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Experiences from the Deconstruction of a Timber Building

Ylva Sandin (RISE), Olof Mundt-Petersen (Polygon AK-konsult), Oskar Linderoth (Polygon AK-konsult, Swerock), Karin Sandberg (RISE)

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Abstract

This study reports on a deconstruction process followed on site, with the purpose of documenting experiences that can help us understand how to design timber buildings for future deconstruction and reuse.

The deconstruction concerned three timber buildings built up by volumes (3D modules produced off-site). Modules were in good shape at the time of deconstruction except for some minor local moisture damages. They were all covered and transported to be reused elsewhere.

Experiences made included that lack of information on the assumed deconstruction process delayed and complicated the work. A need for disassembly plans was highlighted, including things as order of dismantling, positions of lifting points, weight of modules and positions of screws and amount of screw used. Results indicate that simple, clearly visible joints and services, limit the potential problems and damages during deconstruction. The building should simply be designed to be taken down in the future, the amount of screw allowed should be clearly described and the number of attachments should be limited. Furthermore, the risk of burglary during deconstruction needs to be considered as this may cause damage and delay.

Key words: deconstruction, timber building, case study

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Content

Preface

This is a translated and edited version of a report in Swedish, written by Olof Mundt-Petersen and Oskar Linderoth, at the time both employed at Polygon AK (Linderoth is presently at Swerock). Their work was based on an idea originating from research work carried out in Work Package 2 of the European InFutUReWood project, led by RISE.

The environmental impact and waste production from the building sector is unsatisfyingly large. The idea of deconstructing buildings and reusing their parts, rather than demolishing and sending the materials to waste, is currently gaining attention. The InFutUReWood project investigates how timber buildings can be designed today to facilitate deconstruction and reuse tomorrow. Although deconstruction and reuse are uncommon today, there are still some cases where it is done. We believe that it is crucial to follow these rare cases to find out what the current practical obstacles to deconstruction are as well as documenting what works well already. Collecting and compiling such data will give valuable information to designers and timber building manufacturers as to things they should avoid in design and things to keep.

At RISE, we investigate and develop different methods to carry out design for deconstruction and reuse. One method is accounted for in Ylva Sandin, Anders Carlsson, Caítriona Uí Chúlain, Karin Sandberg (2021) *Design for deconstruction and Reuse: Case study Villa Anneberg*, RISE report 2021:96. That method was adapted and used in this study. Focus is on the load bearing structure, rather than surface layers. There are several timber frame types, as light timber frames, post-and beam frames and structures built up by volume modules or planar elements. This study concerns three residential buildings with an expiring temporary building permit and a structure of 3D modules produced off-site. In the project Mätbar återbrukbarhet ("Measurable reusability") financed by RISE, we follow and document deconstructions of other timber building types.

The field visits reported on were carried out by Olof Mundt-Petersen and Oskar Linderoth and the use of "we" and "us" below, refers to them. Any judgements made were made by them. Ylva Sandin developed and communicated the method to use, wrote the summary, led the work in WP 2 of the InFUtUReWood project and translated the report. Karin Sandberg initiated the study and led the InFutUReWood project.

Olof and Oskar's work was financed by TMF (The Swedish Federation of Wood and Furniture Industry - Trä- och Möbelföretagen) as part of their participation in the InFutUReWood project. Ylva and Karin were financed partly by the InFutUReWood project and partly by RISE.

Thank you, Anders Rosenkilde, TMF for making this study possible. Thanks also Team Träteknik at RISE for enabling the translation, so that we can contribute to the international discourse on the important question of how to build for deconstruction and reuse.

Göteborg, 27th January 2022

Ylva Sandin

ForestValue

InFutUReWood is supported under the umbrella of ERA-NET Cofund ForestValue by Vinnova – Sweden’s Innovation Agency, Formas, Swedish Energy Agency, the Forestry Commissioners for the UK, the Department of Agriculture, Food and the Marine for Ireland, the Ministry of the Environment for Finland, the Federal Ministry of Food and Agriculture through the Agency for Renewable Resources for Germany, the Ministry of Science, Innovation and Universities for Spain, the Ministry of Education, Science and Sport for Slovenia. This is supported under the umbrella of ERA-NET Cofund ForestValue, and ForestValue has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 773324.

Summary

The environmental impact and waste production from the building sector is unsatisfyingly large and the idea of deconstructing buildings and reusing their parts, rather than demolishing buildings and sending the materials to waste, is currently gaining attention. This study follows a deconstruction process with the purpose of documenting experiences that can help us understand things to avoid and things to promote in the design of a timber building intended for future deconstruction and reuse.

The study showed that the deconstructed modules were in good shape at the time of deconstruction with only some minor local moisture damages. Modules were protected with plastics during transport and a risk for moisture damage due to condensation and a need to monitor humidity and temperature inside the plastic was identified. A dehumidifier might be needed. The covered modules were transported to be reused elsewhere.

The deconstruction firm reported that lack of information on the recommended deconstruction process delayed and complicated the work. They stressed the need for buildings to have a disassembly plan.

- Instructions should be provided for the order of dismantling and order of lifting for each building component.
- Information should also be provided on choice of crane truck, positions of lifting points and weight of each module as well as positions of screws and the amount of screw used.
- Deconstruction instructions should also be placed directly in its applied environment since drawings etc. tends to disappear during the years. Simple things as marks pointing out lifting loops and joints as well as a short description would have simplified the deconstruction process.
- The deconstruction should be planned already during the design phase and the building should simply be designed to be taken down in the future.
- It must be clear where the attachments that connect the different building parts are situated and how to access them during deconstruction.
- For the original assembly, the amount of screw allowed should be clearly described.
- For deconstruction, it is advantageous if the number of attachments is limited.
- The risk of burglary during deconstruction needs to be considered as this may cause damage and delay.
- The risk of moisture damage during the deconstruction process should be considered, both due to rain when the roof is removed, and due to the fact that the building becomes more accessible (for thefts of materials for example).

Purpose

The purpose of the study is to document and compile experiences from the deconstruction of wooden house modules that are intended to be reused. The goal is to identify problems and difficulties encountered during deconstruction but also opportunities and lessons to take with you to similar projects in the future.

Delimitations

At the request of the owner of the buildings, the project has been anonymised. As part of this process, the identities of supervisors and site managers have also been anonymised.

No in - depth analysis of the results (in addition to this report and its annex) is included in the study, due to its time and resource limits.

The object

The project consists of three three-storey buildings built up by wooden house modules (Figure 1). One of the buildings also have a basement floor. All buildings consist of apartment modules with studios (a bedroom/living room and a kitchen). The modules in each house are stacked in two rows and three levels. Between the two rows there is one common access balcony indoors from which the apartments are docked. The access balconies are in turn reached from staircases and access balconies in outdoor climate. The middle building has a ground floor of concrete, the other two buildings have a foundation with a LECA-insulated crawl space.

The buildings were built about 15 years ago with a temporary building permit, which was extended for several rounds. According to unconfirmed information, the buildings have been empty for about 2 years before the dismantling started in April 2021.

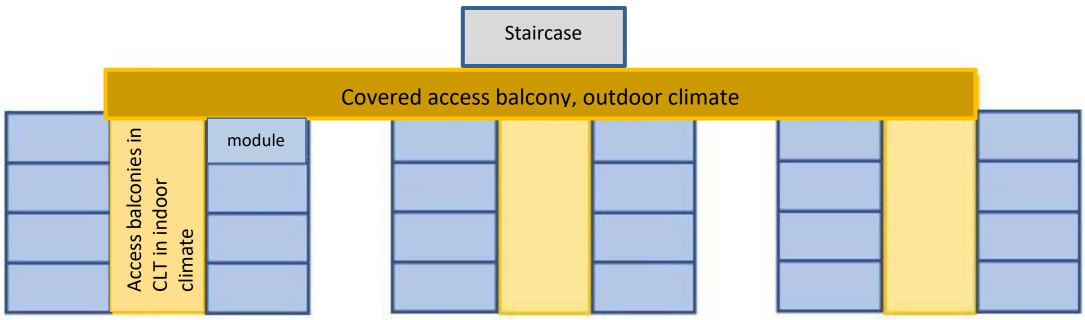

Figure 1 - Schematic overview of apartments (studios), access balconies and staircase.

Method

The deconstruction site was visited at two occasions. Interviews were carried out with the site manager. The deconstruction process was documented by photos and notes. To structure the interviews and notes, a method and spreadsheet developed in the InFutUReWood project was used (see Ylva Sandin, Anders Carlsson, Caítriona Uí

Chúlain, Karin Sandberg (2021) *Design for deconstruction and Reuse: Case study Villa Anneberg*, RISE report 2021:96.) The site visits and writing of the initial report in Swedish was done in April 2021. The translation and editing of this version in English was done in January 2022.

Results

Selected images from the site visits carried out, are attached in Appendix 1. The results are mainly compiled in the attached Appendix 2. Below, several observations and experiences are described, that are considered too comprehensive to fit into Appendix 2.

Overall damage assessment

From an overall perspective, our perception is that the modules look good, and that no larger/extensive moisture damages could be found during either of the two site visits.

Moisture damage found

Occasional local moisture damages were noted at pipe connections. Probably these have arisen in connection with the dismantling of pipes and the discharge of standing water. Our view is, however, that the local moisture stains that were noted on gypsum boards can be easily remedied by replacing the damaged paper of the gypsum plaster board. Some of the moisture damages could probably have been avoided if the pipes could have been emptied of water in advance and the pipes could have been more carefully deconstructed.

Reuse basement and foundation

Under the middle building there is a basement in concrete. Under the other two buildings the foundations consist of edge beam elements in concrete and a closed crawl space isolated with LECA.

Although not directly connected to the task of documenting deconstruction and reuse, a reflection was made that from an environmental perspective, it should be investigated what proportion of the houses' total CO_2 footprint the basement and the foundation constitute. In a reuse context, it would be of interest to know how large the environmental impact from using concrete is, compared to the impact of producing new wood-based modules instead of reusing them.

Lack of assembly documentation and deconstruction instructions

The site management has not had access to any documentation from the original assembly. Neither has it had access to any deconstruction instructions. The lack of documents is judged to have created lots of extra work and increased project costs. Below are some examples of problems that could probably have been avoided with sufficient documentation/instructions:

1. In what order were the building components installed, and in what order are they intended to be deconstructed?

Of course, the roof is installed after the modules are in place, but it is not obvious when and how, for example, panels, access balconies and staircases should be dismantled. If the assembly scheme had been known (and well documented) it could have served as instructions also for deconstruction. The assembly order should appear from as-built documents, archived both at the real estate company and in the building.

2. Lack of deconstruction instructions

In connection with the buildings being designed and built, a plan or at least a proposal for a plan, should also have been produced, for how to dismantle the modules. This regards several different dimensions and scales. During the design and construction of the buildings, instructions should also be produced for how the modules are to be dismantled.

The instructions may, for example, contain the following points and descriptions:

a) Order of dismantling for each building component.
b) Suggestions for logistics management during deconstruction. For example, in what order the building parts must be lifted down as well as the location and choice of crane truck.
c) Information about lifting points.
d) Information about the weight of each module.
e) Information on how different building parts are assembled; where the screws screwed are and how much screw was used.

An experience from this project is that it should be clear which attachment points that are to be used and how many screws that should be used for each point of attachment. For the original assembly, it should be clearly prescribed how much screw that is allowed to be used.

Simple things as clear marks written directly on module walls (only visible during assembly and disassembly) pointing out lifting loops and joints as well and giving a short description would have been of great help and would have simplified the deconstruction process. Please note that such instructions needs to be placed directly in its applied environment since drawings etc. "aims" to disappear during the years.

Furthermore, the deconstruction should be planned already during the design phase. The building should simply be designed to be taken down in the future. It must be clear where the attachments that connect the different building parts are situated and how to access them during deconstruction. For the deconstruction, it is advantageous if the number of attachments is limited as far as possible.

Damage and burglary

During the relatively short time that the dismantling has taken place, three burglaries have taken place. At the first burglary all the copper/copper pipes that the professionals had cut off and placed in a locked space in the basement was stolen. In the second burglary, the burglars themselves cut off and stole the remaining parts of copper pipes that the professionals had not yet dismantled. During the third burglary, the burglars entered the apartments and stole shower mixers and mixer taps for the sink. In many apartments, this has created consequential damage to sinks that were simply crushed to get rid of their mixer taps as well as damage to bathroom walls where the shower taps were installed.

One experience to take away from this is that one should consider the risk of burglary, theft, and those consequential damages these may cause.

Risk of moisture damage during deconstruction

In addition to mechanical damage (due to defective deconstruction instructions) there is an obvious risk of moisture-sensitive building parts being exposed to rain during deconstruction. Just like in assembly, these building components should be protected against rain during deconstruction.

Risk of moisture damage during transport

Modules must be protected from rain and snow during any transport from the workplace. Regardless of how the modules are stored, it is probably beneficial to have as short a storage time as possible. Wrapping modules with plastic is probably a good method to use during transport, but it must be ensured that undersides of modules are also protected as they could otherwise be damaged by sludge and splashes. However, there can be other moisture-related risks related to the intermediate storage of the modules wrapped in plastic (see below).

Risk of moisture damage during intermediate storage

The modules must be protected from rain and snow during any intermediate storage. No matter how the modules are stored, it is probably beneficial to have as short a storage time as possible. If the modules are stored wrapped in shrink plastic (as during transport) there is a risk that one gets an unfavourable climate inside from a humidity point of view at least if they are stored in sunlight. It is recommended that you check the climate in the modules during storage and use dehumidifiers if necessary.

Personal safety and working environment during deconstruction

Personal safety and work environment are outside our specialist competence, but we can state that it must be considered how a good personal safety and working environment during deconstruction can be achieved. It must be ensured that scaffolding and guardrails are adapted to the reverse assembly process that deconstruction represents.

Flexibility in the reuse phase

The apartment modules in this project have been fitted with six layers of gypsum plaster board, probably to cope with noise and fire requirements. The design of the modules should be such that they, without extensive measures, can be adapted to any variations in the requirements when they are reused. This is something that should be considered preferably already during the design phase.

Conclusions

Some overall conclusions can be established from the survey:

- A deconstruction can be facilitated if:
  - The number of mounting screws and nails is limited.
  - The joints and screws that attach volumes, stairs, balconies etc. to each other are clearly marked and clearly visible on site.
  - The positions of lifting points as well as weights of volumes are clearly marked on the physical volumes.
  - There is a clear deconstruction instruction, or at least an instruction from the initial assembly, available.
- The deconstruction must be planned to be carried out during a continuous period of no rain and planned to be carried out as fast as possible when the roof or other weather protection has been removed.
- The risk of moisture damages during transport and intermediate storage must be handled.
- The deconstruction process should be planned already in the design phase. A simple structure and construction process probably creates good conditions for a simple and successful deconstruction.
- The risk of burglary must be handled. The unrelated phenomenon of theft of copper pipes may in practice create major damage.

Appendix 1 Photo documentation

The document is a compilation of some of the photos taken in connection with two site visits during dismantling: 2021-04-12 and 2021-04-22 respectively.

Content

Access balconies and staircases

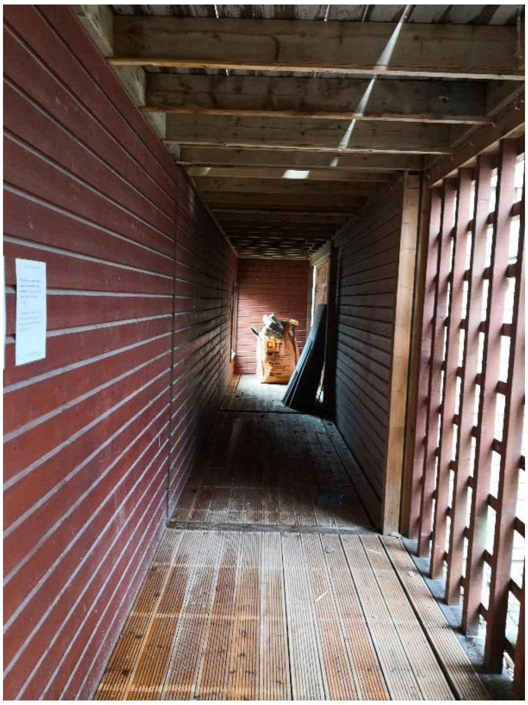

Figure 1 - Access balcony connecting the buildings.

Figure 2 - Space where access balconies previously were.

The CLT floor in the bottom floor was planned to be reused as outdoor balconies at the ground level. The CLT floor was aimed to have a small slope to the center where rainwater was captured and further transported away

Figure 3 - Transition between module and access balcony/staircase.

Figure 4 - Access balcony/staircase

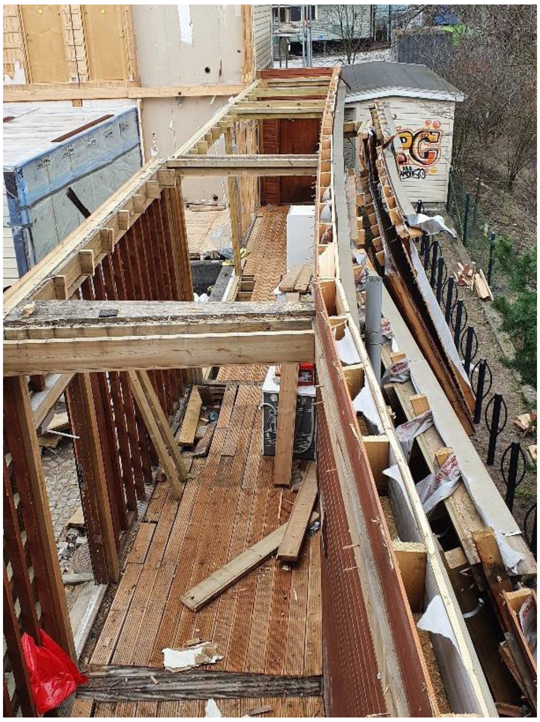

Figure 5 - Ongoing demolition of access balcony/staircase

Figure 6 - Example of excessive use of screw; here in attachment of access balcony to apartment module.

Figure 7 - Moisture damage to the roof of the staircase/ access balcony.

Figure 8 - Moisture damage in staircase ceiling.

Figure 9 - Moisture damage in staircase ceiling.

Apartment modules

Figure 10 - Apartment modules from the outside.

Figure 11 - Apartment modules from the inside.

Figure 12 - Bathroom in apartment. Sinks, pipes, and mixer taps were stolen from all apartments in connection with a burglary.

Figure 13 - Joint between two apartment modules. The arrows illustrate how the modules were screwed together, which made deconstruction more difficult.

Figure 14 - Example of long screw, used when the modules were screwed together.

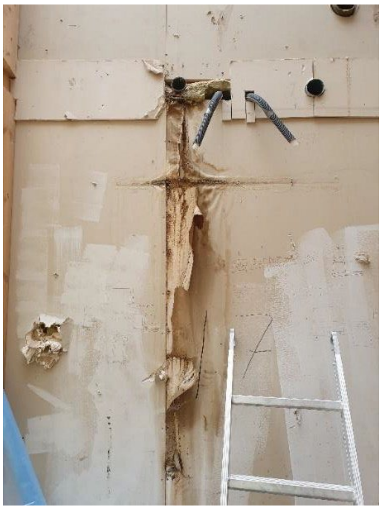

Figure 15 - Moisture damage around pipes that were cut in connection with disassembly.

Figure 16 - After detaching the modules, they are lifted down using a crane.

Figure 17 - The modules are covered with plastics before transport and intermediate storage.

Figure 18 - Wrapped modules waiting for transport.

Figure 19 - Risk of moisture problems when the modules are covered with plastic (already condensation on the inside).

Figure 20 - Condensation inside the plastic.

Basement floor

Figure 21 - Basement floor in concrete with storage rooms and laundry rooms.


Figure 22 - At the time of our investigation, there was no plan for the basement structures after dismantling.


Figure 23 - The parts that did not have a basement floor were built on a crawl space.

Appendix 2 Compilation of results

The compilation below is based on observations and conversations with site manager NN in connection with two site visits during ongoing dismantling (2021-04-12, 2021-04-22).

	1. Comments	*2. Vehicles and tools (in addition to normal)*	*3. What happens to the part?*	*4. Need for reconditioning, storage and controls*	*5. Possible problems with transport or intermediate storage*	*6. Waste*
Roofs and trusses		Lifting crane, chainsaw	They are disassembled. The exterior roof and trusses are discarded. Undamaged roof insulation is saved and used in other projects (e.g. additional insulation of barns) according to NN.		The loose wool insulation was packed in garbage bags. It is a relatively tricky process to package in this way. Furthermore, moisture-related damage can occur if the insulation is wet or damp when packaged. This risk increases with prolonged storage time.	Exterior roofs in the form of roofing felt, tongued and grooved board as well as trusses cannot be recycled. The tongued and grooved board and roofing felt must be discarded after disassembly and the trusses are far too project-specific for them to be reusable.
Balcony accesses		Lifting crane, chainsaw	Demolished. Undamaged material is saved. Even if the material can not be reused indoors it could be used for terraces or other outdoor surfaces according to NN.	The dismantling required that the roof be removed first which meant that some balcony accesses were exposed to a lot of precipitation. The balcony accesses could not be protected from this.	Provided that the material is not to be reused in inhabited environments (or equivalent), there are no particular requriements for e.g. the climate during intermediate storage.	Materials damaged in connection with disassembly.
Stairwells		Chainsaw	Moisture damage was observed in the roofs of the satirwell buildings. The stairwells are demolished but undamaged material was saved and will be reused according to NN. Most of the material however is probably sorted as combustible.			Moisture-damaged material is discarded. Our assessment is that virtually all material will need to be discarded.
Apartment modules	NN believes that the modules have never been intended for housing. He thinks they were designed to be used in a hotel business as they are built with fire class 90 rather than 60. For example, there are six layers of plaster in the walls of each module.	Lifting crane, chainsaw. As the modules were built with six layers of plaster are quite heavy. It is probable that cross laminated timber (clt) modules can be built with a weight of less than 4,5 tonnes with entails crane lifting from a heavy truck (approx 1500 sek/hour) with a range of 14 m. The current modules weigh more than 4,5 tonnes, which means that a larger and more expensive crane truck (approx. 3000 sek/hour) is needed. The logistics on site i.e, the range needed to get close enough to the modules, is also decisive for the type of vehicle needed.	The aparment modules will be converted to "Attefallhus" and resold. The modular framework is reused in its entirety, as well as the interior cladding (except for the ceiling of MDF boards which is discarded). The bay windows are also demolished and replaced with balcony doors. The outer cladding and insulation are replaced. Undamaged insulation is saved and reused in other projects according to NN.	The apartment modules observed during the site visits appeared to be in good condition, with the exception of local moisture impact where water-carrying pipes were had been cut. The modules will be transported away and temporarily stored in an open field. During transport and storage, the modules must be protected against rain and splashes (this is now done by covering the outer surfaces with shrink wrap). The climate in the modules should be checked during storage (this will be done with relative humidity (RH) and temperature sensors). We also suggest that the modules be ventilated with a dehumidifaction system.	The intermediate storage is probably the most critical moment for the modules' future function. The shrink plastic risks turning the modules into greenhouses thus increasing the risk of moisutre-damage.	The insulation is replaced, mainly as a result of it being damaged during disassembly and the ceilings (MDF-boards) are discarded. Furthermore, the bay windows appear to be poorly insulated. NN promises to provide feedback with photos and status of the bay windows during demolition (not yet completed 2021-04-22).
Basement floor	Floors and walls made of concrete. Contains storage and laundry rooms. The basement was filled with water during one of the burglaries after the water-carrying copper pipes were cut.		There is no plan for the basement floor yet (210422)			
Installations/Services	Copper pipes and mixers were stolen in connection with burglaries.					

	7. Easy accessibility (demountable without damage?)	*8. Independence (impact on adjacent parts)*	*9. Reusability / recyclability*	*10. Recyclability*	*11 Simplicity (disassembly / reassembly)*	*12. Personal safety during disassembly*
Roofs and trusses	No, there were too many connections and fastenings to the trusses for them to withstand the disassembly (ie too many screws that were screwed into the underlying hammer band or nails in the raw sheet piling and connections between different building parts from assembly).		See point 7. Undamaged roof insulation is saved and reused in other projects according to NN (see also point 5). Note that reuse of the insulation in new buildings is probably not allowed, but that it could be used as additional insulation in e.g. barns.	Sort roof boarding and trusses as wood, ie can be used for bio based heating	There was no documentation from the assembly nor instructions for disassembly (see also point 7). The loose wool could be sucked out relatively easily.	Risk of trampling through roofs during dismantling / demolition.
Balcony accesses	The apartment modules were screwed to the balcony accesses, which meant that the balconies had to be demolished before the modules could be dismantled and lifted away. In addition, several " extra " and unnecessary screws with hacksaw blades mounted on a jigsaw had to be cut. Furthermore, all modules are held together by the batten that lies behind the surface-mounted panel when the batten is mounted in place.	See answers under point 7.	Limited, but there is the possibility of outdoor uses. The duckboards used for the balcony access can be reused as long as they have not been screwed on with too many screws and the screws can be dismantled without damaging the timber.	Sort as wood, i.e. can be used for bio-based heating	There was no documentation from the assembly nor instructions for disassembly (see also point 7).	
Stairwells	The main part of the disassembly remains (210422). Just like in other parts of the building, an unnecessarily large amount of screws has been used, according to NN. This has made the demolition/dismatiling process more difficult and damaged material that could otherwise be resued.		Low if not non-existent.	Sort as wood, i.e. can be used for bio-based heating	There was no documentation from the assembly nor instructions for disassembly (see also point 7).	
Apartment modules	See the answer to the corresponding point for the balcony accesses. The lack of installation documentation and disassembly instructions has created extra work and caused damage to the modules, such as the insulation. NN questions why the modules were not covered with windscreen, it would have protected the insulation? It was not known how much the modules weighed, or where they could be lifted. It was decided to drill their own holes to attach the wires to. Another detail that emerged during the disassembly is that the modules were screwed together with long screws (see photos); sometimes in places where it has not been known that this has happened and with screws whose heads are damaged during assembly and cannot be unscrewed during disassembly. The solution has been to saw off these screws with a hacksaw connected to a tiger saw.	See answers under point 7.	Relatively good. According to NN, they can be rebuilt and fill many purposes. However, the disassembly has damaged the insulation of the modules. The modular framework is reused in its entirety, as well as the interior cladding (except for the ceiling of MDF boards which is discarded).	Discarded insulation is sorted as combustible material	There was no documentation from the assembly nor instructions for disassembly (see also point 7).	Uncertainties in connection with the modules being lifted away because it was not known how much they weighed or where cables, loops or other lifting devices could be attached. In the first stage, a jack was used to be able to get the underlying loop under the modules. Test lifting was performed to estimate the weight and reduce the risk of modules collapsing / dropping or sling breaking They then drilled their own holes to attach the loop when lifting.
Basement floor				Concrete from the basement must be crushed		
Installations/Services			The bathroom mixers are obviously recycled because they were stolen. Unfortunately, most sinks have been crushed in connection with the mixers being stolen.	Copper obviously has such a high recyclability that people are willing to steal it. First the dismantled copper was stolen, then the thieves came back and sawed off the remaining wires.		

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