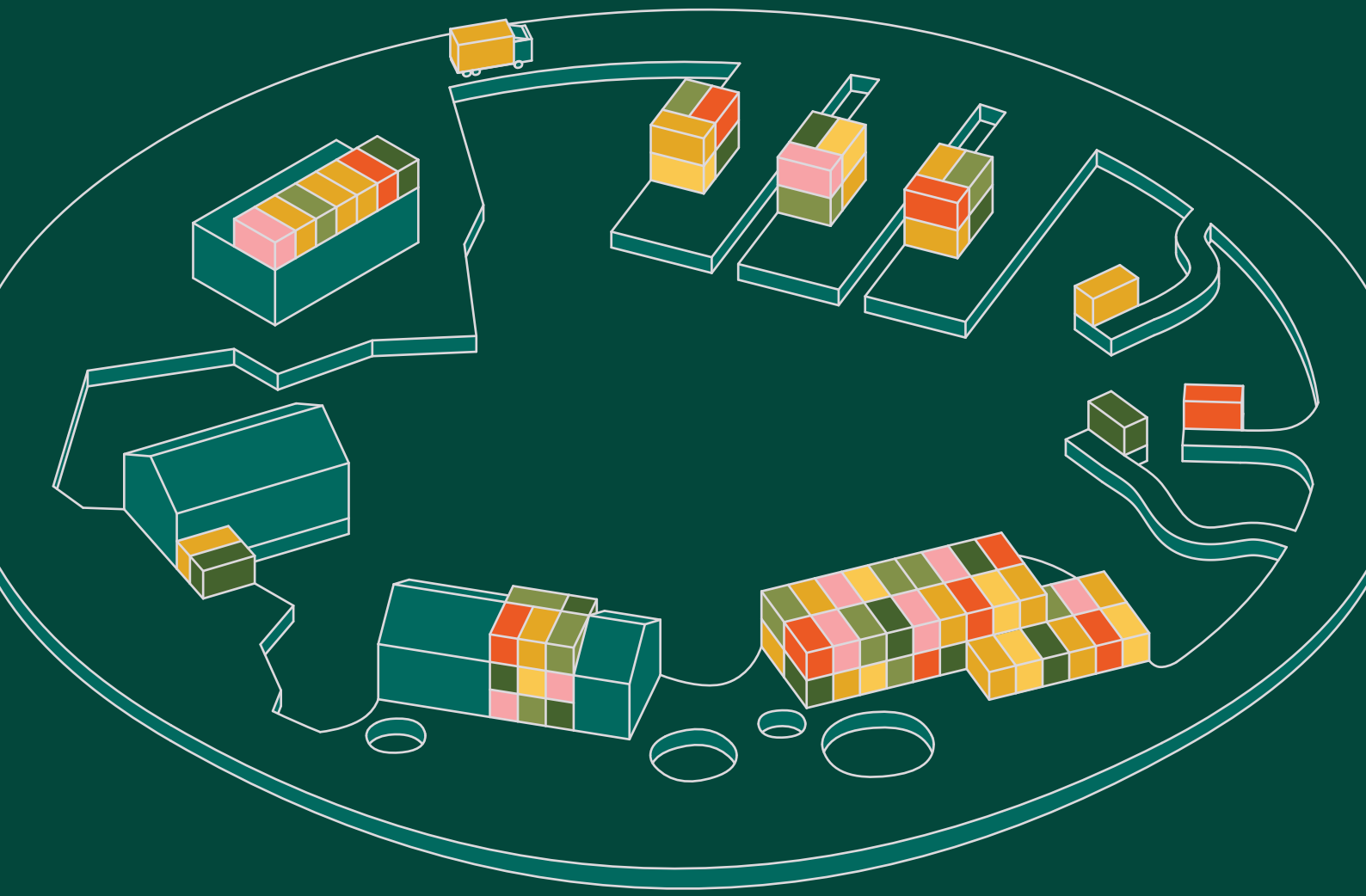
3cycle building system

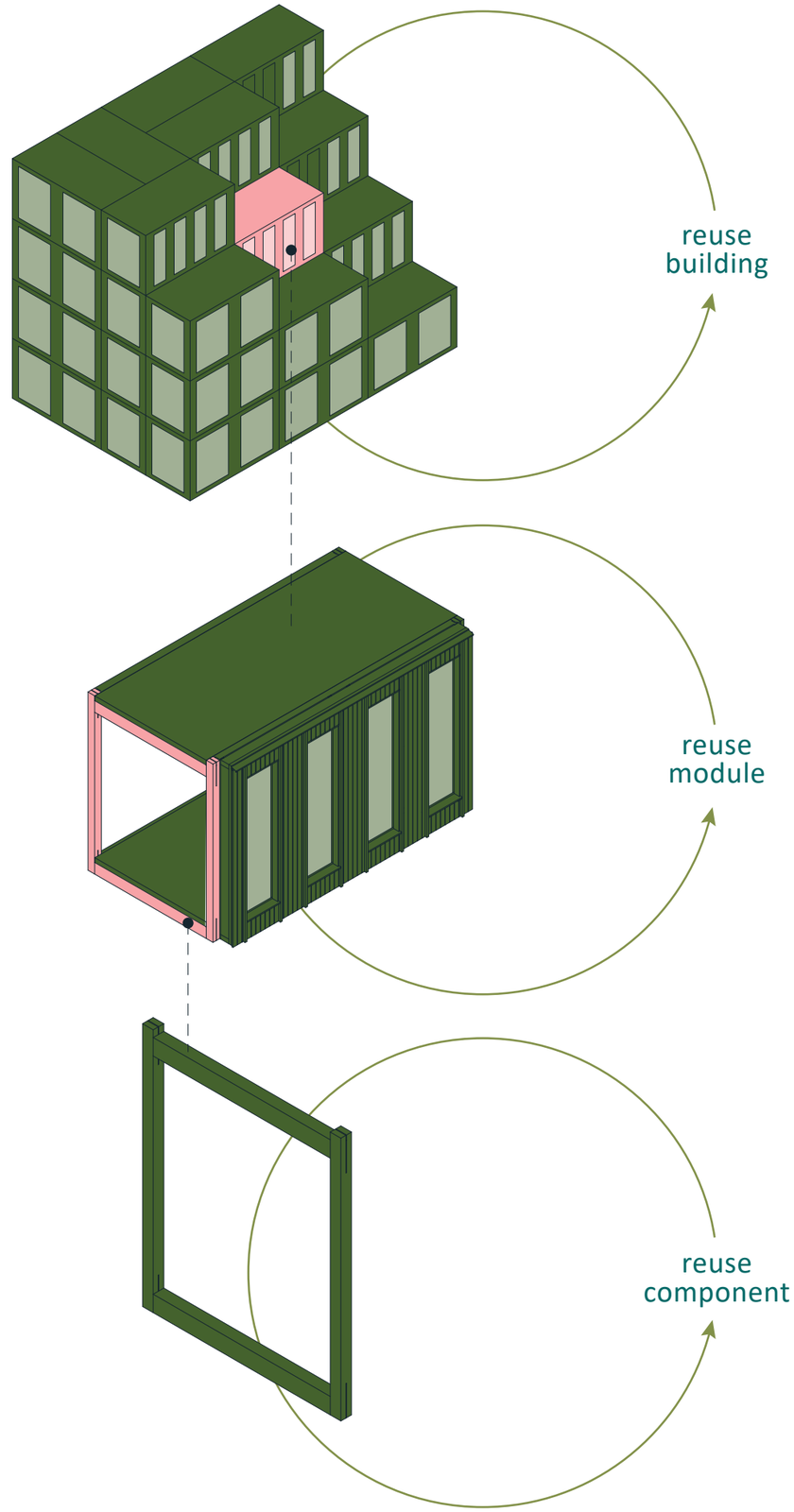
Sustainable construction system for modular and circular buildings



1. Circularity

3cycle buildings are circular in multiple levels. The largest circular unit in the system is the ***entire building***, as it can be demounted, moved and reassembled on a different site, if the need occurs. Secondly, full ***room modules*** can be reassembled, removed or added to a building. The smallest reusable parts of the building systems are its ***components***. They are designed for disassembly, allow for easy repair or upgrade and can be easily reused in differing combinations in the same or other buildings. All building components, designed based on the principles of the *3cycle* system, should be recyclable and maximise the use of low-emission and bio-based materials.

The core of the building system is its design for disassembly, following the standard ISO 20887. Connections are easy to open and demounting does not result in damage or contamination of the buildings, modules or components materials. Preserving their value keeps the materials from being dumped on landfills or burned in incineration plants and makes them more attractive for future reuse. All the materials which continue to be reused and which are circulating in the building stock save on future extractions of resources and productions of materials, thus reducing the environmental impact on climate and ecosystems. This way, *3cycle* buildings can contribute to the transition towards a sustainable building sector with responsible consumption and production.



2. Base Module

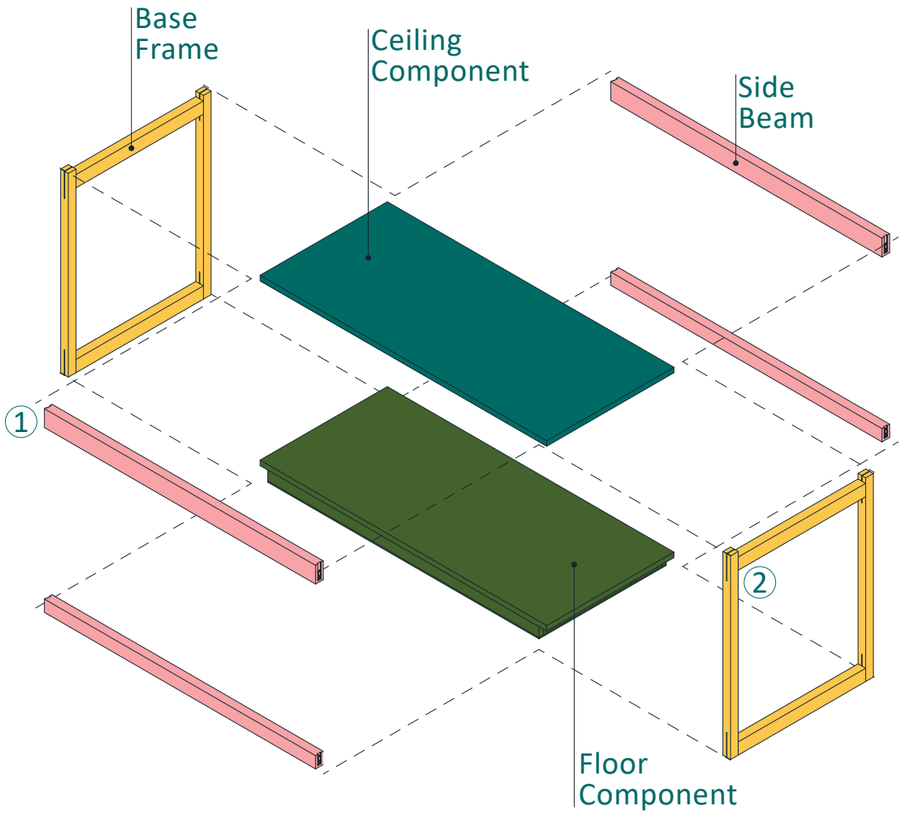
The key part of a building in the *3cycle* building system are the ***Base Modules***. They are highly customizable components to which further elements of the building system can be attached.

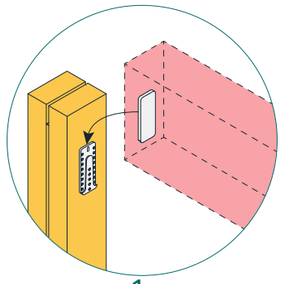
Each *Base Module* is composed of a list of components.

- The ***Base Frame*** is a structural frame located at the short side of each module. Its height determines the height of the *Base Modules*. The dimensioning, materiality and/or coating of the frame posts can be based on specific building projects and their required spatial properties, structural strength and/or fire safety.
- The ***Floor Component*** is attached mechanically to two *Base Frames* on its short sides. The components can be customised in regards of structural strength (type and amount of floor beams) and thermal or acoustic insulation. Typically, insulating material is filled in between the structural beams of the component.
- The ***Ceiling Component*** closes the *Base Module* to the top. It is laid onto two *Base Frames* on its short sides. The components function is, in contrast to the *Floor Component*, not structural. Its main purpose is to allow for a high degree of prefabrication off-site, including interior works. Additionally, the component is a fire barrier which protects the structural components above. Different coatings or claddings can be used to increase the fire safety. Building acoustics are improved, as floors and ceilings are not joined structurally, reducing the intensity of mechanically transmitted sound.
- The ***Side Beams*** are structural beams hanging between two *Base Frames* on the long side of *Base Modules*. They are required at the envelope of a building to attach facade panels. In the interior of a building their use is more flexible. They are required beneath interior walls but can be left out otherwise to run building services horizontally and vertically in the building.

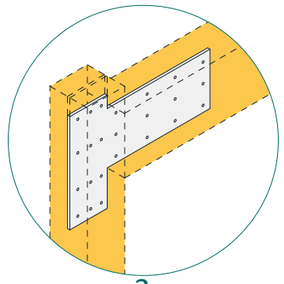
The *Base Module* can always be disassembled into its sub-components, as all connections are mechanical and reversible. This preserves their value and increases the chance of sub-components being reused in various building projects with different requirements.

The dimensions of the *Base Modules* are restricted by transport limitations. The standard width of a module is 3 metres and the two standard lengths are 3 and 6 metres. Different lengths, heights or non-rectangular shapes can be introduced, if required. However, the use of standard components has to have priority to ensure the circularity of the system.

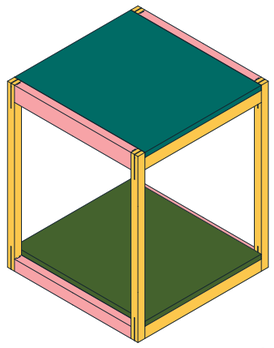




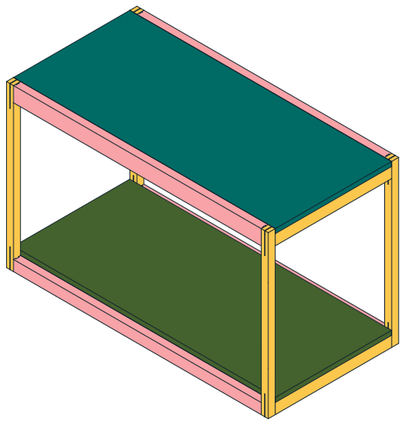
1
concealed timber connector



2
steel plate connector



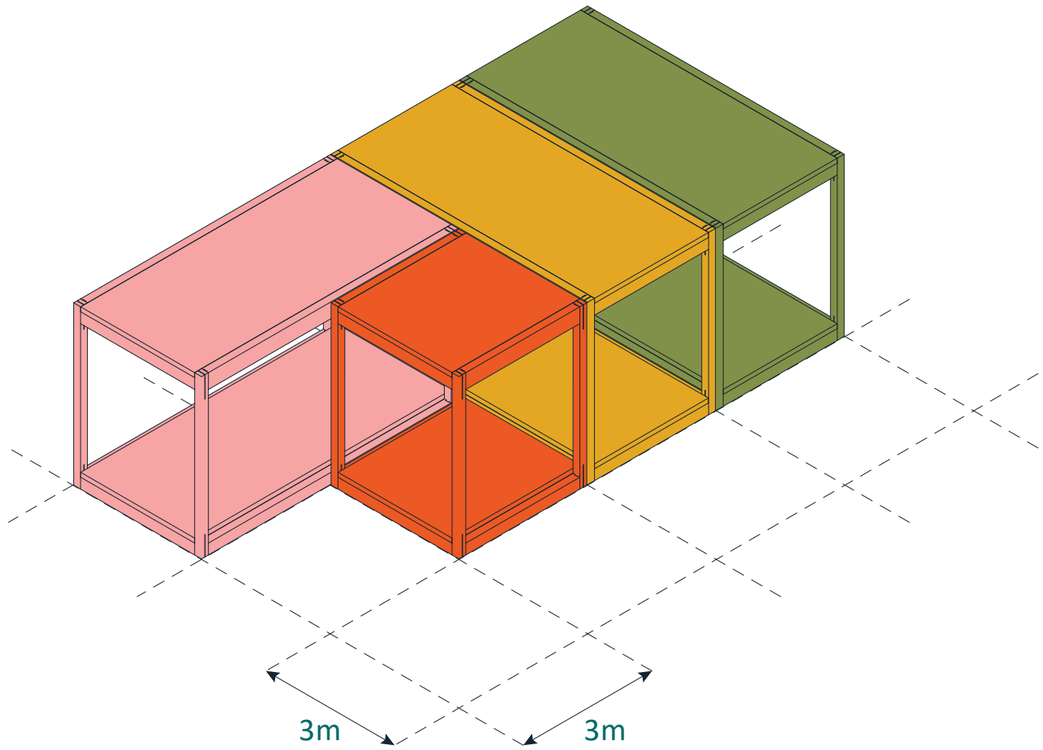
3x3 metres *Base Module*

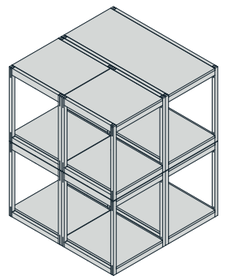


3x6 metres *Base Module*

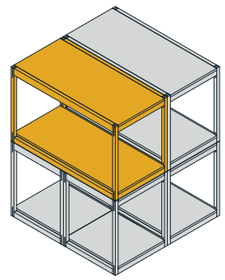
3. Module Arrangement

- Generally, all *Base Modules* should be placed in a 3 by 3 metres design grid to enable the connection of multiple modules independent from their rotation.
- Multistorey buildings should aim for a similar arrangement of *Base Modules* in each floor to ensure that each frame post of the upper modules is connected to another one beneath.
- Balconies, fire escape stairs and other structures which might be added to the outside of the building have to be self-standing and can be only anchored to the *Base Modules*.
- The *Base Modules* are most stable and least deforming in their short direction. Connecting a *Base Module* to a 90 degree rotated one increases the stiffness of the structure and reduces the need for shear walls. Nevertheless, shear walls will be required in most cases and have to be placed in accordance with the static calculations.
- The standard *Base Module* is designed for up to 4 storey buildings. Taller buildings should use variants of the *Base Module* with adequate structural capacity on their base.

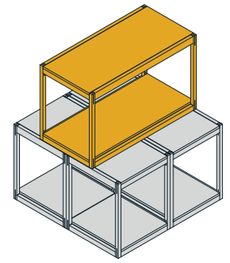




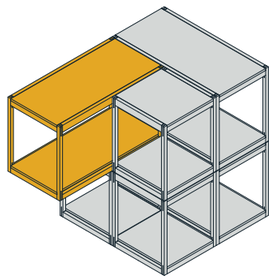
duplication



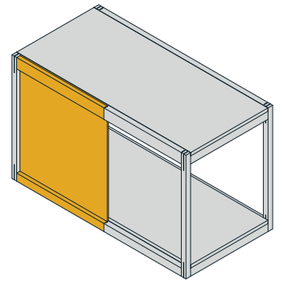
bridging



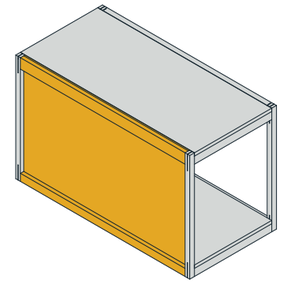
no connection



overhang



half shear wall



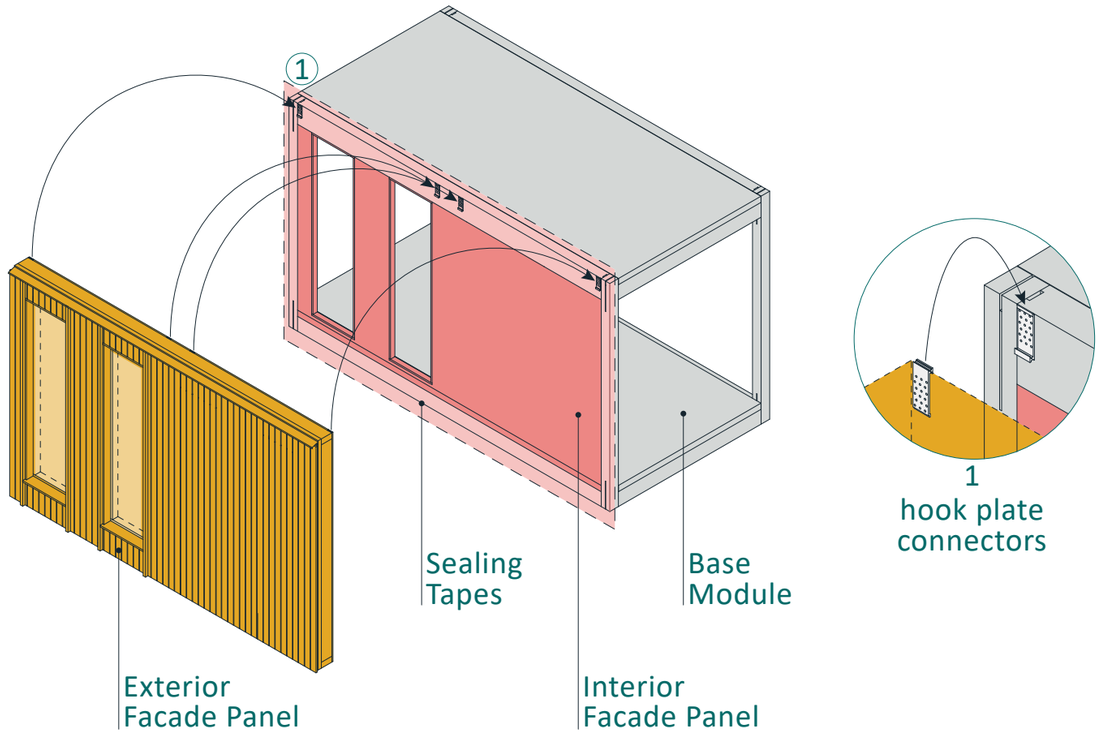
full shear wall

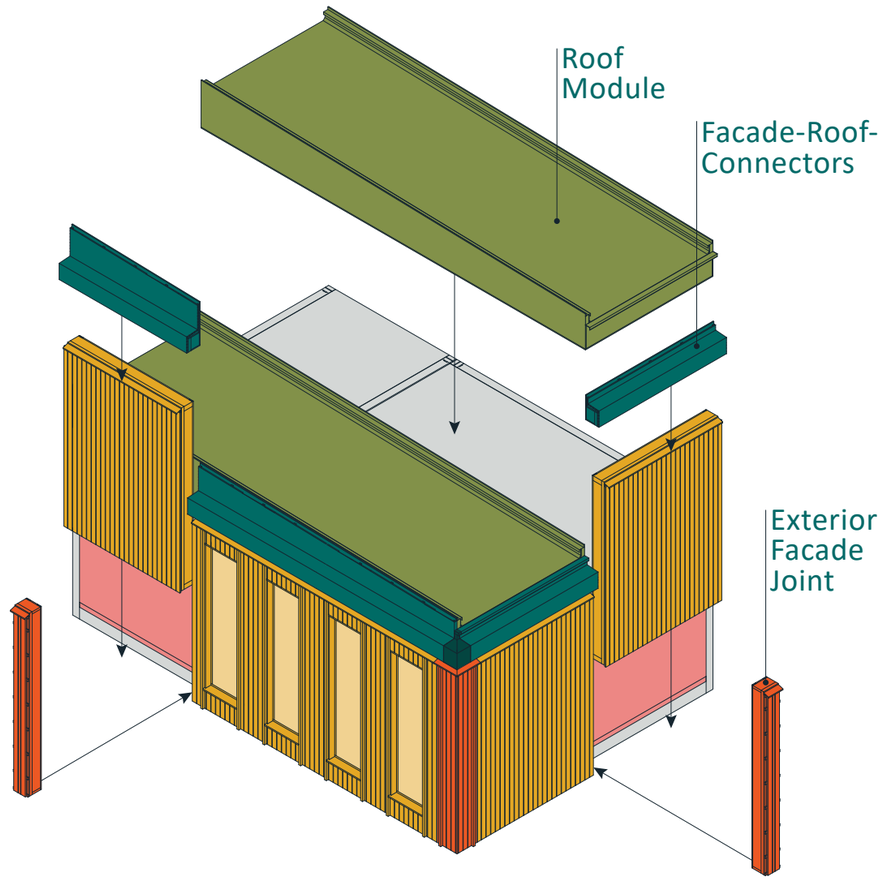
4. Building Envelope

The building envelope consists of roof and facade elements which are fixed to the *Base Modules*.

The facade consists of an interior and exterior layer.
The ***Exterior Facade Panels*** are hung with hook plate connectors to the *Base Frames* or *Side Beams* of the *Base Modules*. These panels function as the thermal envelope and protect against wind and rain. Windows and exterior doors are placed in them. The type of construction, thermal performance, window ratio and aesthetics can be chosen based on the project. However, the weight and structure of the panels have to be according to the limitations and positions of the hook plate connectors.
Interior Facade Panels are placed in the *Base Frames* or between *Side Beams*. They form the vapour barrier of the building and can provide space for additional insulation. Vapour barrier adhesive tapes are added from outside on the seams between the *Interior Facade Panels* and the structure of the *Base Modules* to seal the vapour barrier. Therefore, these panels are preferably built in the *Base Modules* in the factory to avoid exterior works on-site.
Exterior Facade Joints are used between *Exterior Facade Panels* to give easy access to the module and vapour barrier joints. This way, *Exterior Facade Panels* can be installed already in the factory and only the lightweight joints have to be added on-site.

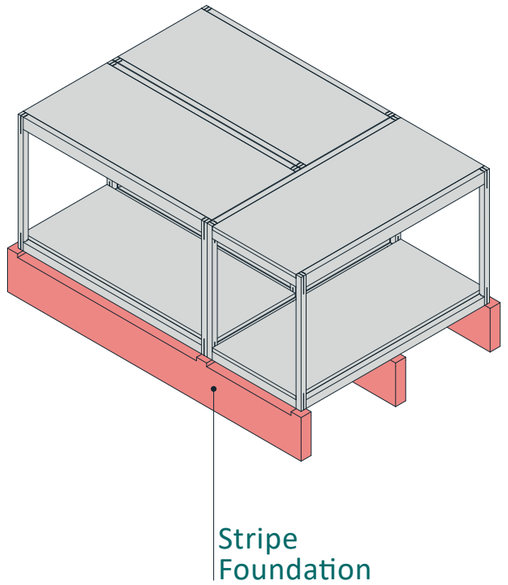
All kinds of insulated roof constructions can be added on top of the *Base Modules*. However, in order to preserve the building's adaptability over time one should use ***Roof Modules*** which are based on the 3 by 3 metres design grid. Each standard module is a low-sloped roof with parapets on three of its sides. Parapet cappings are used to connect and waterproof the connection between modules. *Roof modules* which do not extend above Exterior Facade Panels enable the latter to be unmounted or mounted independently during a building's life. In this case insulated ***Facade-Roof-Connectors*** are placed above *Exterior Facade Panels* to avoid cold bridges. The length of the connectors is typically based on the length of the facade elements beneath.

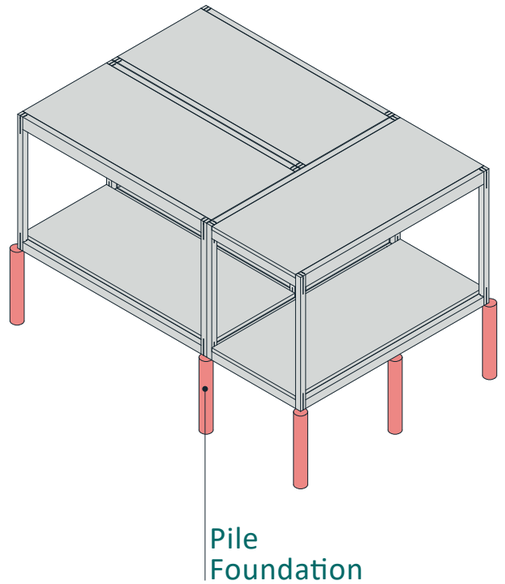


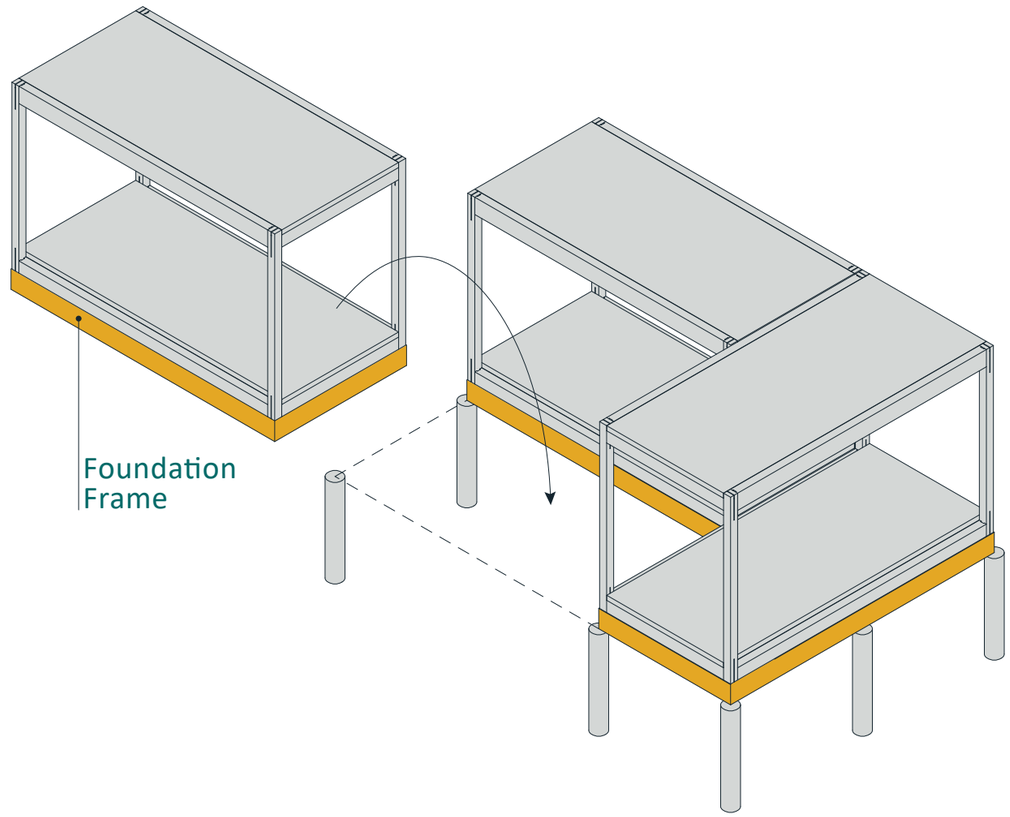


5. Foundation

The foundation has to support the four bottom faces of the *Frame Posts* of each *Base Module*. Insulated ***Foundation Frames*** can be added between *Base Modules* and the foundation to increase the thermal insulation of the building. Ventilated foundation types, such as stripe foundations with base floor or any types of pile foundations are preferably used as they reduce the risk of moisture damage from condensation in the *Foundation Frames* and *Floor Components*. The use of screwpile foundations can improve the adaptability and circularity of the building as they can be easily added, removed and reused or recycled.



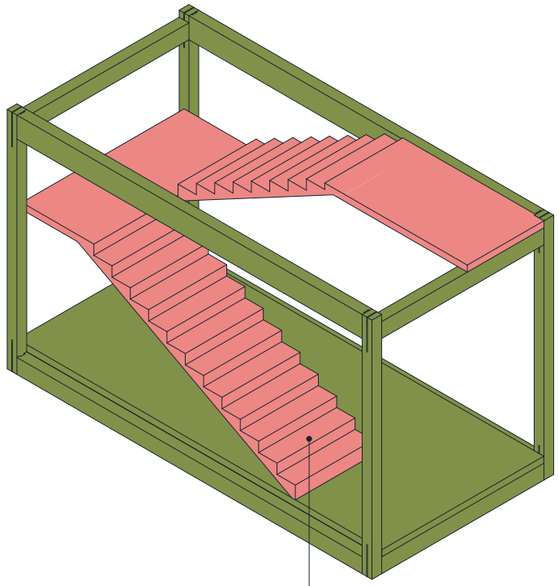


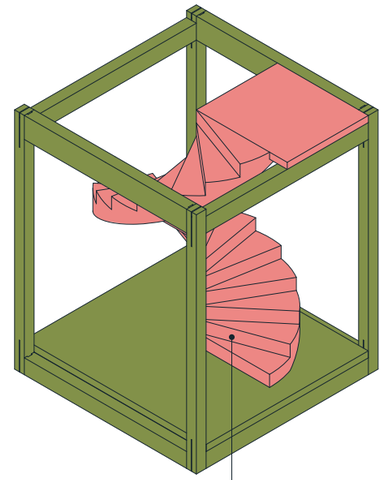


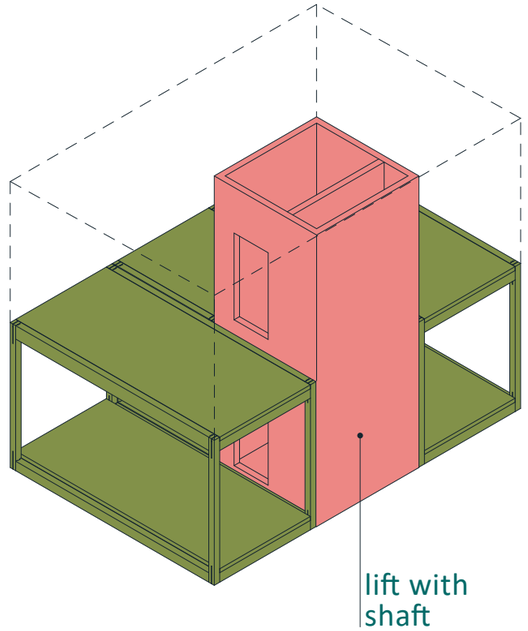
6. Circulation

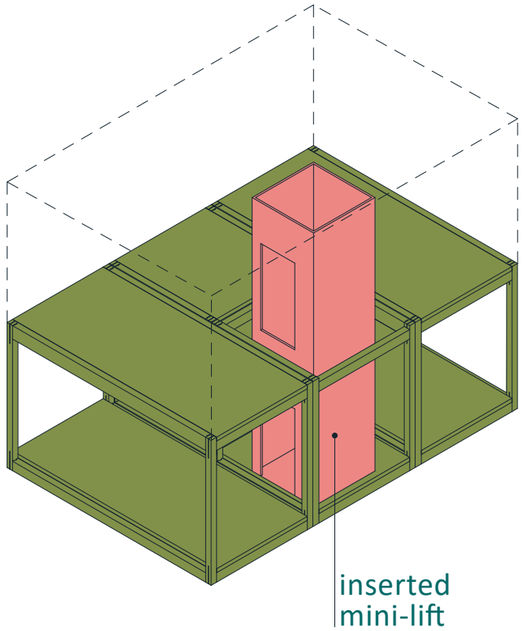
Horizontal circulation spaces such as corridors in optimal case follow the 3 by 3 metres design grid and are placed in standard *Base Modules*. Alternatively, a self-standing deck access can be placed, similar to balconies, in front of the facade of a building.

Vertical circulation is ensured firstly by stairs. U-turn stairs or winder stairs with a maximum stair width of 1250mm can be fit into 6 metres long modules. In a few cases spiral stairs might be used, which can fit into 3 metres long modules. Larger staircases and other stair types do not fit in the modular 3cycle building system and have to be designed individually. Exterior stairs and exterior fire safety stairs have to be self-standing and can only be anchored to the *Base Modules*. Lifts are not part of the modular system due to the high amount of regionally available products as well as country and project specific requirements. Small lift systems might be placed into *Base Modules*, while larger ones are built as self-standing structures in between *Base Modules* or anchored to the exterior of the building. Lift shafts can function as shear walls if designed accordingly.









7. Building Services

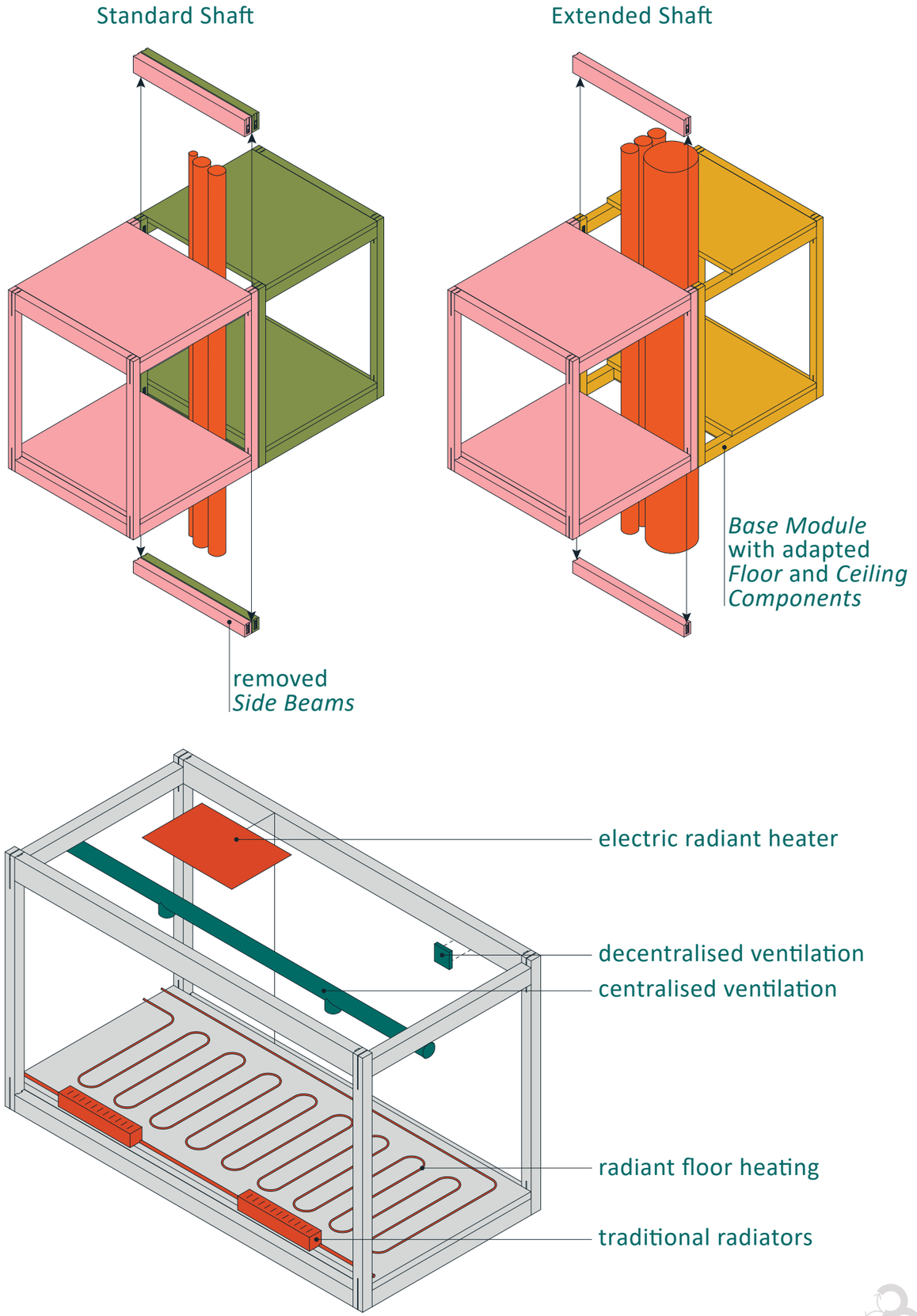
Building services ensure the day-to-day operation of a building. The systems are divided as follows: ventilation, heating and cooling, water/sewage and electricity distribution.
In order to give space for the vertical distribution of pipes and electric channels the *Side Beams* of the *Base Modules* can be removed. This way shafts with up to 340mm width can be created. If larger shafts are required they can be integrated into *Base Modules* by customising the particular *Floor Components* and/or *Ceiling Components*. Horizontally, pipes and electric channels should run at the ceiling. They can be left exposed or covered by a suspended ceiling but in either case easy access has to be ensured to not hinder the building's adaptability over time.

Centralised or decentralised ***Ventilation*** systems with heat recovery can be used to provide fresh air. Decentralised systems consist of individual units placed through the exterior walls and do not require venting air via pipes to a centralised core. However, if the *Exterior Facade Panels* are installed on-site, then decentralised systems have to be installed on-site, as well.

Multiple ***Heating*** systems can be used with the *3cycle* building system. Easiest to implement are traditional radiators and floor, wall or ceiling-mounted radiant electric heaters. They do not hinder the adaptability of the building system and allow easy removal or adding of modules from or to a building. Water-based in-floor radiant heating systems are generally cheaper to operate than the previous systems and can be joined with sustainable systems such as heat pumps or solar collectors. However, they require more work on-site as the heating pipes and the final floor layer have to be finished in situ. Expansion or downsizing of a building is in this case more work intensive, too. Therefore, the fitting heating system has to be chosen based on the expected amount of the building's transformation during its lifetime.

Water and sewage can be distributed vertically in the space between two *Base Modules* with removed *Side Beams*. In the best case a wetroom is planned in a single module with an adjacent vertical shaft to reduce pipe lengths and avoid the crossing of pipes through multiple modules. Pipes cannot be placed in the *Floor Components*. Therefore, furniture with sewage connection, such as toilets and showers, should be placed close as possible to vertical shafts.

The distribution of ***Electricity*** is project specific and can be done in floor or ceiling height and exposed or covered. To not hinder the adaptability of a building, individual modules could be plugged to each other. Otherwise, preinstalled cable channels are used to wire the building on-site after finishing the installation of all modules.



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