Life Cycle Habitation

Table of content

Introduction

With focus on Appropriate Technology, GrAT – Center for Appropriate Technology, has been intensively involved in sustainable and circular technologies, concepts and their practical implementation since its foundation in 1986.

In Austria, GrAT has been working on topics such as sustainable and circular construction and renovation since the 1990s. To this end, a high resource and energy-efficient building compound – "Life Cycle Habitation" - was designed and built in the region of St. Pölten (Lower Austria). The building compound consists of eight residential units and an event space, built with straw bale technique of different innovative construction types (load-bearing and prefabricated modular construction). The buildings are supplied with a highly innovative renewable energy-supply system. The consumption of electricity is reduced by approximately 80%. LIFE Cycle Habitation is carbon neutral over its entire life cycle. To guarantee wide dissemination and promotional effects as well as to monitor the energy consumption during the use phase, the innovative buildings and technologies can be experienced by tenants.

The modular prefabricated building consists of a two-storey terrace house with 6 residential units (one terraced house and 4 flats) and an event space. Another complex was built as a single storey semi-detached house with two residential units.

In order to become a sustainable, resource-saving and CO2-neutral building compound over the entire life cycle, the following innovative aspects were taken into account in the planning, design and construction phase:

- Extension of the use phase by easy adaptation along user needs, flexibility in the construction and easy separability of modules/components/materials
- Use of regional building and insulating materials made from renewable materials
- Minimization of construction site waste and construction residues through efficient planning and modular prefabrication
- Reduction of excavation material through innovative point and strip foundation
- Reduction of asphalt and concrete for access roads and paths through ecological and water-permeable pavements
- Abstraction of building materials during conversion or deconstruction
- Avoidance of polluting and interfering materials
- Possibility for re-use of construction materials/modules after deconstruction
- Recycling of materials after use
- Compostable building materials

"LIFE Cycle Habitation" proves the feasibility of efficient, climate-neutral and economically affordable residential buildings and serves as a showcase for further replication.

In order to achieve the long-term transformation of the European Union into a climate-neutral, circular economy and society by 2050, energy-efficient buildings with zero emissions in the construction and use phase are an indispensable block for achieving the goal. The use of regenerative building and insulation materials combined with renewable energy sources such as solar thermal and photovoltaic enables CO2-neutral, circular workflows in new construction and renovation. Wood, wood-based materials and building materials made from renewable materials (Nawaros) are durable, suitable for cascading use and bind CO2 in buildings for the duration of their use phase.

The implemented project achieves positive environmental effects in the following areas and contributes to achieving the European and Austrian goals regarding climate protection, circular economy and bio-economy:

- Saving CO2 in the construction and use phase, by using renewable building and insulation materials for the entire construction and by utilizing renewable energies, results in a climate-neutral building
- Reduction of the material footprint through efficient use of resources in production, waste avoidance and utilization of regional materials
- By involving local small and medium sized enterprises (SMEs), the regional added value was increased and the transport volume was reduced
- By avoiding pollutants in the components, recycling is improved. The connections can easily be separated and returned to the life cycle.
- In order to demonstrate economic efficiency and replicability, the efficient production processes and cross-trade cooperation are promoted.

While the use phase, it will be possible to analyse and scientifically evaluate the energy and resource consumption during the use phase.

Due to the intense planning work in the project, the future construction of further buildings using this ecological construction method is more economical. The preliminary planning work means that the reconstruction costs are only minimally (approx. 5-10 %) higher than those of conventional construction methods, while the life cycle costs of the buildings (construction, operation, deconstruction) are significantly lower. The demonstration of a functioning overall system can help to reduce inhibitions and reservations.

Project description

The innovative project "Life Cycle Habitation" - demonstration of a CO2-neutral building compound with an innovative energy supply system - shows economic feasible solutions on this matter. The housing project consists of a recyclable and resource-efficient two-storey wooden residential building with six residential units of different sizes and an event space, as well as a semi-detached house consisting of two bungalows, erected as a partially load-bearing straw construction. Each residential unit has a carport parking space with integrated storage room as well as a patio or balcony.

The modular prefabrication and the consistent use of renewable materials demonstrate the ecological and economic feasibility of circular and energy-efficient housing developments.

The residential buildings offer a healthy and comfortable indoor climate for residents and have a positive CO2 impact over the entire life cycle. The combination of timber and straw insulation, as well as the smart architecture of the buildings, offer excellent thermal comfort in both winter and summer.

The prefabrication was carried out regionally and complete with building service components and interior fittings. This led to a significant shortening of the construction time and a reduction in transport routes and construction site waste. For all building components, attention was paid to separability by type and avoidance of pollutants. The buildings itself are constructed on resource-efficient and easily degradable strip and point foundations.

The whole residential complex is supplied with energy from renewable sources, in particular solar thermal, photovoltaic and biogas. Each residential unit is equipped with an energy traffic light. The red or green light shows if the system is currently producing more electricity than is being consumed (green), or whether electricity has to be drawn from the grid (red). The accompanied monitoring system evaluates material and energy flows during the use phase of the buildings. The results show the economic and technical feasibility as well as potential for future building projects.

The overall project goal is to demonstrate innovative building concepts of high residential quality which also reduce CO2 emissions as well as resource and energy consumption significantly over the entire life cycle.

Life Cycle Habitation – Planning stage

At the beginning of the process a shortlist of innovations and possible solutions was created based on evaluation matrices, simulations and building physics calculations as well as a comprehensive literature and database research on the topics of superstructures and straw construction as well as innovations for building services (especially in the field of climate-neutral heat generation).

Based on simulations, resource efficiency calculations, flexibly adaptable use taking into account modular prefabrication, the entire life cycle of the building was already considered in the planning phase, tested and improved. In the detailed planning phase, the building design was optimised for modular prefabrication involving specialist planners and craftsmen (timber construction, HVAC, electrical, etc.), including the dimension of components to reduce offcuts, efficient cable routing, disconnect able joints, selection of durable and high-quality materials, etc.

Regarding the construction, optimization potentials with regard to geometry, materials, orientation and shading, air tightness and thermal bridges were determined with the help of models and calculations. These results were subsequently supplemented and further optimised by choosing specific HVAC systems. The results of the evaluations of this dynamic simulation were integrated into the planning process and used to create criteria for the bidding process (e.g., material selection, HVAC components, required U-values of building components).

With help of dynamic simulations, the design could be continuously improved throughout the planning process in terms of energy and ecological performance.

Life Cycle Habitation – foundation

Resource-efficient point and strip foundations were used for the building’s foundations. This enabled savings to be made in the area of excavation material and the associated Co2 emissions. It was also possible to significantly reduce the amount of waste produced during construction and in terms of subsequent disposal. In addition, soil sealing was reduced to a minimum.

On site, access roads and paths were constructed with ecological, water permeable surfaces which also reduces the amount of mineral construction waste e.g., asphalting, and avoidance of soil sealing.

Life Cycle Habitation – modular prefabrication

The factory-based prefabrication of the modules enabled a shorter construction time, efficient dimensioning and minimization of offcuts as well as waste avoidance on site. The modules were manufactured and pre-assembled by all trades in the general contractor's construction hall. Packaging waste from various small and medium sized enterprises could be separated by type at the factory and recycled or disposed properly. As a result, there was hardly any waste at the construction site itself. In order to increase efficiency and save materials during cable routing, two types of modules were created. An "intelligent module" that accommodates all connections and building services such as heating distributors, main connections and main lines, bathroom, WC and kitchen, and a pure "living module" that has electrical connections for light and sockets as well as the necessary ventilation connections.

The modules, which were already equipped at the factory, could be assembled, and installed on site within a short period of time (7 days). They can also be disassembled and transported just as quickly, which increases the flexibility and possibilities for further use.

On site, only the finishing touches concerning roofing, insulation and facade were carried out.

Life Cycle Habitation – semi-detached house

The semi-detached house consists of two residential units and was built using a partially load-bearing straw construction on resource-efficient point and strip foundations. The exterior walls were constructed with partial load-bearing insulation from large straw bales, prefabricated and assembled on site. The construction elements of floor and ceiling were insulated with blow-in straw insulation (ISO -Stroh). The room partition walls consist of 3-layer panels insulated with hemp. Same as in the terraced house, the walls were painted with a white glaze made from linseed oil. The suspended ceiling is modular to facilitate access to the pipes and HVAC components.

The large straw bales not only serve as insulation but do have a structural function. On the outside, wood chip insulation boards without diffusion barrier and a thermal plaster were used. The avoidance of glued joints and use of plug-in and screwed joints enables separation by type at the end of use.

The two residential units, each with approx. 107 m2 floor space, consist of kitchen-living room, three bedrooms, a storage room, bathroom, WC, lobby as well as a large terrace.

Due to the prefabrication of the construction elements, the time on site was significantly reduced. The shell of one house, including the assembly of the interior walls, took three to four days to assemble. The interior fittings and the installation of HVAC components and windows was carried out on site. A special feature of the atrium houses is a clay cladding on the east- and west-facing exterior walls, in the living room and one bedroom. This leads to a particularly pleasant climate and a balanced moisture level.

The patio of each atrium house was constructed with screw bases and natural larch wood. This allows simple and cost-effective maintenance during use and a recycling-friendly deconstruction in the end.

The utility and sewage lines run via a central shaft into each house. This detail contributes to shorter pipe routing and the avoidance of thermal bridges.

Life Cycle Habitation – terraced-house

The two-storey terraced-house was erected with prefabricated modules on resource-efficient point and strip foundation. The house consists of a total of 6 residential units of different size (two storey flats and smaller apartments) as well as an event space. Different layouts with floor plans between 50 and 100 square metres show that it’s possible to include flexible planning in modular timber construction.

For thermal insulation of the building, an untreated (free of pollutants and impurities) blow-in insulation made of shredded straw was used. This innovative type of straw insulation fulfils all necessary physical parameters in terms of thermal insulation and fire protection. Straw also has the advantage of regional availability as a by-product from agriculture and that chaff can be separated and composted after deconstruction.

The modules were equipped with all the necessary HVAC components and interior fittings during prefabrication and solely had to be assembled and installed on site. The supply pipes run in specially prepared ducts, so that the modules can be connected easily in a plug & play system.

The modular prefabrication of the individual units was carried out independent of weather conditions in a production hall. The electrical installations, HVAC components, interior fittings and installation of windows were carried out in the factory in cooperation with various local enterprises. The readymade modules were transported to the construction site and assembled in sections. For example, four modules of two flats, each with a living area of 55 m^2, were moved, assembled and connected within only seven hours.

Another part of the terraced house with the two-storey flats consisting of eight modules, was completed within one working day.

The roof was constructed in a way that the building structure was protected from weather conditions during the entire building process. At last, the wooden facade was put in place and the straw insulation was installed.

As far as possible, glued joints were avoided in any of the building components and interior fittings. A great value was placed on materials which are free of harmful and hazardous substances. This contributes to the health and comfort of the users. In addition, it also allows the materials to be sorted and recycled when the building is dismantled.

The interior walls, which were also prefabricated, were made of a hemp-insulated sandwich construction of 3-layer panels and painted with a white linseed oil glaze. In some modules, the partition walls were designed in a way that it can easily be moved or removed completely without much effort. Another interior design innovation is the modular ceiling design. Sufficient space for the electrical cables and screwed ceiling panels facilitate access for maintenance and replacement works.

Both the apartment building and the semi-detached house are equipped with controlled ventilation and underfloor heating. All residential units are connected to the PV community system. The hot water tank and heating distribution are fitted in a compact (hidden) wall-mounted storage system.

Life Cycle Habitation – event space

The event space consists of a 32 square metre multi-purpose room (kitchen, meeting room), a barrier-free WC and a large terrace with an innovative solar barbecue.

This part of the building also houses the staircase to the residential units on the first floor. The floor and ceiling were prefabricated in the factory as individual building elements and then assembled on site.

The space will be open to the public and the innovations of the project will vividly be demonstrated.

Excerpt Solar Grill

A solar grill demonstrates that thermal solar energy can also be used for cooking, even when the sun has already set. For demonstration purposes, the prototype of a solar thermal cooking unit was installed on the terrace of the event space. This works according to the principle of concentrated solar thermal energy. It means that a special thermal solar collector, in this case vacuum collectors, is additionally equipped with mirrors. This increases the temperature level. Thermal oil is used as a heat transfer medium and can get up to 300°C. According to the Teppanyaki system, a specially manufactured plate enables heat transfer and thus cooking or grilling. To ensure that the system also works when the sun doesn’t shine, a storage tank is integrated. Like a hot water tank, the heated oil can be kept available for a longer period and is used when needed.

Life Cycle Habitation – innovative energy supply system

The innovative energy supply system relies on the highest possible proportion of self-sufficiency through renewable energy sources. A communal photovoltaic system and solar thermal energy supplies the residential units with electricity and hot water. A micro-CHP, powered by biogas, supplements the supply during winter. The entire system can thus be operated in a climate-neutral and cost-efficient manner.

The development of the building services concept was focused on the economy and energy efficiency of the systems including the greatest possible coverage of the energy demand from renewable sources. Solar yields and coverage rates within different variants developed by the innovation team were simulated and the technical solutions were evaluated in terms of efficiency and self-sufficiency as well as economy (financial feasibility and cost-benefit calculation). Based on these results, the components and specifications for the energy supply system (thermal and electrical) were determined.

The building for the main HVAC components, the service and maintenance room, was constructed using wooden elements and insulated with straw. On its south facing roof, the thermal solar system was mounted directly at an angle of approx. 36°. The PV system was mounted on the carport roof oriented in both east and west direction.

The solar collector has a total area of 33.4 square metres and covers the hot water demand for all residential units during the summer months. The PV system consists of a total of 66 modules and has an output of 23.76 kilowatts peak.

As far as possible, the electricity generated by the PV community system is distributed among the participating parties according to their needs. In addition, energy traffic lights were installed in all appartements. If the traffic light shows green, there is a surplus of electricity. If the light shows red, the user knows that additional electricity must be obtained from the grid. This feature is intended to create awareness for the use of renewable energy sources.

In addition to the solar thermal system, a micro gas turbine is operated as a combined heat and power plant with 100 % biogas. At full load, it has a thermal output of 15 kilowatts and an electrical output of 3.2 kilowatts. This output is sufficient in regular operation during the heating period due to the good thermal insulation of the buildings.

A gas boiler, which serves as a backup and to cover the peak load, is also operated with biogas.

The generated thermal energy is fed into a 5000-litre storage tank. With the solar system, the upper third of the storage tank is heated up to 85 degrees Celsius. The biogas-powered devices switch on if there is a lack of solar energy input and keep the temperature in the upper part at 65 degrees Celsius.

Two district heating pipes lead from the maintenance room to the flats and event space. The transfer from the 2-pipe network takes place via the decentralised wall storage systems in each flat. These are charged three times a day to the set temperature of 50°C to cover the hot water demand.

Each residential unit is equipped with a decentralised ventilation system with heat recovery. Two different types are used for demonstration and comparison purposes. One is a conventional unit for central installation with indirect supply via air ducts. In addition, a facade unit for external wall mounting and direct supply to the room using overflow openings to other rooms.

The flats are equipped with additional hot-water connectors for washing machine and dishwasher to avoid thermal conversion losses and thus save energy. The water supply for the WC flushes is a separate circuit, fed from a rainwater tank. The garden irrigation systems are also supplied via the rainwater cistern. In case of prolonged drought, the water is replenished via the drinking water supply.

Life Cycle Habitation – Monitoring

Parallel to the development of the building services concept and the planning of the energy supply, the measurement and control concept for data collection during the use phase of the buildings was defined. The data collection regarding material and energy flows, indoor climate parameters for selected reference rooms, energy flow of individual energy services and household appliances, data from the decentralised ventilation systems, etc. was elaborated. In cooperation with the building services planners, the sensor and measuring points were selected. A list with all necessary measurement and data points as well as time intervals of the recording was elaborated and incorporated into a monitoring scheme.

To document and prove the projects impact regarding the achievable savings of energy, resources and waste, accompanying monitoring already took place during planning phase. This monitoring is also continued in the utilisation phase up to the disposal phase (deconstruction concept and calculation of disposal indicator) in order to make the project results tangible.

For the data collection, system boundaries, necessary key figures and verifications, as well as the methodology were determined. The data collection from the factory planning stage and during the execution phase was carried out in cooperation with DPM Holzdesign. The material consumption, certificates of origin and environmental certificates of the individual components and trades during the production and construction of the buildings were subsequently collected and recorded by the general contractor (in accordance with the agreement and the contract). Same applies to the transport routes from the supplier to the factory or construction site for the most mass-intensive building materials. During the factory planning, the calculations for the OI3 eco-index were extended to the building and the overall life cycle - 100 years.

The terraced house has a heating requirement of 12 kilowatt hours per square metre and year. The semi-detached house has a heating requirement of 14 kilowatt hours per square metre and year. The figures calculated from simulations for energy generation and consumption serve as a starting point for monitoring during the actual use phase of the buildings.

The control, regulation and monitoring of the building service system is carried out via a DDC or direct digital control system. It’s accessible directly from the maintenance room or via web interface. Failure messages are forwarded via a building control center. In addition, information on the status of the system and consumption as well as production data can be called up and, if necessary, the system can be adapted.

Each residential unit is equipped with corresponding meters to record energy flows and, above all, the consumption of renewable energy. Energy (traffic) lights were installed in all residential units to visualize the energy surplus or grid consumption of electrical power to the residents. In addition, the total energy flow for all buildings is recorded.

Monitoring is carried out via an online tool which gives the possibility to read out the data in real time and view specific periods of time to compare individual residential units. Using simulations, an energy balance was calculated and a share of self-supply from local renewable energy sources of 97.5 % was determined.

Life Cycle Habitation – Conclusion

The project "Life Cycle Habitation" has proven that it is possible to build cost effective, climate-neutral and recyclable buildings, using locally sourced materials and modular, industrial series production. If the cost of innovation developments is factored out, the cost for a replication is approx. 5 - 10 % higher than in comparable, conventional construction. However, this "extra" in construction cost is evened by significantly lower operating costs during the entire life and deconstruction at the end of the use phase. This results from the energy saving through the high-quality thermal building shell, the avoidance of conversion losses in household applications (dishwasher, washing machine) through direct use of thermal energy, the high self-sufficiency through renewable sources and drinking water savings using rainwater for garden irrigation and toilet flushing.

If at all, disposal cost is marginal when deconstructing the buildings due to the materials used and the separability of the construction by type. The buildings have already been designed and constructed with recyclability in mind, and the possible reuse of many materials and entire components at the end of its life.

Disclaimer

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Life Cycle Habitation

Photo documentation of structural engineering

01 Resource-efficient foundations

Soil excavation for the foundation. Due to the shallow foundation depth of □ 1.5 - 1.7 m and the slender dimensioning of the stepped strip and individual foundations, soil excavation can be reduced to a minimum.

STB is used for the base foundations, and the columns are made of reinforced formwork blocks with a vertical connection reinforcement into the base, a filling of in-situ concrete and termination of STB. The formwork blocks are not bonded, as the concrete filling provides the necessary stability.

Single and strip foundations completed and stepped. Compared with a conventional floor slab, approx. 45% of concrete can be saved in this way.

View of the foundations for the carports and the technical room; with partial basement for garbage room and general storage cellar/bicycle storage room. Each parking space also has a directly connected storage room. At the same time, the official requirement of a noise barrier on the station side is fulfilled.
All excavated soil will be stored on the construction site and used for site levelling and backfilling. The topsoil will be stored separately and re-applied at the end of the construction phase for the design of the outdoor facilities.

Aerial view of the construction site with the finished foundations for the buildings (semi-detached houses and apartment buildings) and the already insulated connection/supply shafts for the individual residential units. The finished modules can then be connected directly to these (plug & play principle). In the area between the apartment building and the semi-detached houses, the rainwater cistern and the additional retention basin required by the building authorities will be installed later.

Upper part and connection of the readily installed rainwater cistern (approx. 26 m3). Here, the roof water is collected and the service water is used for toilet flushing and garden irrigation.

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02 Modular prefabrication of the multi-apartment house in the factory

Production of a floor element; floor panel made of HDF (high-density fiberboard), filling: 48 cm Iso-Stroh insulation and wooden ribs in between. The element is later closed with an OSB board. Elements for the floor and top floor ceilings are already equipped with the insulation in the factory.

A "raw module" for the ground floor with cross laminated timber walls (BSP) and ceiling support made of BSP, insulated floor element open with Iso-Stroh insulation filling.

Support of the top floor ceiling for an upper floor module in the factory in Kasten, without straw insulation yet. This is inserted directly after assembly of the wooden structure and then closed with HDF boards.

Interior view of a "raw module" with cross laminated timber walls (incl. milled holes for laying cables) and ceiling panel made of BSP. The floor element is closed with OSB3 panels, and the panel joints were provided with special adhesive tapes for airtightness. The advantage of the construction with BSP and OSB is that, from the point of view of building physics, no additional vapor retarders are required.

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03 Series production of the modules in the factory

With the serial production of the modules in the factory, time and costs can be saved. The entire interior construction of the modules with all the trades involved (electricians, plumbers, carpenters...) can thus also be centrally controlled and handled in a time- and cost-efficient manner. Another major advantage of this construction method is the independence of the manufacturing process from the weather.

Factory hall of the general contractor in Kirchstetten (serial production of Top 1 - 4 = 14 modules, Top 7 + 8 = 4 modules were produced in the smaller factory in Kasten).

After prefabrication of the "raw" wooden modules, these are also serially processed by the various trades and fitted with the building services and interior fittings.

04 Building services and interior equipment of the modules in the factory

Interior walls consisting of a wooden stud construction and 3-layer spruce boards are erected and filled with a compartment insulation made of hemp insulation mats. Figure below right: The flexible partition walls are installed only after the floor is laid, in order to ensure a continuous floor covering, in case of displacement or removal of the partition wall. Finally, the interior walls are painted with natural and solvent-free white linseed oil glaze.

Interior sanitary installations from top left to bottom right: Installation of innovative hot water storage system Enerboxx (without its distribution module yet) in the bathroom; WC tiled and with installations, facing shell for the installations in the bathroom, installation of underfloor heating with a dry construction system made of gypsum fiber boards, underneath of which, an underlay board made of wood fiber. The advantages of the system are short installation time, low thickness (approx. 20 mm), low weight and easy dismantling (e.g. for renovation).

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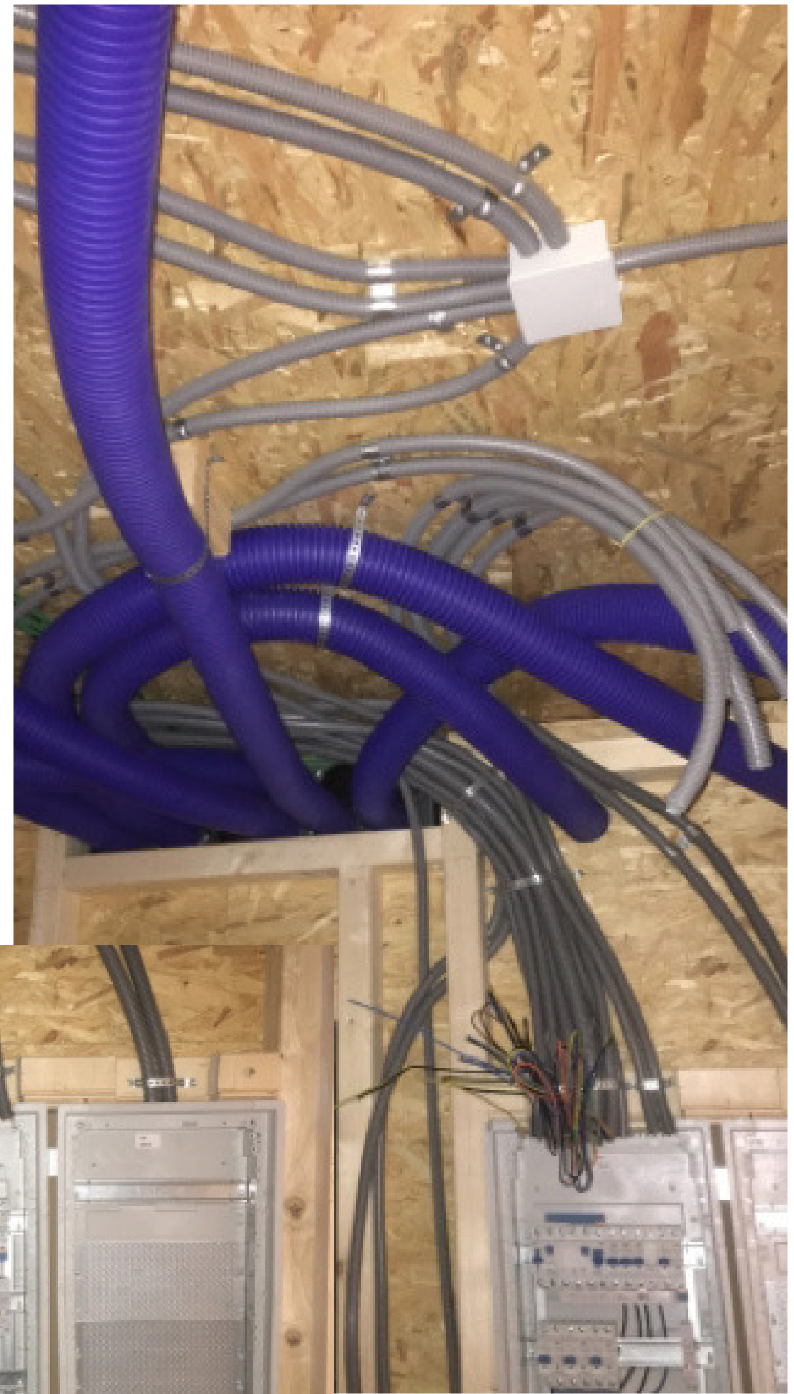
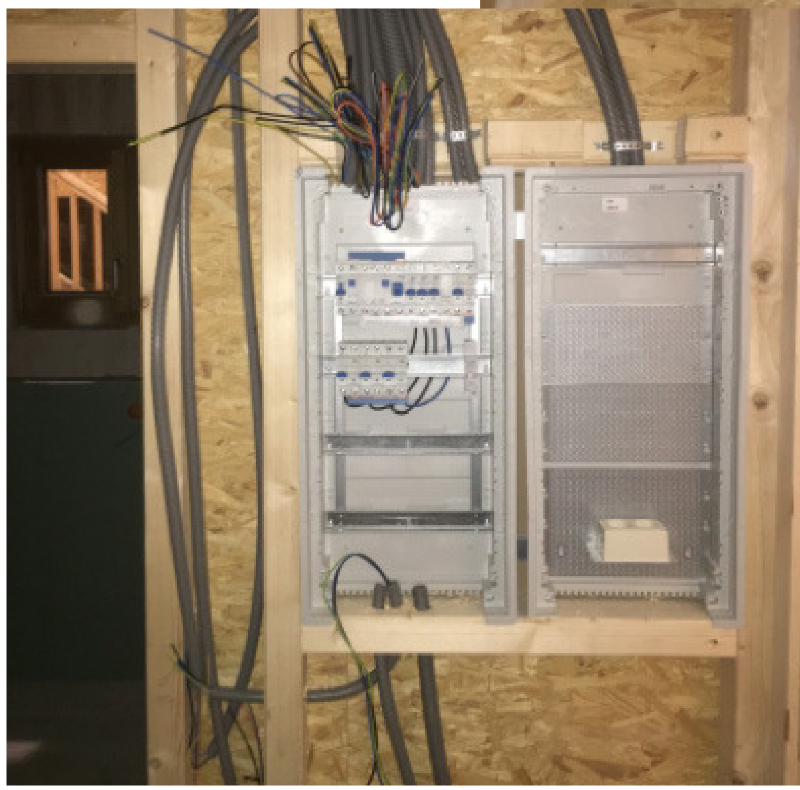
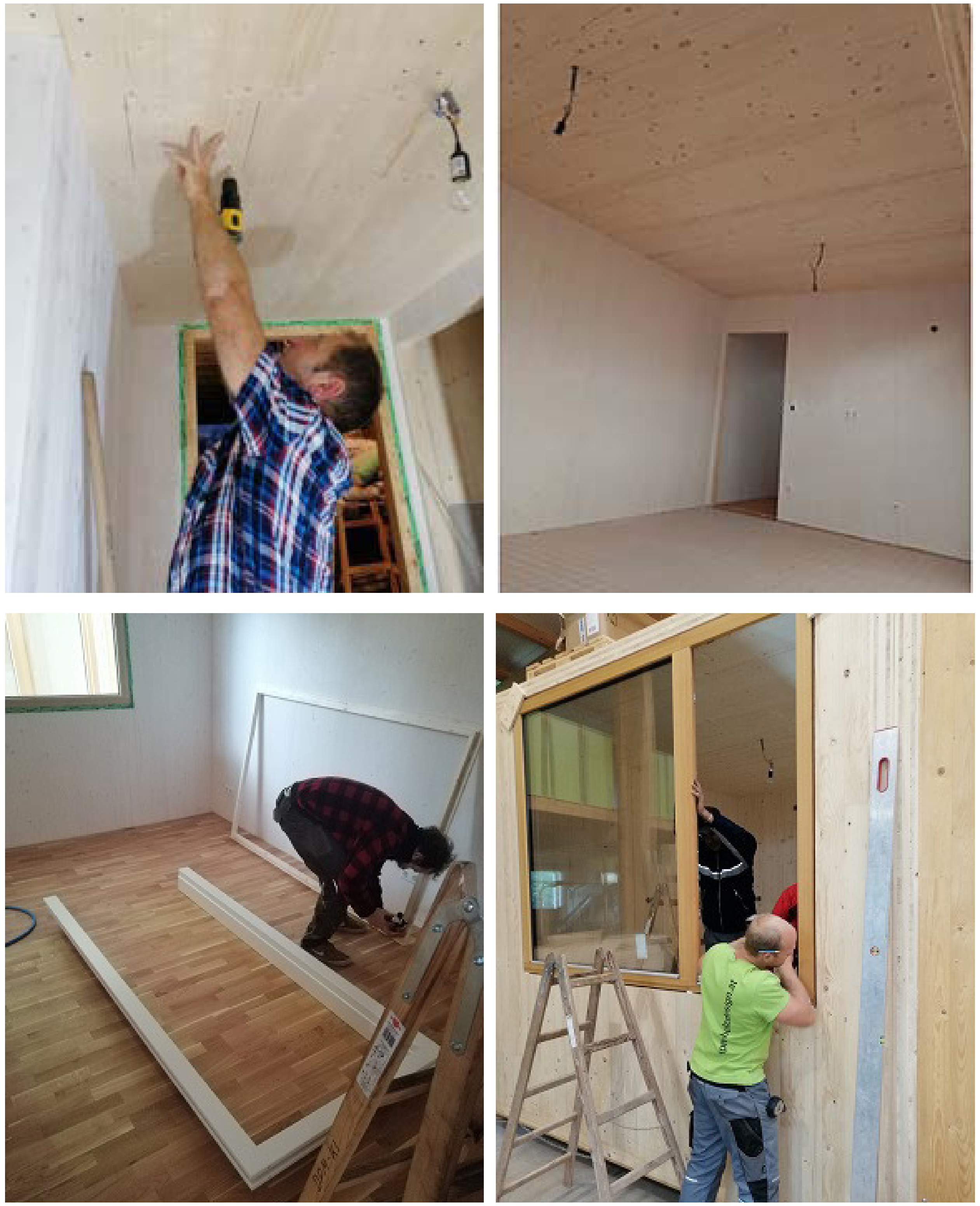
From top left to bottom right: Exterior connections and installations of decentralized living space ventilation (facade unit), supply and disposal lines for later direct connection to the supply shafts on the construction site prepared; factory prefabrication of building services lines (living space ventilation and electrical). In order to have good maintenance access, the suspended ceilings are also designed modularly as individual elements, which can also be easily removed individually (see pictures next page).







Interior joinery work from top left to bottom right: Assembly of the modular ceiling panels for the lower ceiling, installation of the frames for the interior doors, the installation of all windows and also the front doors are already done in the factory.

The finished modules are then prepared for transport to the construction site. The use of an innovative construction time sealant, which can be left on the modules due to its low SD value (Diffusion-equivalent air layer thickness), eliminated the need for the otherwise customary packaging of the modules in plastic film for weather-protected transport; this further reduced the volume of waste.

November 3, 2021, early in the morning: The four modules for the first construction phase (Top 7 & Top 8) are completed at the factory and leave the plant in Kasten for transport and relocation to Böheimkirchen. - Top 7 (ground floor) the first residential module is loaded and arrives at the construction site in Böheimkirchen.

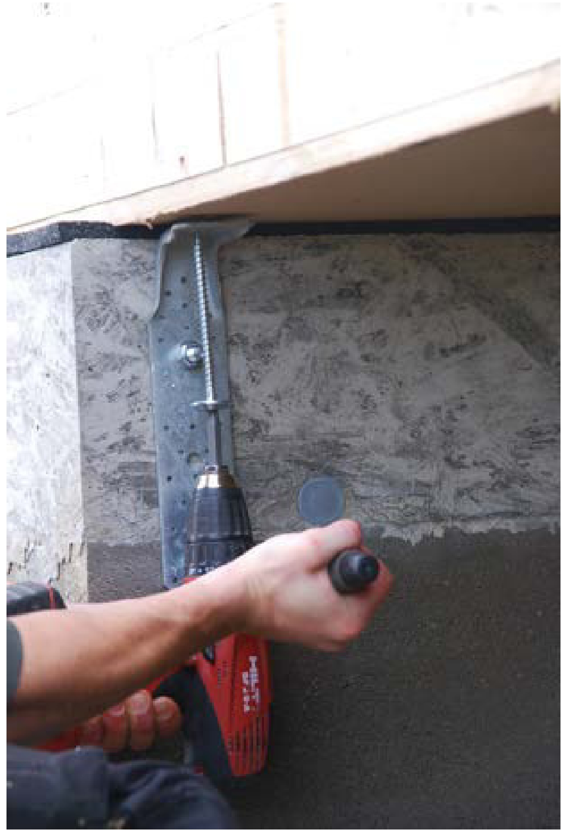
05 1st construction phase on site - moving and assembling the modules Top 7 - 8

Preparation of the foundations for the support of the modules with support pads made of rubber granulate (moisture and friction protection for timber construction), the metal connectors for screwing the modules to the foundations have also already been pre-assembled on the foundations.

The first module (Top 7 residential module) is lifted onto the foundations by crane and precisely aligned.

The individual modules are bonded to ensure airtightness and firmly screwed to the single and strip foundations.

03 November 2021, noon: - 2 modules are already in place;



03 November 2021, evening: all modules of the 1st construction phase have been moved and assembled.

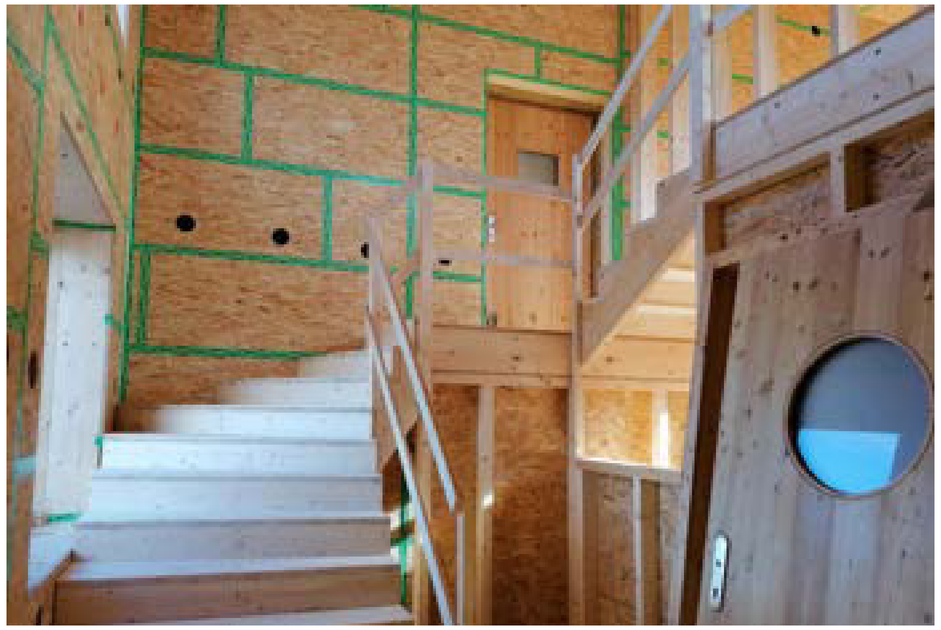
The roof construction for the first construction phase was completed two days later.

06 Construction phase: Community center and staircase

The staircase and community center were built in lightweight construction with prefabricated elements. The staircase for Top 8 and Top 4 is the connecting element between the modular prefabricated units on both sides.
The interior fittings were carried out on site at the construction site. The prefabricated elements also ensured an extremely short erection time for the shell (2 days). The blow-in straw insulation was carried out after construction in the interior. The wood stud construction of the interior walls was erected not in the factory, but on site due to the height over two floors. The staircase was also constructed entirely of wood and wood-based materials.

07 3rd and 4th construction phase: Top 4 - 1

3rd construction phase: Moving and assembly of the modules for the units Top 3 and Top 4, each consisting of 2 residential modules and a building services module with a living area of approx. 84 m2.
All module joints and cable routing are sealed airtight with special adhesive tapes for wood materials.



For sound insulation and insulation between the floors, a layer of Iso-Stroh is placed loosely and covered with OSB boards. The modules of the upper floor are then placed on top of this.

Within one working day, all 6 modules were also moved and assembled in construction phase 3. The modules are screwed together horizontally. A vertical screw connection is not necessary due to the strong static friction of the modules to each other.

4th construction phase: Moving and assembly of Top 1 + 2 (terraced houses 2-storey), consisting of a total of 8 modules. Parallel to this, work on the insulation and façade has already begun in the first and second construction phases.

One module per row house will already be equipped with the finished interior staircase in the factory. The corresponding upper floor module is equipped with a precisely fitting opening.

Here, too, all 8 modules of the construction stage can be assembled within one day.

In the following days, the roof structure for the "flying roof" will also be completed and the scaffolding for work on the insulation level and facade will be pulled around the building complex. Meanwhile, the last two residential units will be connected to the central building services supply.

08 Insulation, facade and outdoor facilities

Directly to the outer wall of the modules, the wooden structure (compartment for blow-in insulation) is attached around the building on site.

The cavity is closed with DHF boards (= diffusion-open and moisture-resistant synthetic resin-bonded, medium-density wood fiber board). The 48 cm thick blown-in insulation made of straw chaff (Iso-Stroh) is inserted. The special preparation also keeps dust level well below the limits.

The ventilated wooden façade (vertical floor-ceiling formwork made of sawed larch) is installed on the counter-battening of the exterior wall and the terraces, balconies and house entrances, also made of wood, are installed. Meanwhile, the interior of the staircase and the community center is also completed

09 Completed multi-apartment building June 2021

South side with finished terraces and balconies

North side with house entrances, Top 4 and Top 8 on the upper floor can be reached via the staircase, all other residential units are accessed with an outside entrance via a small wooden walkway. All paths and driveways are covered with ecological flooring to keep the sealing as low as possible.

10 Erection of shell load-bearing straw construction

Prefabrication of the individual elements such as outer wall, floor, top floor ceiling in the factory




Exterior wall construction: The large straw bales are already compressed at the factory and inserted into the glulam frames with ribs (as settlement limitation and static support during load transfer). The elements are planked on the outside with soft fiberboard (as a plaster base) and on the inside with OSB as a vapor barrier. This creates a partial load-bearing straw wall structure combined with the advantage of prefabrication in the factory.
The floor element and the top floor slab are finished with Iso-Stroh insulation in a thickness of 60 cm. Due to the greater loads, the floor elements are planked with wooden laths made of rough-sawn larch in addition to the DHF board in the lower area.
The wooden stud construction for the partition walls of the semi-detached house are also already manufactured in the factory and planked on one side with 3-layer spruce boards.

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11 Moving and assembling the elements on the construction site

In April 2020, the prefabricated elements for the first semi-detached house (Top 10) were moved and assembled on the construction site in 2 days. On the third day, the roof truss could already be erected.

Moving the first floor element and threading the lines from the installation shaft; view over the entire construction site with crane and floor and exterior wall elements of the first part of the semi-detached house (Top 10) already moved and assembled on this day.

Before the top floor slab was moved on day 2, the prefabricated interior walls were lifted into the open structure and assembled.

The individual elements were connected with screws and insulated with fleece between the joints. Here, too, adhesive joints were avoided as far as possible from the point of view of building physics. (e.g. to ensure the airtightness of the buildings).

View of the erected interior walls already prefabricated on one side, the open compartments (picture on the right) will later be filled with hemp insulation mats and closed with 3-layer boards spruce.

window fronts. Image above: Laying of the overlay, which is also insulated with blown-in straw insulation.
Figure right: Detailed view of the joint of the two overlays.

After the assembly of the overlays, the ceiling elements are moved and installed. Due to the prefabrication and the accuracy of fit of the individual elements, one residential unit (an atrium house) could be erected within one week including the roof structure.

The ceiling elements are constructed from the inside to the outside as follows:
OSB board; 60 cm blow-in insulation straw chaff; in between ribs;moisture resistant DHF board.
After installation, the elements are connected to each other with long special screws.

In order to minimize the use of construction foam for the air-tightness of the building envelope, fleece is used between the element joints. The joints are then sealed on the inside and outside with special adhesive tapes for wood materials.

Northwest view of the semi-detached house both residential units in the shell finished. The work on the roof truss and flat roof are being carried out.

12 Interior finishing load-bearing semi-detached house

Electrical wiring was installed in the interior walls.
The compartments of the interior walls were filled with hemp insulation boards and closed with 3-s boards spruce. Innovative wooden nails were used to fasten the wooden panels. These are shot into the wood with a compressed air nailer and the resulting frictional heat causes the lignin in the wood nail to expand, creating an inseparable bond with the material.

The east- and west-facing exterior walls of the two residential units of the semi-detached house were clad with clay building panels.
The picture also shows the façade ventilation unit (Top 9) and still packed hemp insulation boards for the interior walls.

The building panels are covered with clay plaster. The final top layer was made of clay plaster with an addition of light sand, which is finely rubbed with a sponge board, so a light, sandy hue and a smooth plaster surface. Keeping those walls unpainted preserves the sorption capacity of the clay for an improved indoor climate. Natural linseed oil with white color pigments was also used for painting the interior wooden walls.

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The dry construction system for floor heating offers two advantages: During construction, rapid installation, since the long drying time of a screed covering is eliminated. During dismantling, simple and unmixed removal, as the individual panels are not glued to the subfloor.

Substructure for the suspended interior ceiling in the rooms; in the space between the ceiling and the top floor, there is enough space for the wiring and building services components (e.g. ventilation unit).
The exposed ceiling is made with individual, screwed panels of spruce, which allows easy maintenance access, but also, for example, to easily move the light outlet if necessary.

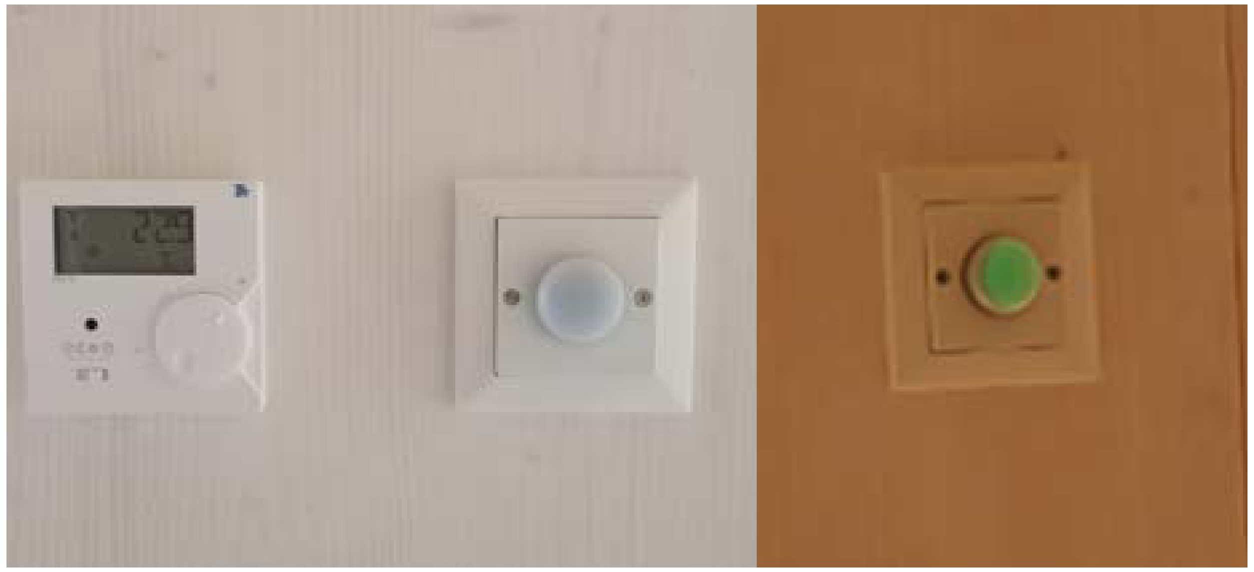
A cork carpet pad is laid over the floor heating system and a floating parquet floor is laid on top. The absence of adhesives ensures a healthy indoor climate and separation by type during renovation or dismantling.

The spacious terraces of the semi-detached house stand on screw foundations and are also executed in larch. All windows have passive house standard and are made with wooden frames.

Views of the completed duplex. Image above: Garden side view from east to west; Bottom image: House entrance view on the north side (photo from west to east).

13 Renewable energy supply of the buildings

On the roof of the technical room (pitched roof in the background) is the solar thermal system with a total gross area of 33.4 m2.
On the roof of the carport, there are three rows of PV modules mounted in east-west orientation with a total output of 23.76 kWp. The PV system is set up as a community system and also supplies the residential units with energy.



All residential units are equipped with room sensors and an energy traffic light. The energy traffic light shows green when there is a surplus of self-produced electricity (PV + Enertwin).

The Enerboxxes (Hot water storage systems) in the individual units are loaded centrally three times a day from the 5000 l buffer storage in the technical room. This in turn is fed with hot water by the solar thermal system and the micro-CHP.

The Enertwin micro-CHP is operated with a low-maintenance gas turbine. It supplies 15 kWh of thermal energy and 3 kWh of electrical energy during operation. It is supplied with 100 % biogas.

Projektträger: GrAT, Gruppe Angepasste Technologie, Wiedner Hauptstr. 8 – 10, 1040 WienIdee, Concept Design, Projektleitung: GrAT / Dr. Robert Wimmer

Architektonisches Design: Architekten Scheicher / Georg Scheicher

Bauleitung, Bauherrenvertretung: Andreas Ranftl

Projektpartner / Energieplanung: teamgmi Ingenieurbüro GmbH,DI Michael Berger

Generalunternehmer: DPM Holzdesign GmbH / Leopold Kasseckert

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Abfallvermeidungs-Förderung der österreichischen Sammel- & Verwertungssysteme für Verpackungen