InnoLiving® - the energy self-sufficient building

Content

Project profile

Address	Cusanusstraße 23 D-54470 Bernkastel-Kues, Germany
Type of project	**Newbuild of an** energy self-sufficient **office building**
Construction time/completion	April 2020
Area/cubage	GFA 68 m² / volume 202 m³
Number of floors	1
Type of construction	modular construction / wood-concrete composite
Attained energy standard	KfW55 for non-residential buildings; KfW40 Comparable to residential building
Heating requirement	**108.5 kWh/m²*a**
Types of energy	**PV installation, solar module, energy window, GVI® wall, heat storage unit – concrete, greenhouse, PCM storage unit, ground collector**

Project participants

Client/Architect	Innogration GmbH
Structural design	Domostatik GmbH
Specialized engineer (HVCA/building physics)	Innogration GmbH
Structural wood construction company	Oster Dach + Holzbau GmbH
Other participants	Betonwerk Büscher GmbH & CO. KG Zöllner Fensterbau GmbH König Metall GmbH & CO. KG TEB-Technologie

1 Building concept: InnoLiving® – the energy self-sufficient building

Developments are always successful when their sustainability and cost-efficiency can be proved in daily operation. The InnoLiving® model building erected in Bernkastel-Kues in Germany pursues this objective.

A small office building erected on an area of approx. 60 m² will in future be used as the workplace for the trainees and dual students of Innogration GmbH. Several new developments can be demonstrated on this building. The objective of this project is to prove that energy self-sufficient buildings can today be erected and also operated with high user comfort.

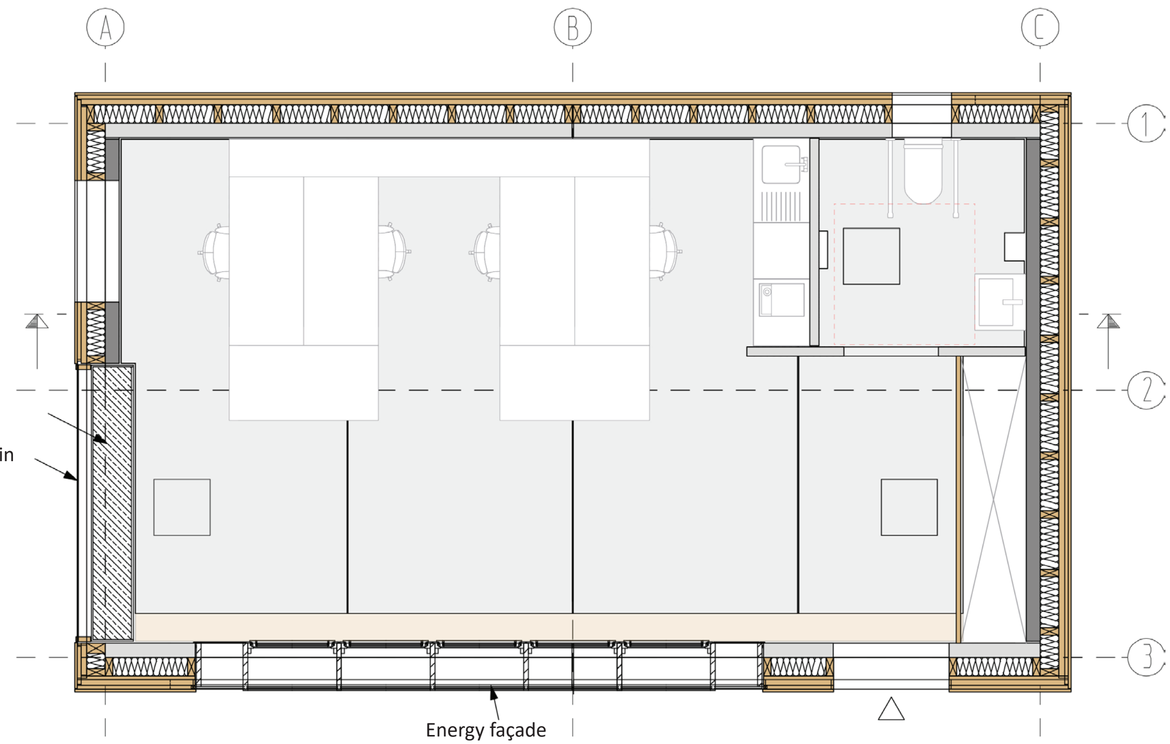
The building consists of precast construction elements. The required insulation for façade and roof is also pre-installed in the precast plant, so that the building can be erected quickly. The walls of the façade consist of an innovative and highly sustainable hybrid element, composed of a thin diaphragm of RC concrete and a wooden post-and-beam construction. The floors, spanning more than 10 m, are constructed of concrete, with little material used owing to the form of the cross-section and prestressed reinforcement.

The building services system uses appropriate technologies for collecting and storing thermal energy from the environment and for its distribution in the building for utilization. Distribution of energy takes place through the loadbearing floor and the high-performance, newly developed ceiling sails as well as through the concrete walls with switchable vacuum insulation.

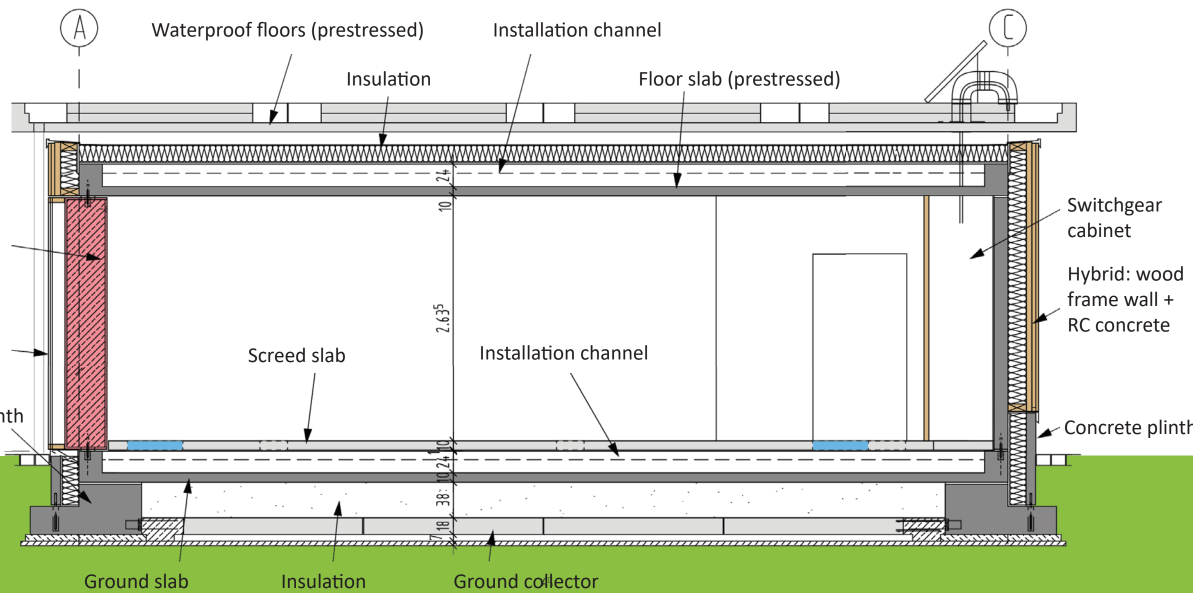
The façade and the special construction of the roof system are used for collection of thermal energy. Storage of thermal energy takes place, among others, by a loadbearing concrete wall that is completely encased with switchable vacuum insulation.

In addition to the concrete heat storage unit, PCM storage units are used in order to cover in particular the various temperature levels.
Collection of thermal energy takes place by direct utilization of the temperature levels made available by incident light.

Layout



Longitudinal



2 Energy concept: collecting storing and distributing thermal energy

To store thermal energy from the environment, it must be collected in various places. The easiest solution here is to intake air via a heat exchanger, then to transfer it to the water cycle and to pass it on either to the storage unit or directly to the elements for distribution.

This can take place by a heat exchanger with fan, which is installed on the roof or in a large window. Another option is to discharge the air heated in the “greenhouse” via the heat exchanger in the concrete slab to the water cycle.

The large façade window itself, owing to the panes arranged at a distance, functions as a greenhouse. The air, heated between the glass panes, is taken up via the spiral pipes arranged above the upper edge and then passed on via the water cycle for further use.

The greenhouse serves not only to increase the temperature, but – by utilizing spray mist – also to reduce the temperature.

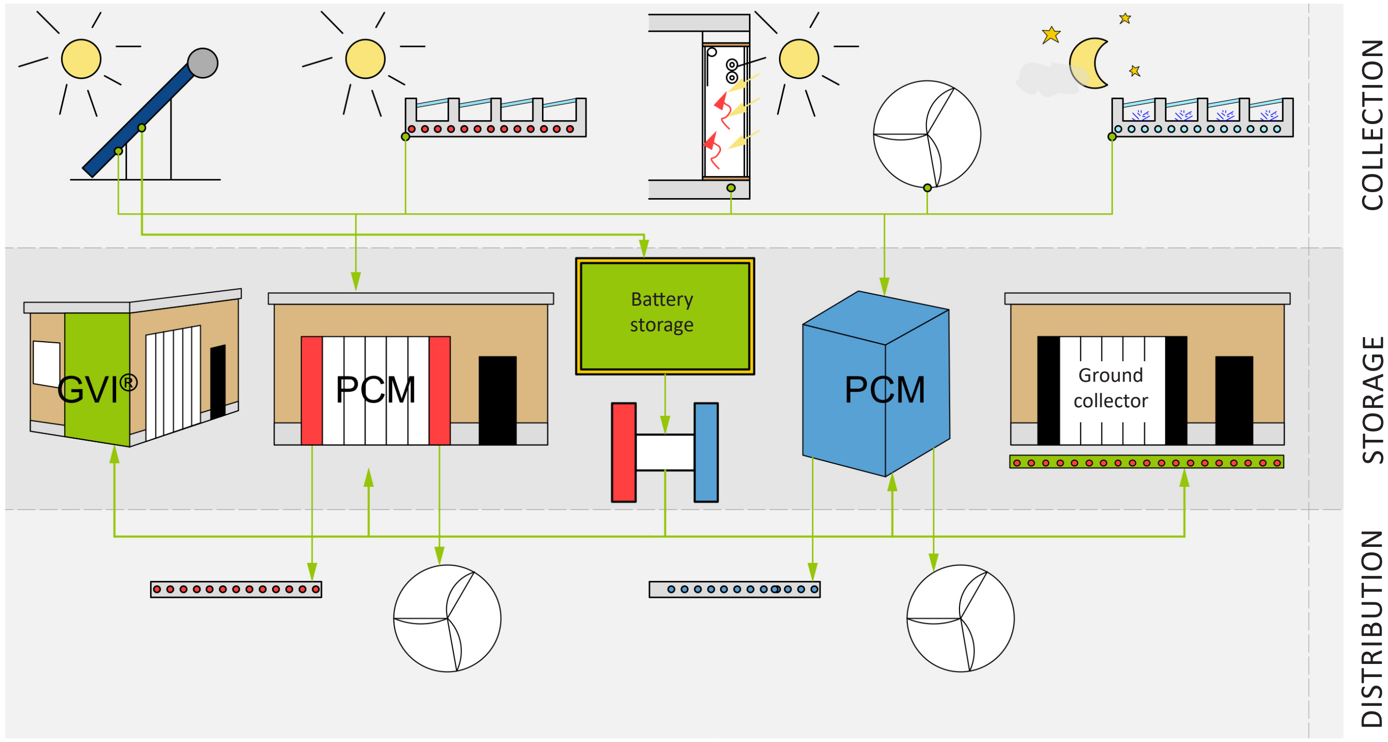
Energy self-sufficient operation owing to:

- **Energy collection**
  (energy façade (C)(4); greenhouse on the roof (D); glass panel in front of GVI® wall (E)(3)(4))

- **Energy collection**
  (ground collector (F); GVI® wall (E)(3)(4); PCM storage unit (G))

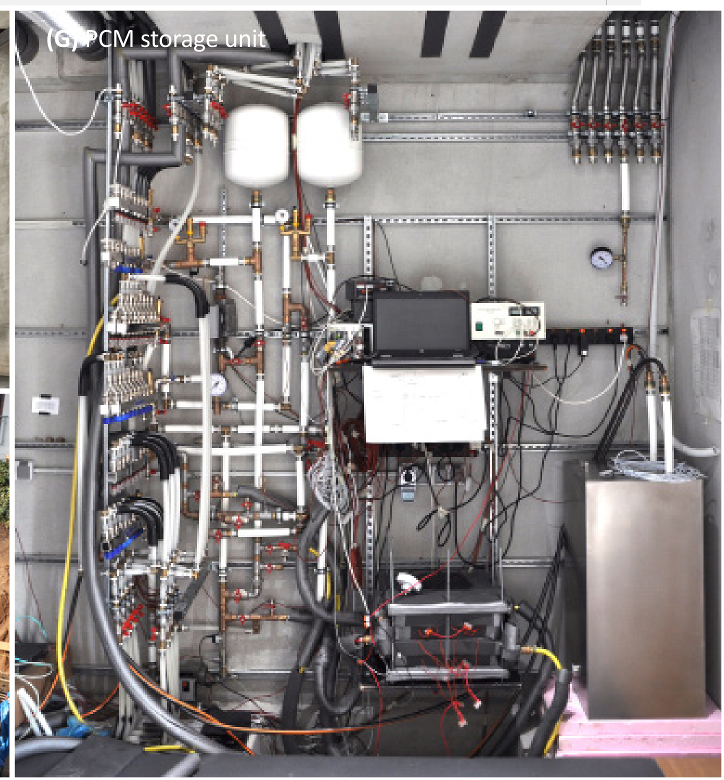
- **Thermal energy distribution**
  (activation of structural element (H); ventilation (I); GVI® wall (E)

Schematic representation of the energy sources, the energy storage unit and the elements for energy distribution




(E) GVI® wall


(G) PCM storage unit


(G) PCM storage unit


(F) Ground collector

(A) Modular construction (B) Hybrid wall construction (C) Energy façade (D) Greenhouse
(E) GVI® wall (F) Ground collector (G) PCM storage unit (H) Structural element activation (I) Ventilation

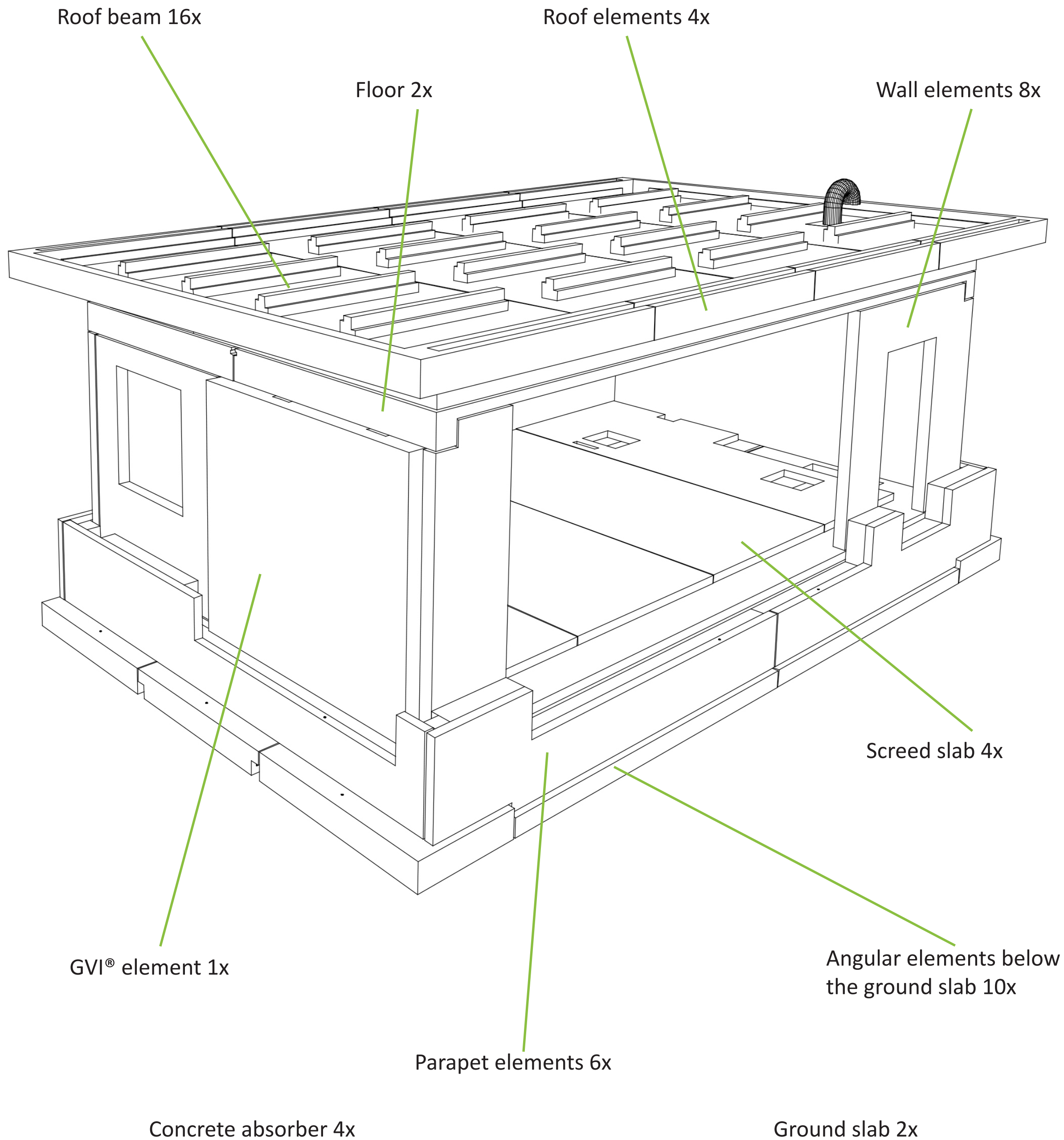
3 Design and its implementation with precast construction elements

In contrast to classic modular construction, the individual elements of a module used in accordance with the technology described here are assembled only at the construction site. These are multi-functional elements that no longer require sequential employment of the individual trades.

Innogration has extensive experience with precast multi-functional construction elements, in particular floor elements, and was able to successfully apply this expertise to the entire building. For the new concept, a number of innovative developments found their way into the modular construction for the new concept.

When prefabrication g of individual construction elements is practiced down to the smallest detail, then their erection at the construction site can take place as quickly as possible. A module consists of the ground slab, the two loadbearing face walls and the floor, which is used as module above it. Precast slabs are decoupled and placed on the floor above as screed.

In this way, module after module can be erected next to each other and above each other. Owing to the long unsupported span, the non-loadbearing partition walls can be positioned later, wherever desired. The façade end alongside the long span consists of a subsequently installed non-loadbearing wall structure.





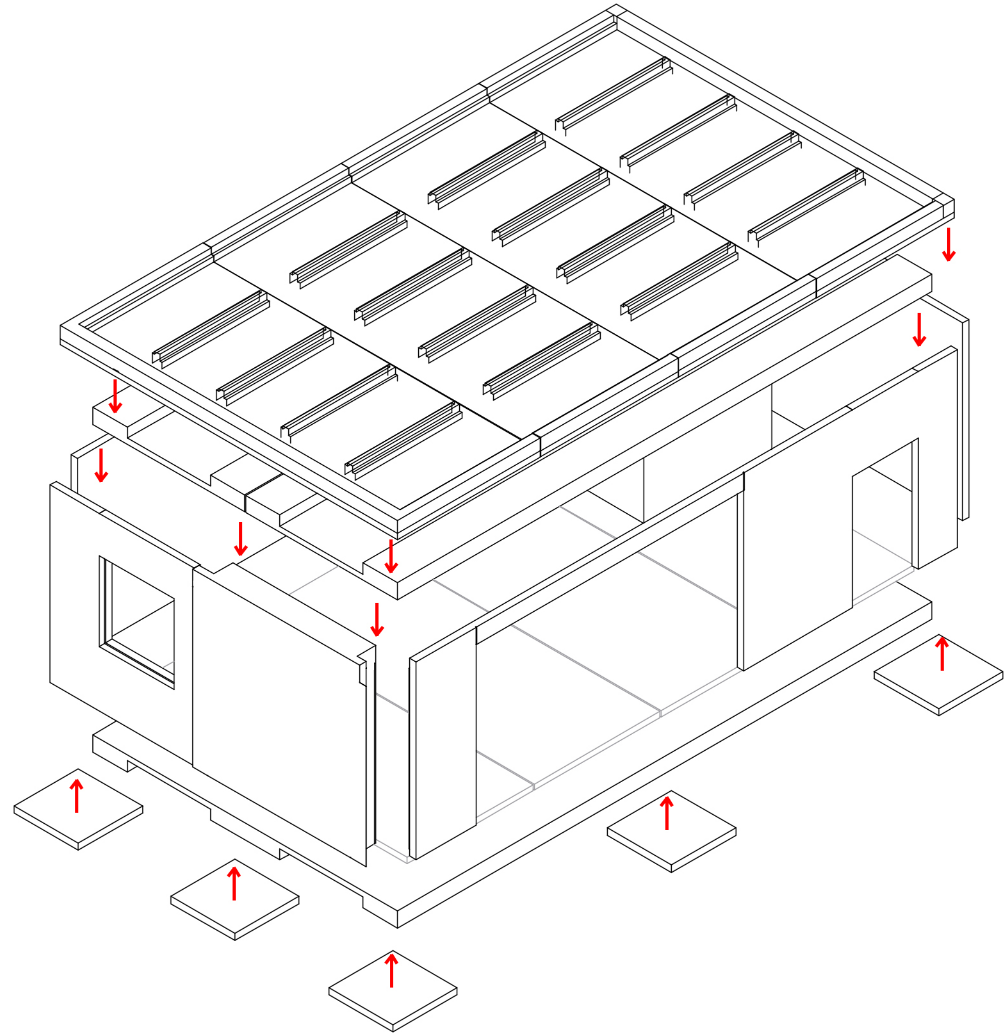

4 Production of the precast construction elements – ground slab, walls & floor slab

Long unsupported spans can be cost-efficiently realized only when the weight of the cross-section is reduced and when prestressed reinforcement is used. Calculation can verify that the sandwich cross-section optimally satisfies these requirements. This cross-section provides low weight and high stiffness and is therefore markedly better than the T-cross-section.

In developing the floors with long unsupported spans for the modular construction of InnoLiving®, a combination of both cross-section types was chosen. This again leads to further optimization in the performance efficiency of the cross-section of the floor.

This development, compared with all forms of cross-sections investigated, represents an absolute optimum. In developing this new form of cross-section, our many years of experience with Innogration and with resolved cross-sections and prestressed structural elements has helped us.

Thus, for example, the floor height of h=0.34m at a span of l/h=10m and slenderness of l/h=30 was able to be implemented. Remarkable here is the elements' own weight of g= 3.80 KN/m². This small amount of material, without loss of performance efficiency, made an equally convincing contribution to resource efficiency. Less concrete material means savings in aggregate, cement and steel and therefore a significant contribution to climate change, by saving additional quantities of CO_2.





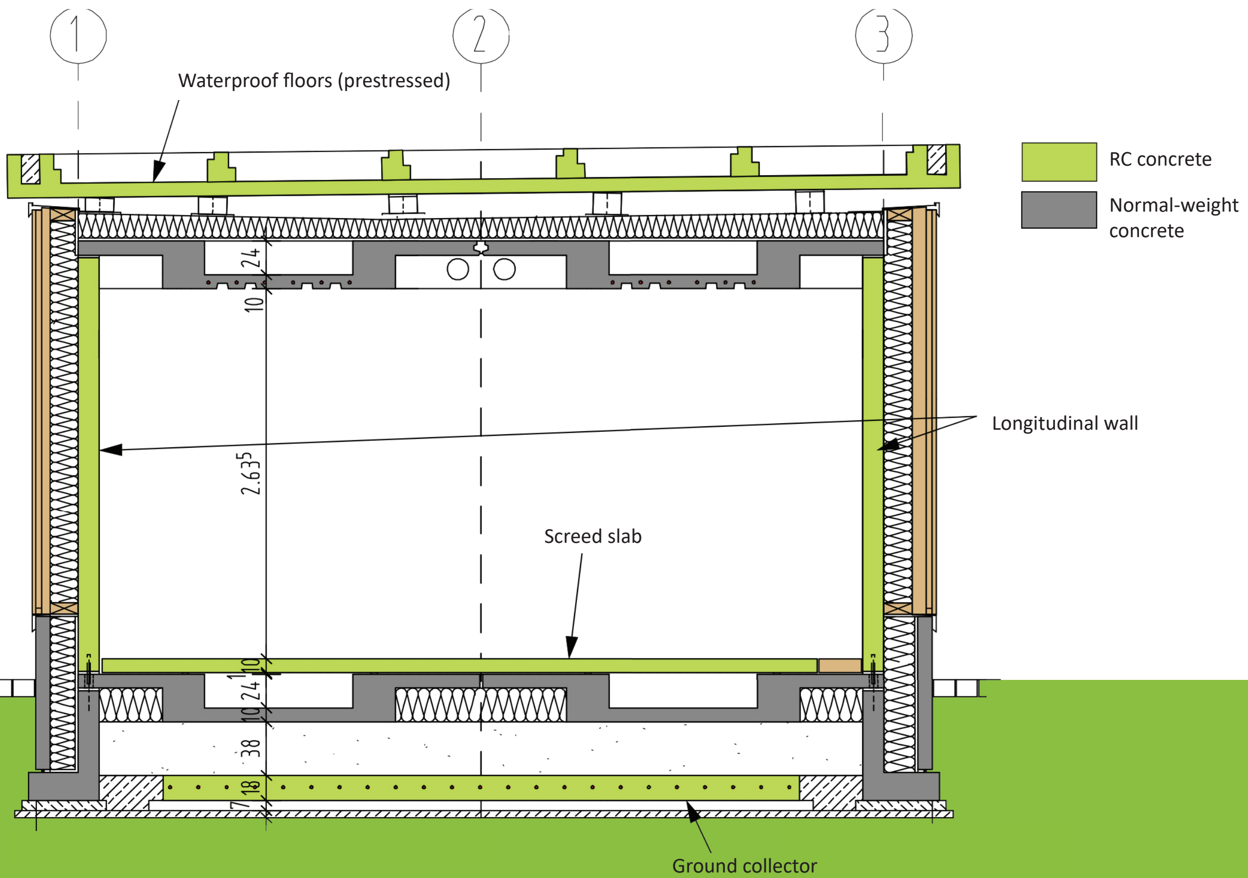

5 Walls in RC concrete

Construction of the building was also intended to provide a significant contribution to resource conservation. Although the raw material of wood first comes to mind in the context of this topic, concrete construction offers a wide range of possibilities as well. Today, for example, concrete can also be successfully manufactured with aggregate from recycled material.

Since the building from InnoLiving® is to be viewed as innovation driver, new paths were followed in production of the walls by using the two materials wood and RC concrete in combination, creating in this way a new hybrid construction material. RC concrete made from 100 % recycled material is used here as sheeting for the wooden post- and beam construction.

Since the floors have a long span, the greatest part of the façades can be constructed of non-loadbearing elements. In this way, the façades on the two long sides of the building could be implemented as wood-hybrid construction.
This was also the reason why the exterior of the building was given wood optics, although the construction is made primarily of concrete.

Utilization of RC concrete with a defined portion of recycling aggregate is already permitted based on an introduced code of practice. However, only a specified portion of aggregate may be substituted with recycled material. But for non-loadbearing construction elements, 100 % recycling aggregate may be used. Owing to the generously designed floor construction with its wide spans, only a small number of loadbearing elements is needed, so that the major part of the elements could be produced completely of recycled aggregate: the ground collector, the screed floor, the façades along the long sides of the building and the roof slab.



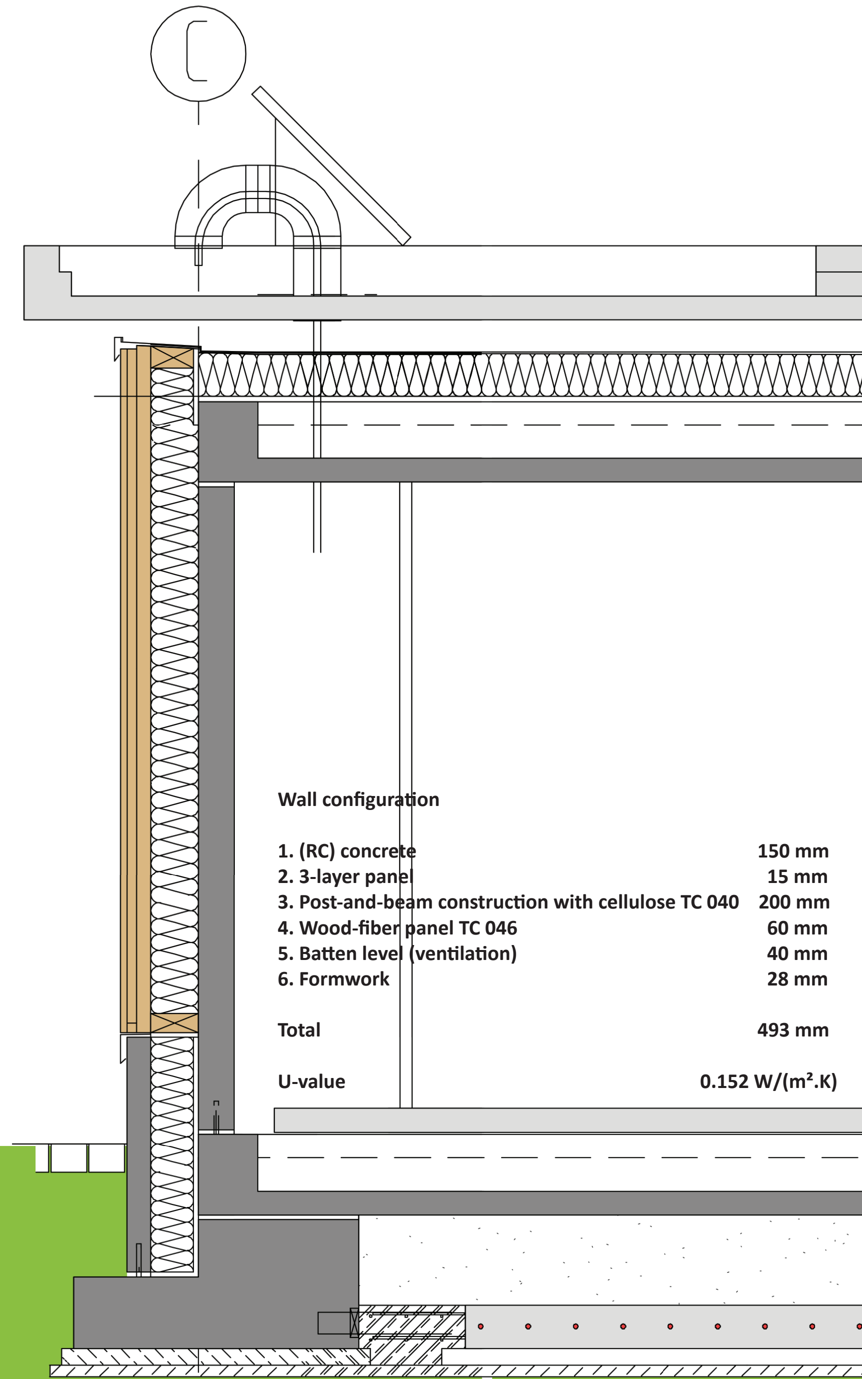



6 Construction of the wall as hybrid element

This wooden post-and-beam construction, in addition to the loadbearing function, also provides the insulation and the design features of the façade. Instead of the otherwise customary slab on the back for stiffening the wood frame construction, a thin diaphragm of RC concrete, is used for this application.

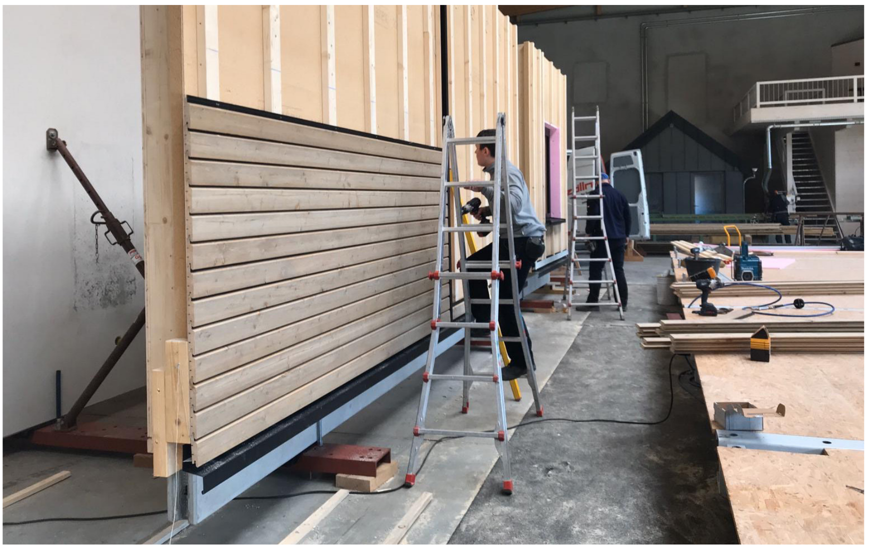
The concrete, in addition to the loadbearing function, also assumes the function of a moisture barrier. Furthermore, the concrete mass is used as buffer storage for the thermal energy, for equalizing the typical temperature fluctuations. In connection with the actively controllable thermal storage unit to be provided, the concrete walls, as passage storage unit, essentially contribute to a uniform climate in the room.

This measure is a means toward intermediate storage of the thermal energy generated in the various time intervals for later utilization. In this way, the absolute magnitude of the energy generated is also reduced, making an essential contribution to energy- and resource-efficient building.



Wall configuration

1. (RC) concrete	150 mm
2. 3-layer panel	15 mm
3. Post-and-beam construction with cellulose TC 040	200 mm
4. Wood-fiber panel TC 046	60 mm
5. Batten level (ventilation)	40 mm
6. Formwork	28 mm
Total	**493 mm**
U-value	**0.152 W/(m².K)**




ABUS

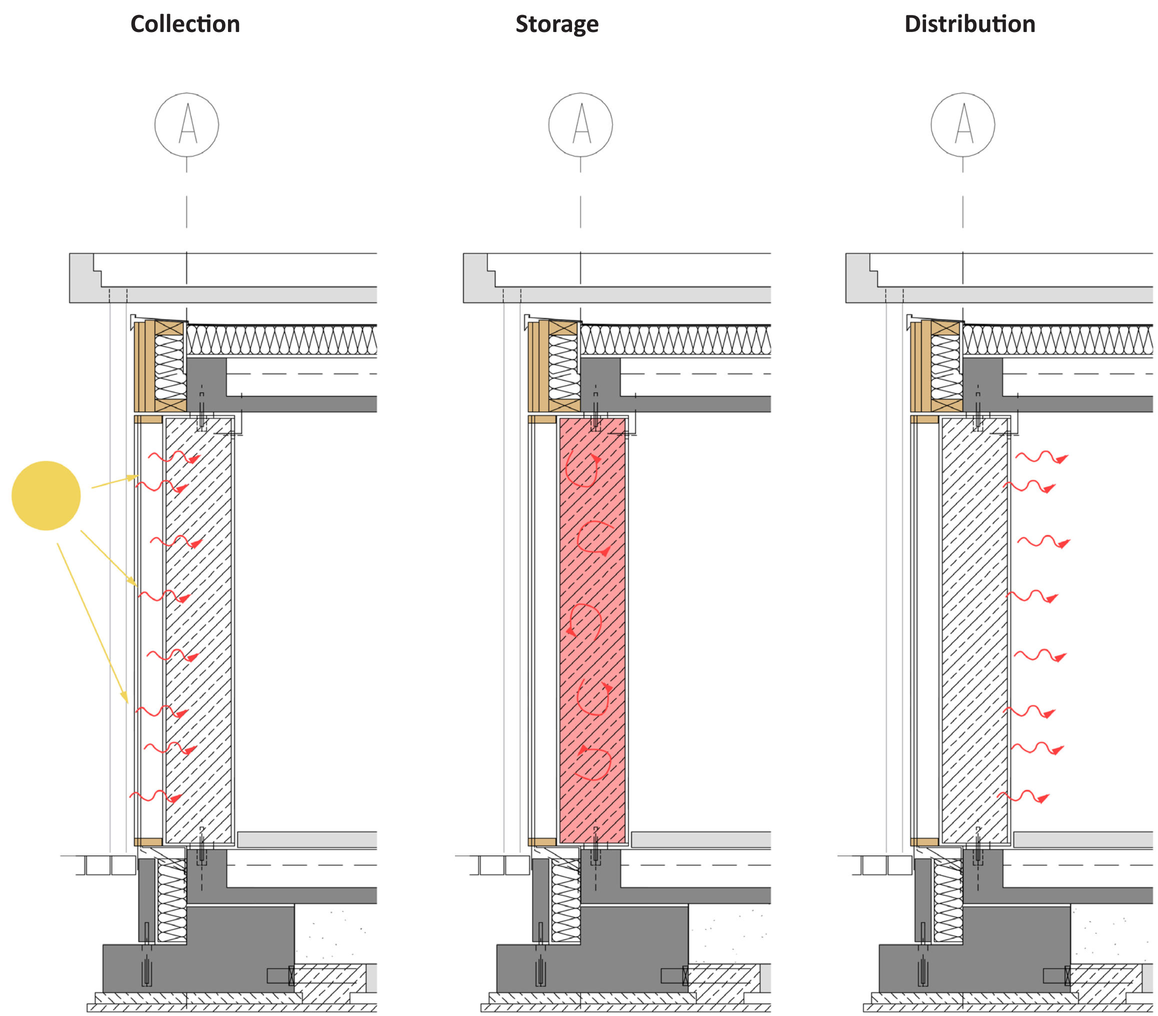
7 GVI® as loadbearing wall and thermal energy storage unit

The concrete wall, insulated with a peripheral vacuum layer, in addition to the loadbearing function, also assumes the task of a heat storage unit. The special feature of a switchable vacuum insulation enables at the same time direct collection and subsequently direct distribution of the thermal energy. With open insulation, the area of the GVI® allocated to the exterior side of the building can directly take up the heat of solar radiation.

This effect is additionally increased by the glass curtain wall, since here the greenhouse effect is utilized. With open vacuum insulation, the area of the inner side of the wall can give off the heat stored in the concrete directly into the room. The GVI® wall thus assumes several functions in that it can collect, store and distribute the thermal energy.

The thermal energy storage unit is further augmented by two additional options: i.e., by two pipes arranged inside the concrete mass, with the water flow contributing, or also giving off, thermal energy. In this way, additional devices can be connected for collecting and/or distributing the thermal energy and the concrete wall functions as storage unit.

The wall is further strengthened by special GRP bars provided in the middle with a heating wire. In this way, the concrete storage unit can be charged with surplus power and later used for other purposes. The great advantage of the multi-functional GVI® wall consists of the various options: for collection of energy and again for distribution. Consequently, this technology can be used for many applications.



Wall configuration

1. Vacuum insulation	20 mm
2. Concrete	400 mm
3. Vacuum insulation	20 mm
4. Air space	150 mm
5. Window profile	68 mm
Total	658 mm

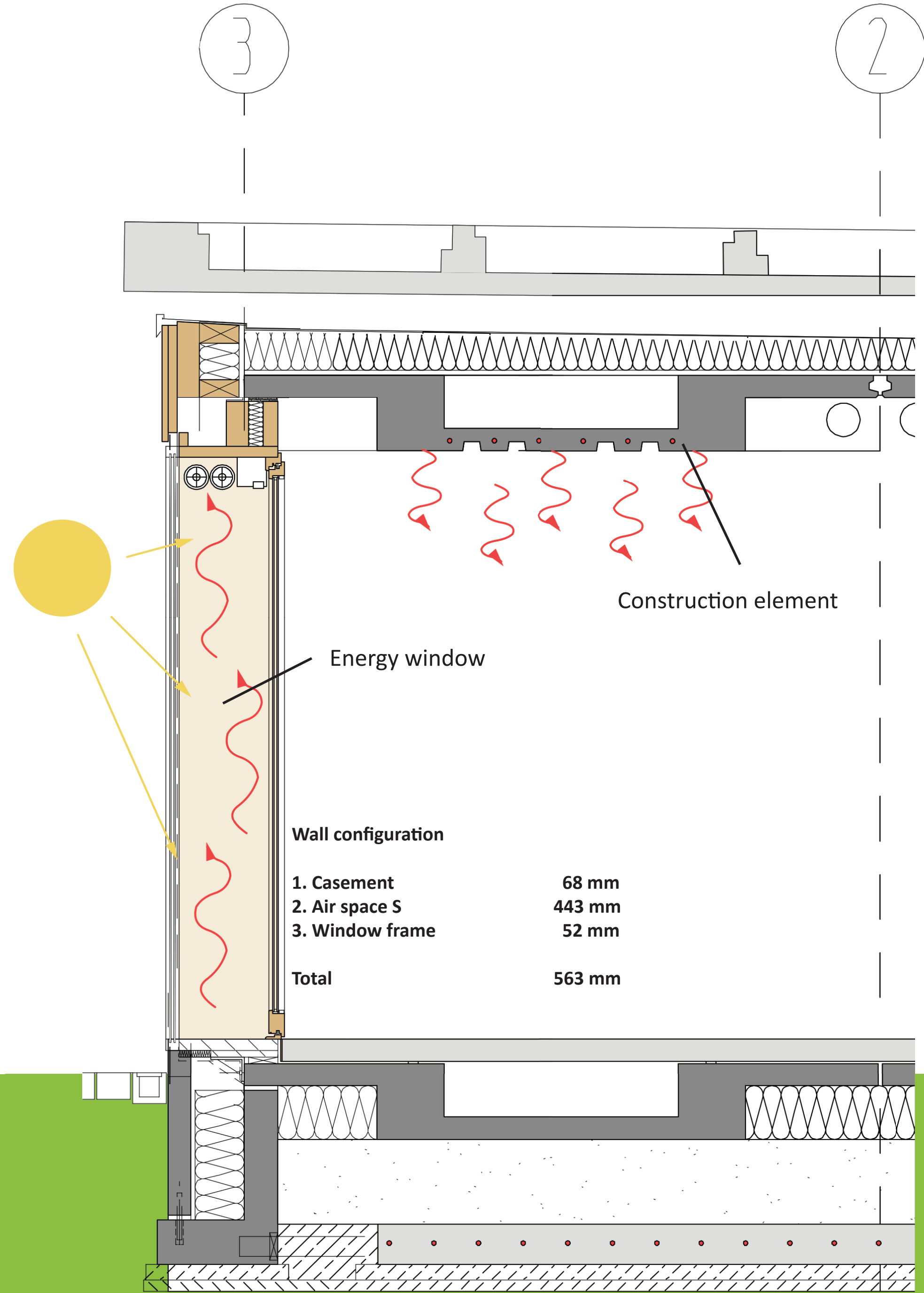

Knab

8 Window element for heat / cold recovery

The story-high air space between the outer and inner glazing of the façade acts as a greenhouse and/or conservatory under direct solar exposure.

The generated heat is further increased by the shading on the inside. The generated heat rises and is discharged via a ribbed-pipe heat exchanger and is temporarily stored.

The associated heat storage units with their highly effective vacuum insulation were also integrated into the window frame. In order to cool the room as well, alternative to the ribbed pipes, the cold night air is directly drawn in and stored by the façade. In this way, the energy façade contributes to air-conditioning and moreover to reducing global warming.



Wall configuration

1. Casement	**68 mm**
2. Air space S	**443 mm**
3. Window frame	**52 mm**
Total	**563 mm**


KATO

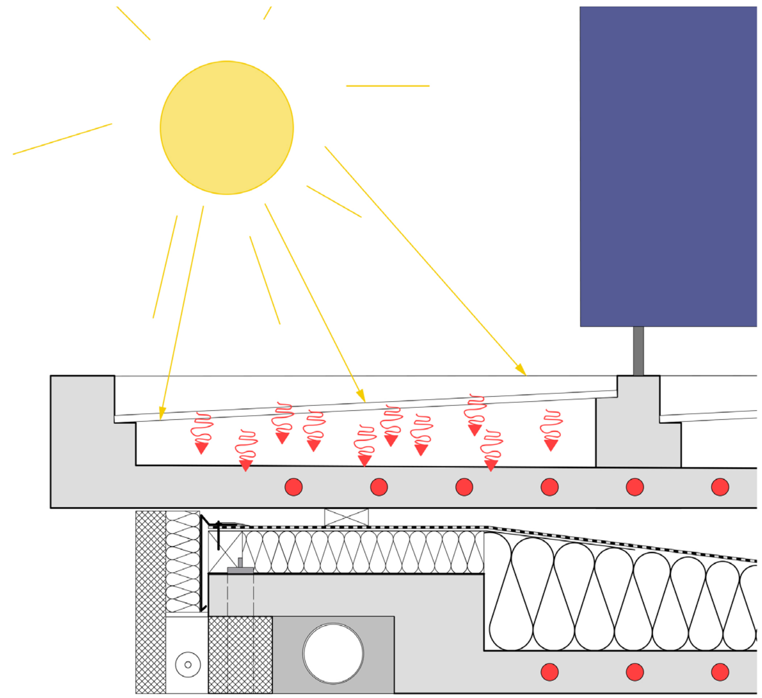
9 Roof structure with fittings installed for energy recovery – heat & cold

The roof construction for mounting the elements of the greenhouse is a special feature. The required individual slab elements, in an assembled state, form a tight roof skin and a basin in which water is collected. The roof slabs with upstands, already prestressed in the precast plant, are watertight owing to the prestressing force, without requiring special sealing.

The slabs, prestressed in only one direction, are additionally prestressed on site in an orthogonal direction. The prestress arranged on site presses the individual slabs together at the upstand, also bridging at the same time the joints between the individual slabs. The cross-section of the concrete is thus bridged in both directions and shows no cracks. This results in a waterproof area, eliminating the need for roofing.

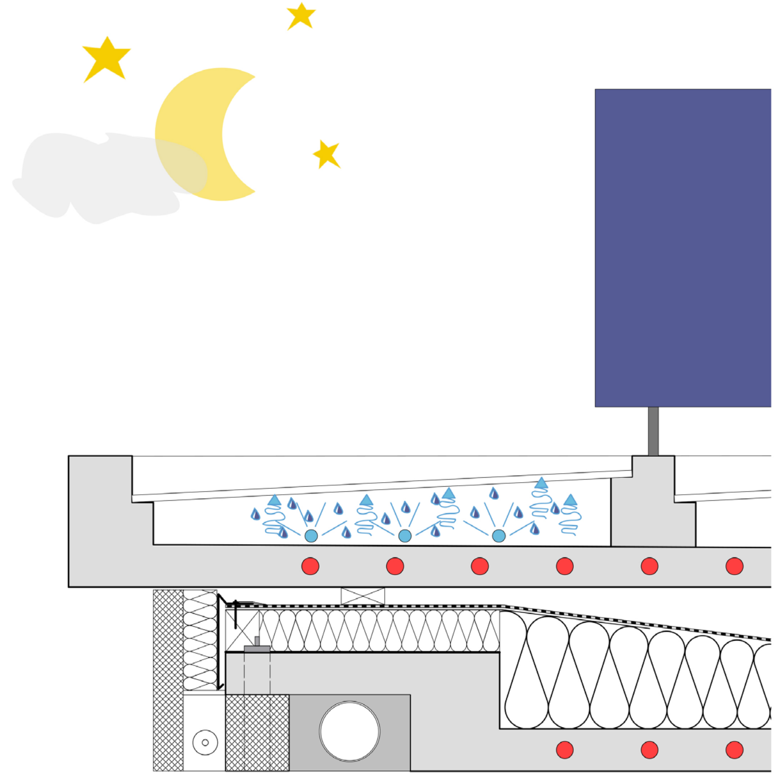
On the one hand, we want to store as much of the available heat as possible and then use it some time later without changing the temperature level. On the other hand, we make use of natural techniques, in order to change the temperature, only slightly as a rule. One of these techniques is the so-called greenhouse effect. Behind a glazed area, a considerable rise in temperature results from solar radiation, so that this temperature can be directly used or stored.

The same takes place by analogy with a reduced temperature when the air humidity is changed. This is known as an adiabatic cooling. This process can also take place in an open room, such as the greenhouse. It was therefore only logical to design the flat roof from InnoLiving® in such a way that heat of evaporation can arise, but that the greenhouse effect can still be utilized by a closed glazed surface.



Day mode

The air heated between the glass panes is taken up by the helical pipes arranged on the upper edge and then passed on for further use via the water cycle.



Night mode

The greenhouse not only serves for increasing the temperature, but can also be used to reduce the temperature by use of a spray mist.




10 Erection of the individual construction elements – connection of the construction elements, schedule for erection

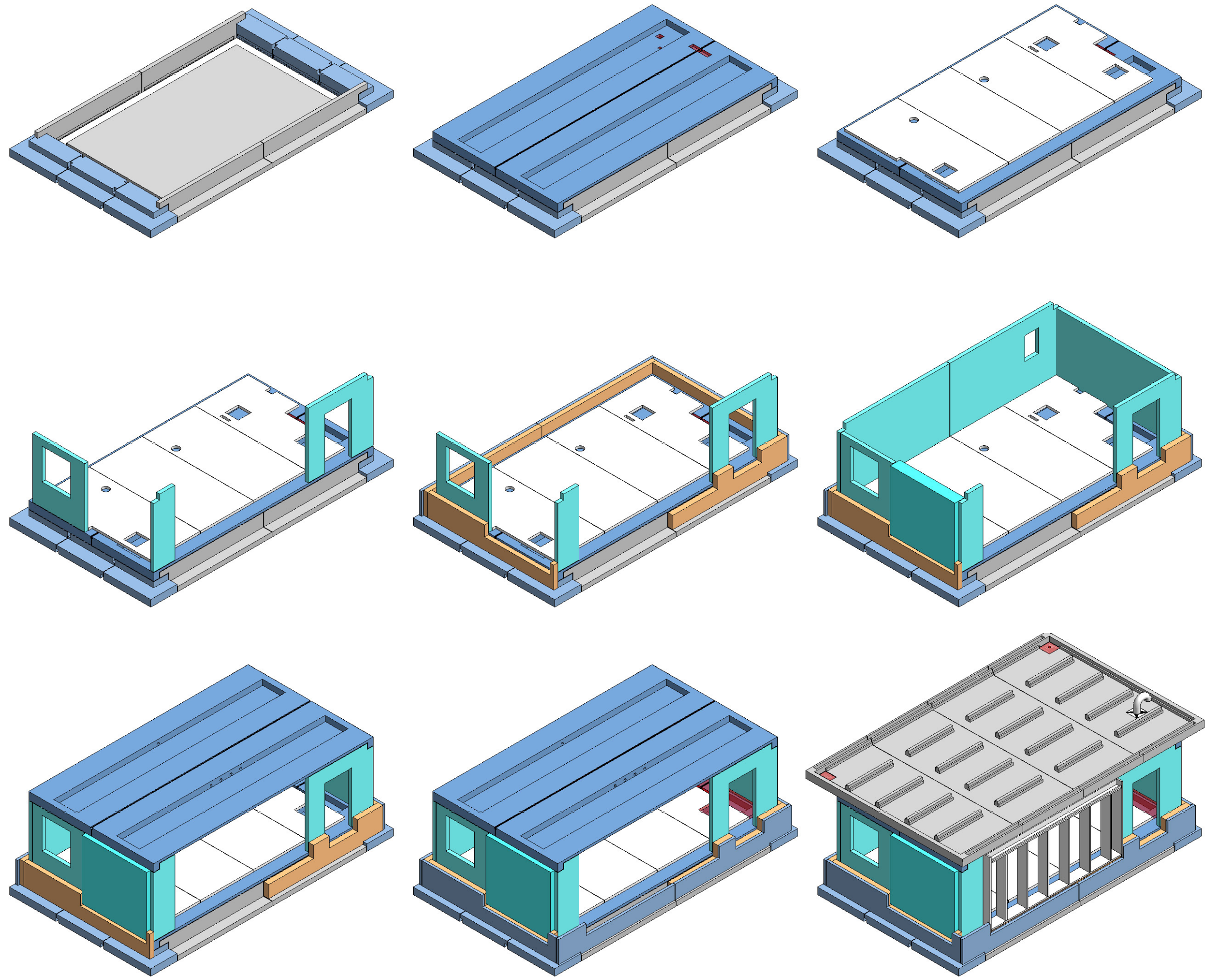
Another challenging objective is to limit to an absolute minimum manual work in construction of the building on site. This can be achieved only with nearly entire prefabrication. This objective applies not only the unfinished structure with its precast construction elements but with all its construction elements, beginning with the foundation, the façade, the roof, and the associated building services. For this reason, it is of special importance to use multi-functional construction elements that are delivered to the construction site as precast elements for assembly and erection.

Accordingly, design and planning focused from the very beginning on the consistent use of precast construction elements of all kinds to reduce erection work on site to the greatest degree possible.

Therefore, it was also planned to erect the foundation and the ground slab with precast construction elements. Of advantage once again is the long unsupported span (l ≈ 10.0 m) and the associated floor element. For construction of a module, for example, the two face walls and the floor slab were required. Only the ends of the slab were therefore provided with a foundation plinth for supporting the slab. Accordingly, the foundation plinths on the face end were installed first. The individual parts were stressed together to create a continuous foundation strip across the short side of the building.

The lateral frost barriers were also delivered as precast elements. The concrete slabs for the ground collector were placed in between and connected with the circumferential foundation strip. The area above the ground collector is filled with insulation material before installing the two ground slabs. This has the purpose of reducing heat loss from the building, but also of encapsuling the thermal energy stored in the ground collector.

The precast wall elements are assembled at the construction site to form one unit. Only the sealing between plinth and façade and between the joints is installed on site. The two floor slabs are installed as soon as the walls have been erected.







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11 Operation and outlook

The InnoLiving® project will succeed to address the topics of the future. With this future-viable concept we will demonstrate that, with the technologies we have developed, renewable and freely available energy can be collected, stored and distributed.

The innovative technological approaches function without any expense to generate energy and operate the building. The InnoLiving® building serves as innovation driver for energy- and resource-efficient building.

The innovations used in the construction and operation of this building involve digitalized and integral planning, processes for collecting renewable energy, its storage and the technology for distributing the energy. With this project, we are making an important contribution for future Co2-neutral buildings.

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InnoLiving® App:

From the idea to implementation. And many other useful information on all aspects of the topic of energy. Download our new App free of charge!