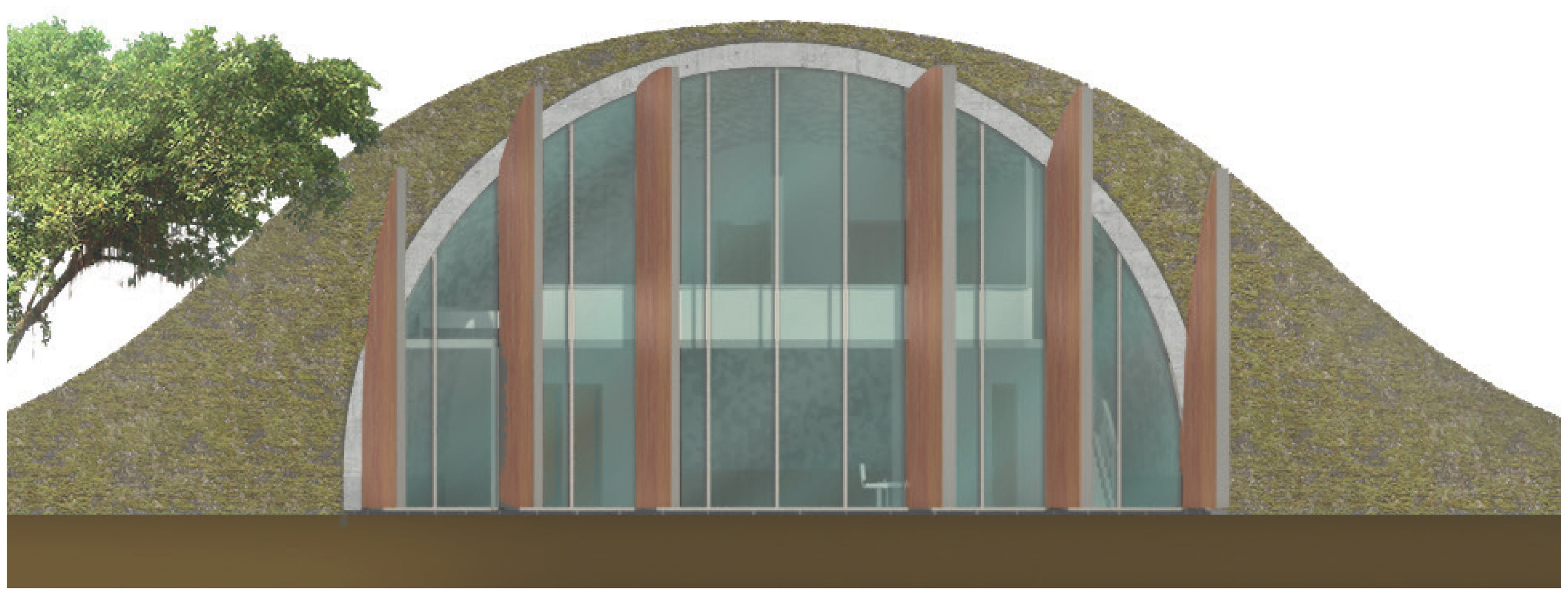


Floor plan - ground floor - 1:100

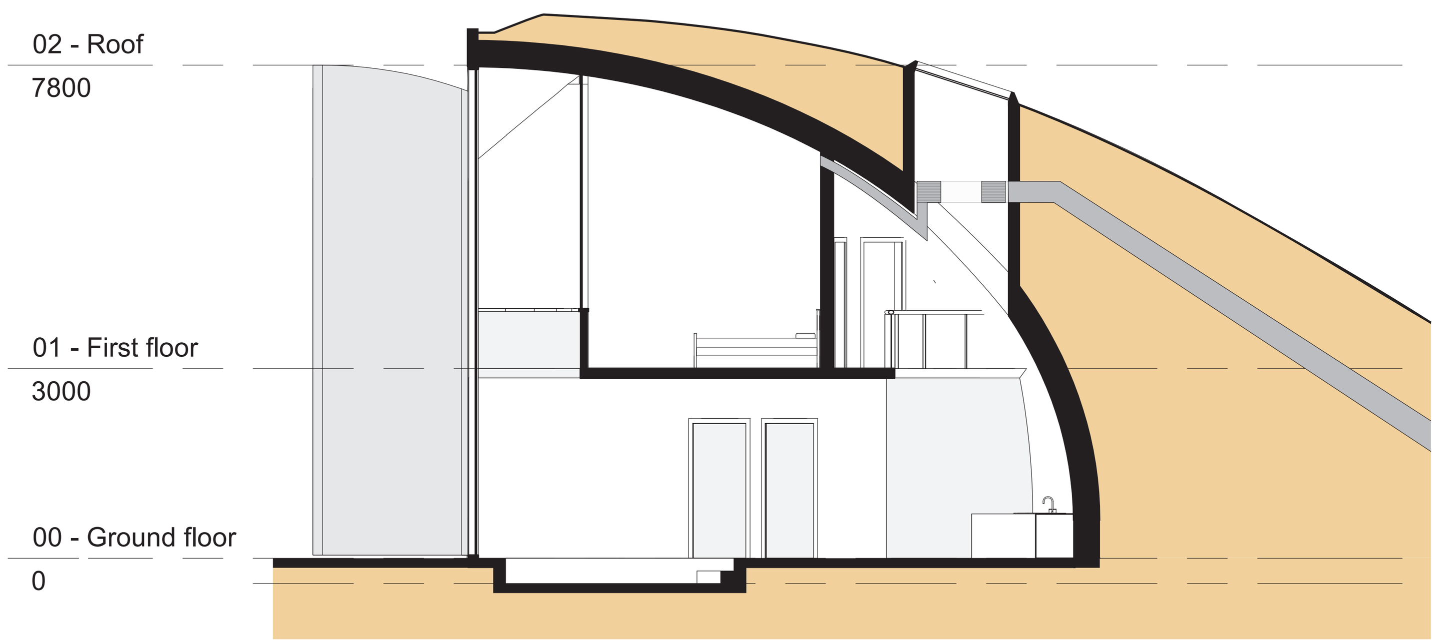


Floor plan - first floor - 1:100

Elevation and section



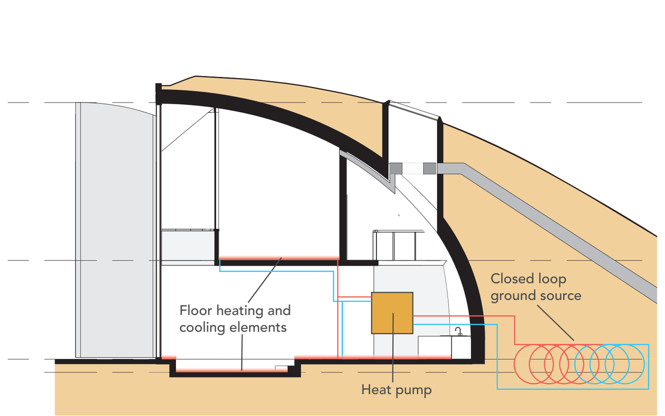
South elevation - 1:100



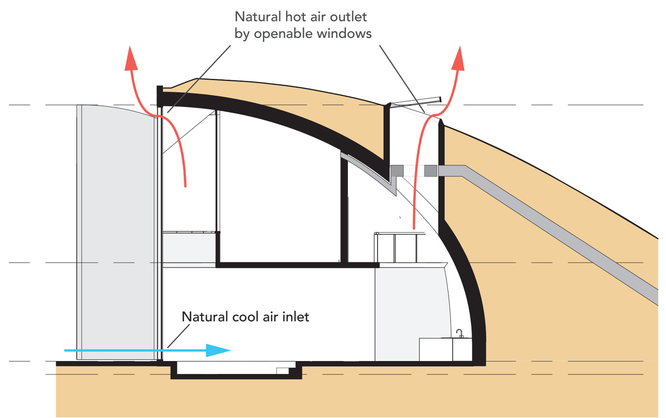
Section South-North - 1:100

DESIGN ELABORATION

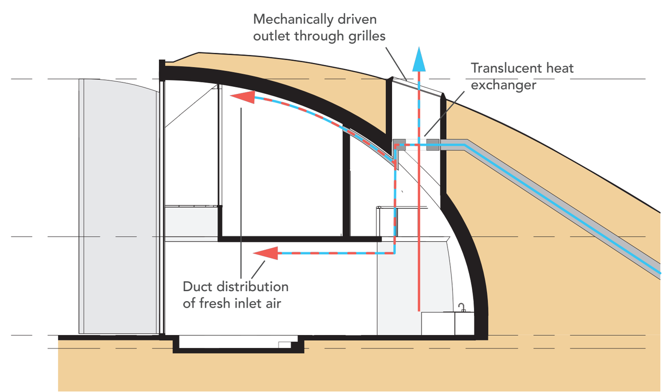
Building services



Heating and cooling scheme



Ventilation scheme - natural ventilation



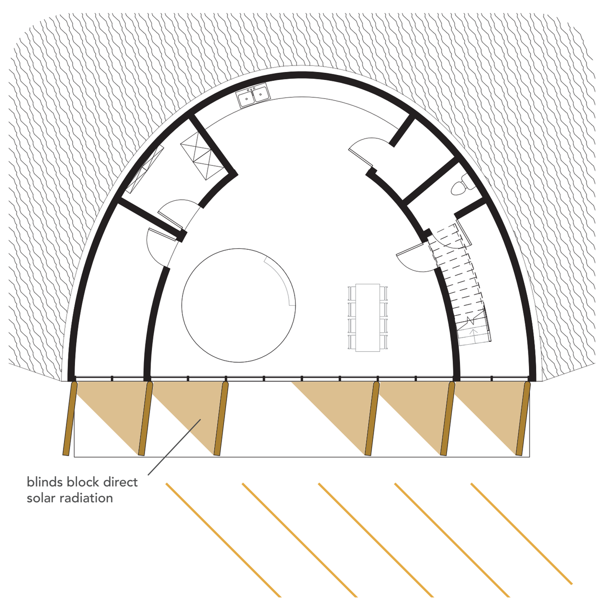
Ventilation scheme - mechanical ventilation

Heating and cooling system & ventilation principles

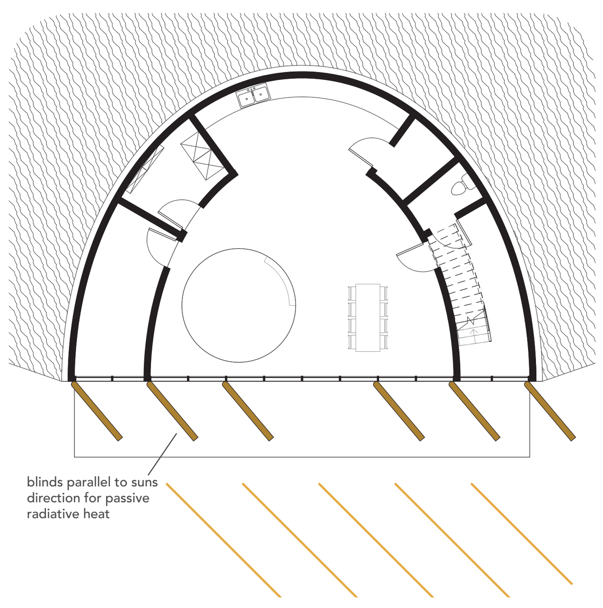
In the northern side of the sphere, there is a shaft that goes through the earth layer. The shaft has two main functionalities:

- Allowing light to enter in the back of the house
- Facilitating both natural and mechanical ventilation with heat-exchange

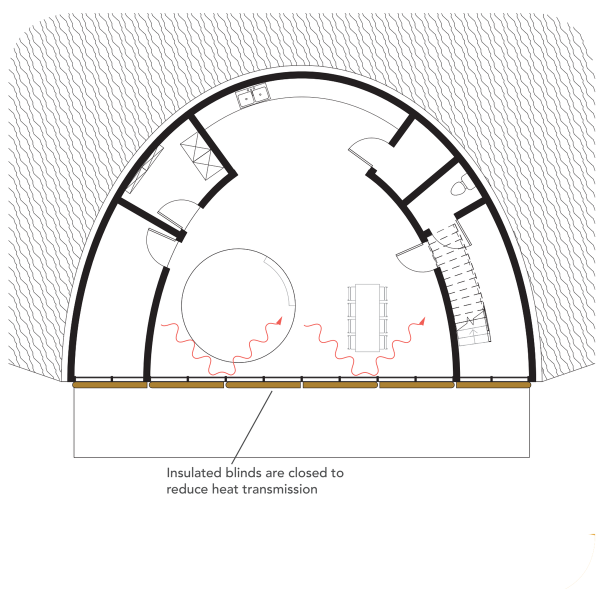
The ventilation shaft allows for a natural draft. The integrated heat-exchanger makes effectively use of the size of the shaft. By integrating the heat-exchanger in the shaft, both natural ventilation and mechanical ventilation are possible.



Blinds in summer - blocking direct solar rad.



Blinds in winter - maximum passive solar gain



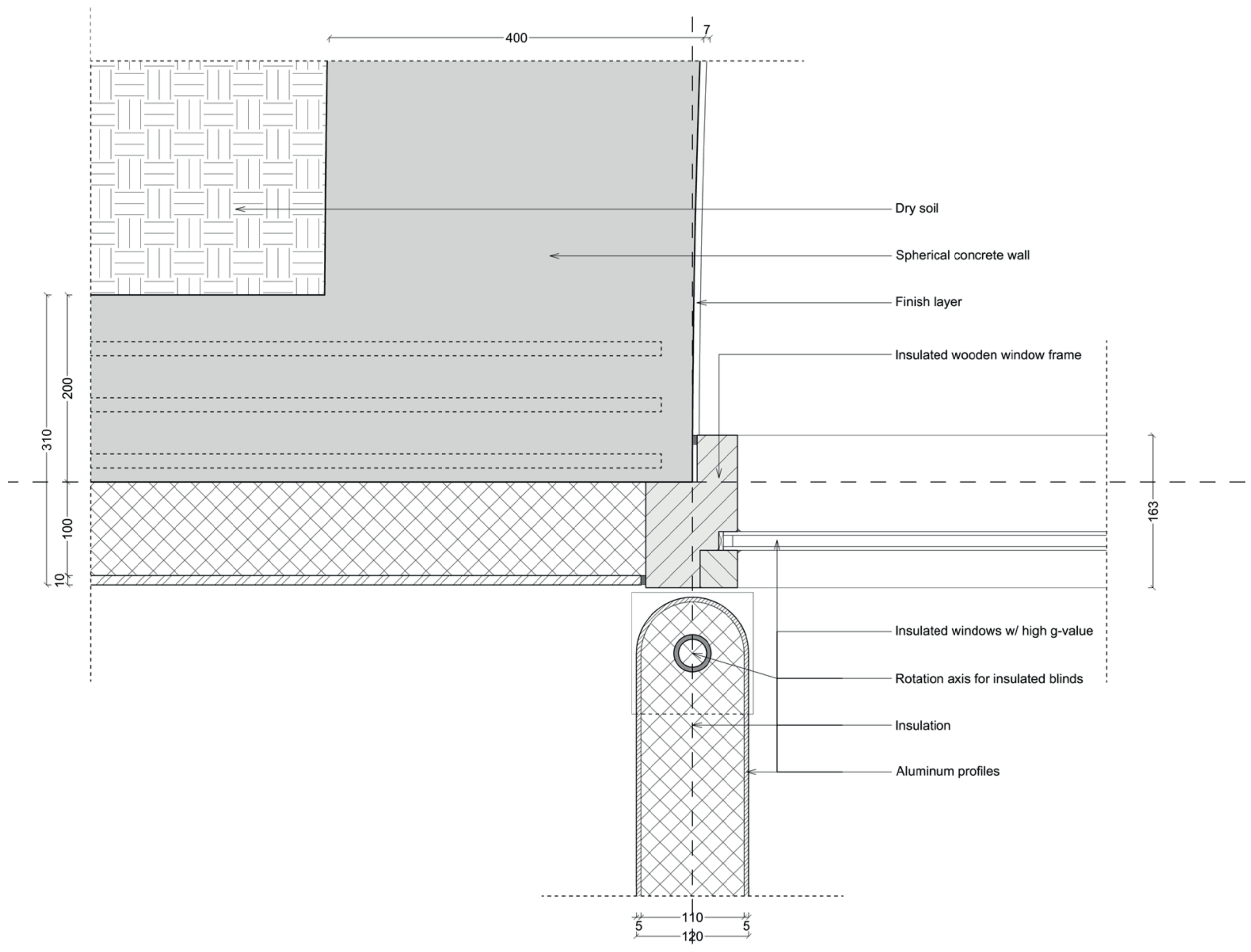
Blinds at winter night - reducing transmission

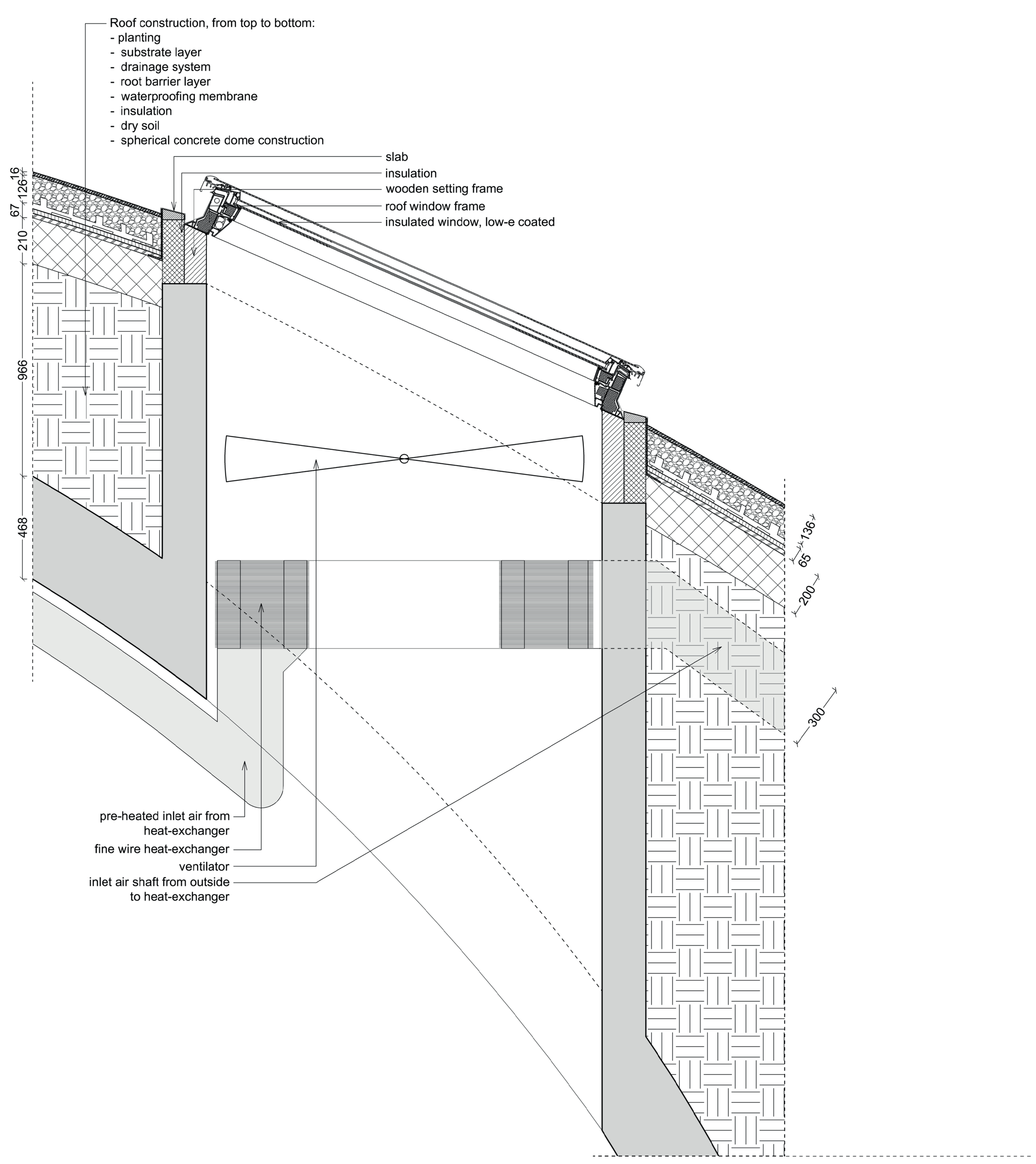
Insulated rotating solar blinds

On the south façade, there is a big window. The window has two main functionalities; allow the passive solar heat to enter and create architectural comfort. This window has a high g-value, combined with a high insulation value. In front of the window, there is an array of six large rotating insulated solar blinds. These blinds have three functionalities:

- Insulate the window during cold nights in which transmission should be reduced
- Rotate towards the sun for optimal solar radiation penetration in the building
- Rotate against the direction of the sun to block solar radiation.

Details





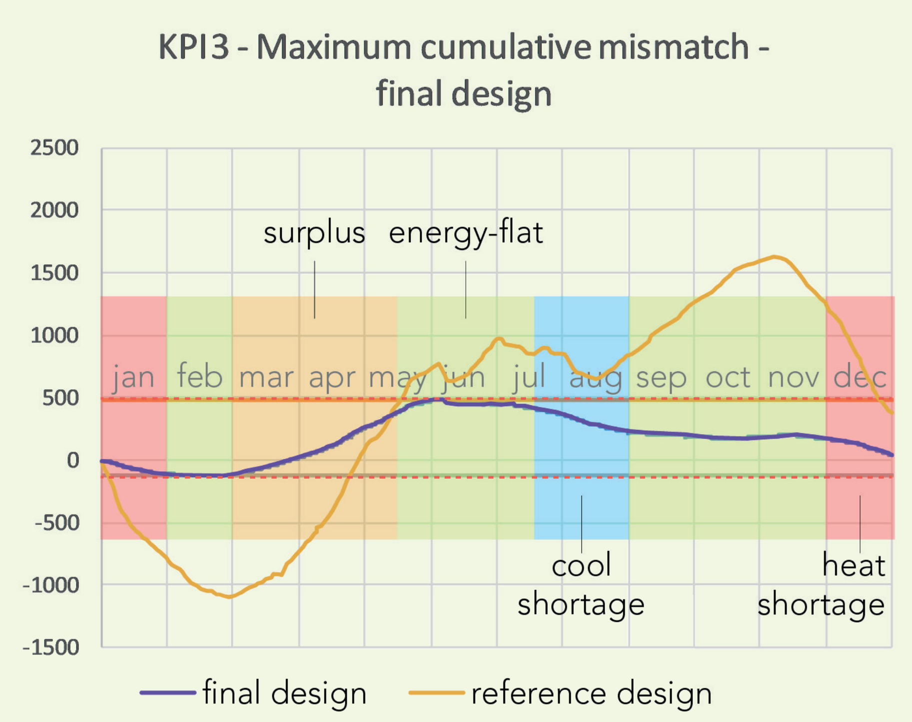
Top: Horizontal detail - 1:5 - facade and insulated blinds

Right: Vertical detail - 1:20 - ventilation shaft and roof window

Energy-flat performance

The overall energy-flatness performance of the final design is much better than the energy-flat performance of the reference design. For every KPI, significant results are achieved. The total annual heating, cooling and supply loads are lower. From March till May, the surplus mismatch rises caused by lowered and shifted cooling loads as a result of much thermal mass. The other months are energy-flat, except from December and January that cause a heating shortage.

The total heating shortage, cooling shortage and supply surplus are respectively 356.4, 425.0 and 826.9 kWh. The figure on the right shows the location of the mismatches. From March till half of May, the main supply surplus occurs. In August there is a cooling shortage and in the middle of the winter there is a heating shortage. The centralized surplus might be a potential for energy-flatness; any process that requires much supply in a short period could solve the mismatch.



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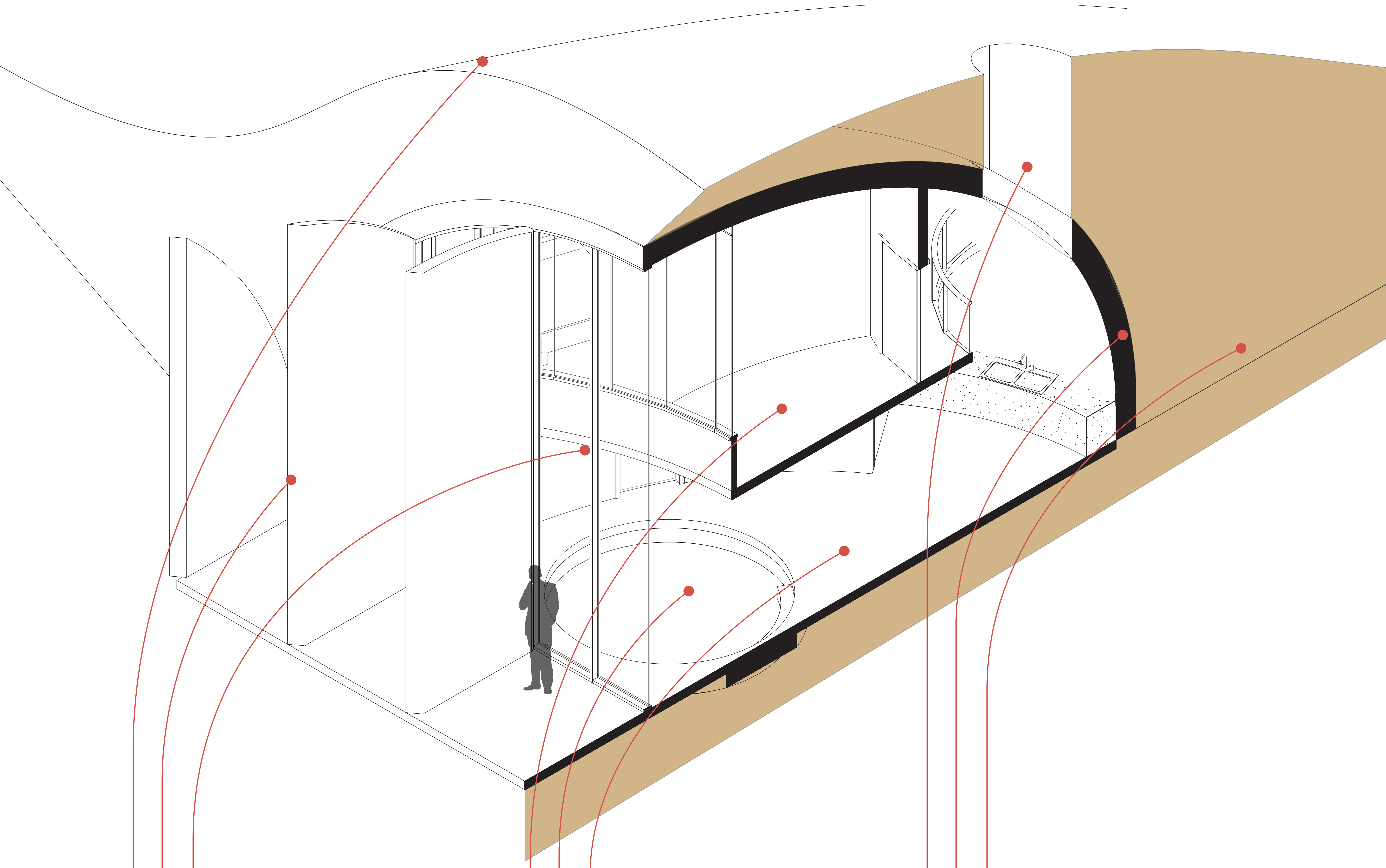
FUNCTIONALITY OF DESIGN



Big south window with high g-value
the sun-oriented window with a high g-value provides passive heat in winter and creates a comfortable light indoor climate

Intelligent energy-flatness control system
the building measures energy surplusses or shortages and indoor climate, and adapts the heat and cool systems to it

Earth sheltered building for thermal mass
the high density and heat capicity of the soil increases the ability of the building to mitigate temperature changes

Solar orientation adaptive insulating blinds
large insulated blinds allow solar radiation to enter in winter, block direct solar in summer and insulate the window at night.

Level differences, overhangs and heavy interior surfaces
level differences and heavy interior materials increase both the thermal mass surface area and volume

Low surface-to-wall area
the spherical form of the outdoor surfaces provides a much volume and floor area per outdoor surface area. The extra volume is beneficial for ventilation.

East + west supply surface
the largest share of the supply surface is oriented to the east and west side. Amorphous PV should be used, to optimally use the diffuse lighting.

Floor plans and windows allow for solar radiation penetration
a deepened first floor allow solar radiation to enter deep in the building, in favor of the thermal mass

Ventilation shaft
the ventilation opening provides cross-ventilation possibilites for natural ventilation. It also contains a heat exchanger to reduce ventilation losses.

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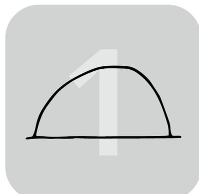
ENERGY-FLAT DESIGN TOOLBOX

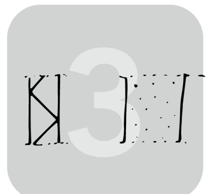
Energy-flat design principles

The parameter studies and preliminar designs resulted in a toolbox of design principles that can be used to improve the energy flat performance. The toolbox is categorized along the conclusions found with energy-flat design simulations. The elaboration can be found in the P4 thesis report, chapter 7.3 - Design toolbox. Below, all the design principles are shown next to their corresponding conclusion.

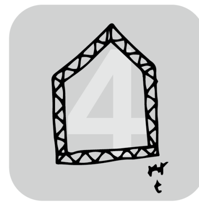


minimize A/V-ratio
a spherical shape has a relative low surface area compared to its volume

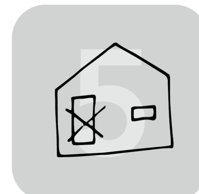
deepen building in ground
the grounds temperature is more constant than the outdoor air temperature



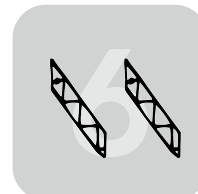
right insulation material
the insulative values of materials differ. A lower conductivity value results in higher insulation.



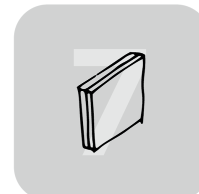
thicken the insulation
the thickness of a material linearly affects the insulation. Make space for thick insulation.



reduce window share
windows have a relative low insulation value and negatively affect the average insulation.



insulated blinds
the low insulation of windows can be compensated with insulated blinds, when daylight is not present or desired.

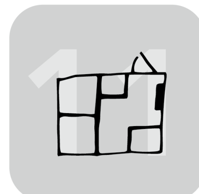


use HR++ glazing
triple glazing, low conductive gasses and reflective coatings can improve the insulation value of glass

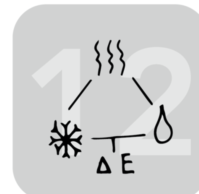
heavy indoor surfaces
making indoor surfaces from heavy materials increases the total amount of thermal mass.

increase mass surface area
the surface area is often a bottleneck for thermal mass due to its slow characteristics

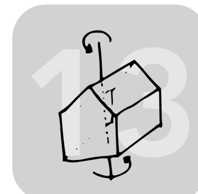
build within earth and soil
a thick layer of earth is effective for mitigating peaks over longer periods.



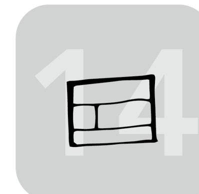
increase amount of surfaces
a bigger amount of indoor surfaces results in a more thermal mass



use Phase Change Materials
PCM's have a high thermal energy storage density and can be most effective on desired temperatures.



rotational building
a building that is able to rate can orient itself towards the sun when desired. A rotating building is a technical challenge

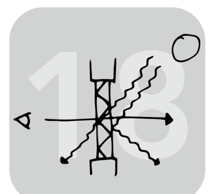


tactical zoning
functional zoning in relation to building orientation, may result in higher comfort and lower energy demand

radiative heating
radiative heating can compensate for lower air temperature, and is more energy-efficient

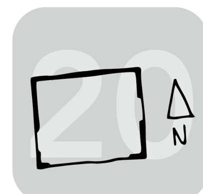
adapative thermal comfort
studies have shown that lower indoor temperatures are accepted in times of lower outdoor temperatures.

comfort by air velocity
similar to radiative heating, a higher cooling setpoint can be compensated by higher air velocities

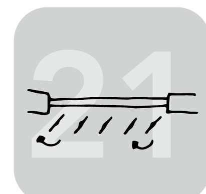


utopian window
ideally, a window has a high insulation value, allows for visual transmittance and can toggle solar radiation gain

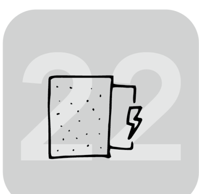
different window types
On south, high g-values are desired for solar radiation gain. On north, high insulation is more important.



high south share, no north
larger windows on the south side are effective for low heating loads. On the north, windows are undesired.



adaptive sunshading
rotating sunshades allow to block solar radiation when undesired, and to let it in when it is desired

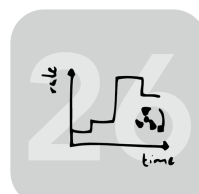


electrochromic glazing
this modern technique changes the g-value of a window by an electric current, being in adaptive sunshading.

horizontal shading
horizontal shading uses the latitude difference of the seasons, blocking solar in summer and gaining it in winter.

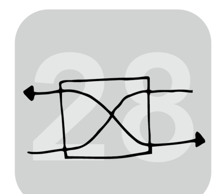
23. natural ventilation
natural ventilation uses pressure differences to drive air and hence

night ventilation
in summer the relative cold nights can be used to cool the building to reduce the cooling load in daytime

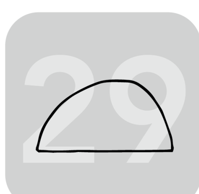


adaptive ventilation rate
adapting the airflow based on the temperature difference and supply profile results in a better match

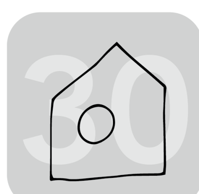
extra volume
extra volume to store fresh air allows for temporal ventilation stop in times of no supply.



ventilation heat exchange
a heat exchange system use the energy from exhaust air to preheat or precool the supply air, resulting in a lower demand



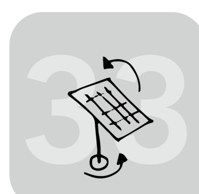
homogeneous & few corners
a more homogeneous construction with fewer corners results in less seams that are vulnerable for infiltration



high surface/seam ratio
a higher ratio results in a lower seam length. It can be achieved by circular windows or having fewer separate windows

use right materials
some materials allow for better airtightness detailling than others. Smart selection improves the airtightness

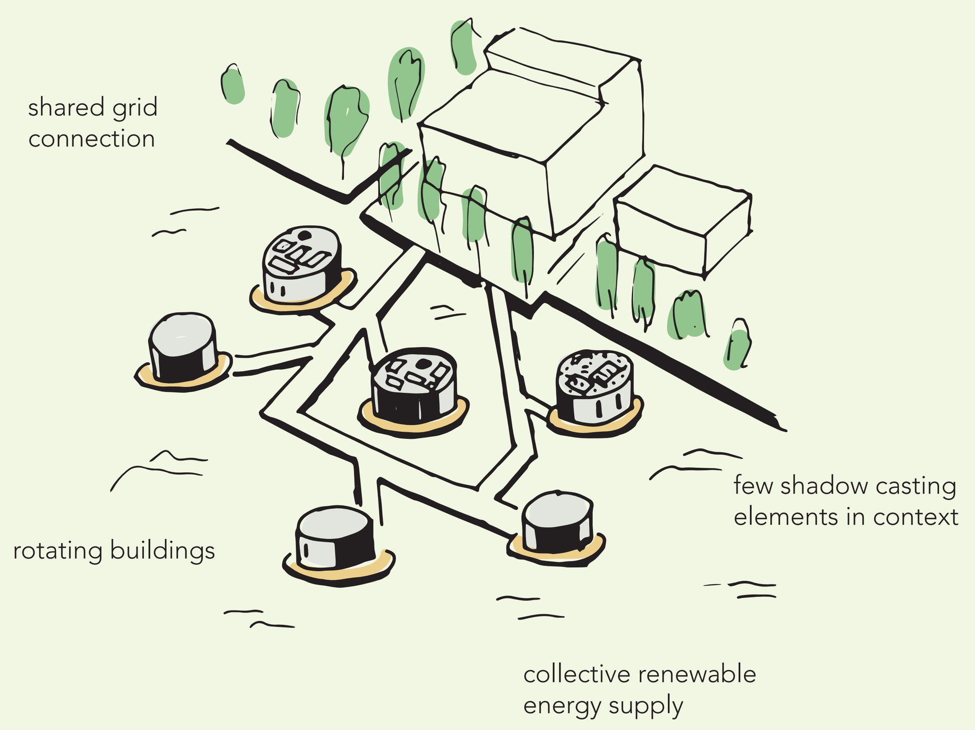
horizontal supply
horizontal elements thave a higher share of diffuse radiation. Vertical supply on the south as well.

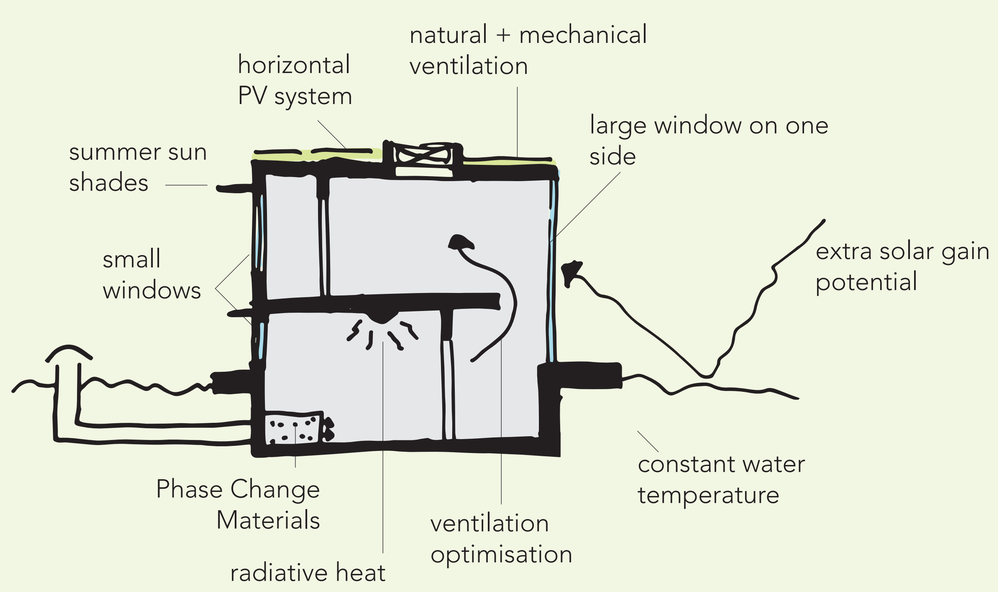


freely orientable supply
a system that is able to change the orientation of the supply elements can adapt to high and low supply demands.

wind or other RES
using other renewable energy sources results in potential supply in times of little solar, for example during nighttime

combine PV and solar collect
depending on the demand, either PV or solar collectors can be a more effective way to fulfill the demand.





Toolbox design suggestions

Two sketch designs are shown which make use of the design principles as described in the toolbox above For both designs, one sketch shows the (urban) context and its potentials for energy-flatness. The other sketch shows a section of the design which describes the principles used.

The upper design is a floating home. It's main potentials are the water environment and the combined grid connection. Its principles focus on thermal mass and the adaptive rotation of the building.

The lower design is a refurbishment of row houses. In this case, the potential lies in the repetition of the blocks and the principles mainly focus on adaptive installations, which are relatively easy to implement in a refurbishment