Höllentalangerhütte – A case study for end of life reuse and recycling methodologies

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Summary

In consideration of sustainable buildings closing life cycle loops becomes more and more important. Up to now reuse and recycling of existing buildings is not examined widely. This paper discusses the theories, methods and practicalities of buildings´ end of life with a main focus on the instruments planning and managing reuse and recycling of existing buildings and their structures. Aim is a realistic estimation of theoretical scenarios for end of life with a case study.
The methods of building survey, material classification and documentation for reuse, recycling and disposal of existing constructions are presented. Exemplary investigations and calculations are done on an existing cottage in the Alps, which is located in a sensitive natural environment. Here the ecologic most beneficial disposal phase of the old alpine hut is main objective.
The existing fabric of the cottage does no longer fulfil today's technical and functional requirements. Additionally it lacks protection from avalanches, ergonomic work environment, spatial and architectural potential to reuse the existing substance in its actual state. Hence as much material and components should be reused and selected for recycling on-site. Critical questions arise from the quality of the material (dry, chemical treatment, moulder, etc.).
The existing cottage was used as a case study for end of life evaluation because it was devoted to rebuild and thus has to be dismantled and demolished in a planned way. Used methods for that were: research with existing planning material, survey on site to measure exact sizes and construction detailing, as well as the technical status of the material. Material samples were taken to examine the content of the construction.
Overall result was that mostly massive timber from which the cottage was built nearly a hundred years ago is reusable and available in reasonable sizes. For future planning the reuse and recycling of existing buildings has to be integrated quite early in the planning process to be able to use the materials in the best way. With existing building documentation fictive mass calculation could be produced which then can be updated by partial surveys. In future architects contracts have to be enlarged to include also reuse of material in early planning stages.

Keywords: Life cycle; end of life; reuse; recycling; material flow; survey

1. Introduction

In consideration of sustainable buildings closing life cycle loops becomes more and more important. Up to now reuse and recycling of existing buildings is not examined widely. Reuse and recycling is taken rarely into account in building processes which is centred on the production, erection and operation of constructions. On the other hand there is a clear need for a life cycle oriented observation of constructions and this includes the dismantling and end-of-life of the buildings. This paper discusses the methods and practicalities of buildings´ end of life with a main focus on the instruments planning and managing reuse and recycling of existing buildings and their structures. Aim is a realistic estimation of beforehand theoretical scenarios for end of life of existing buildings with a case study.

With rising consumption of wood as renewable energy source recycling of material becomes more important.

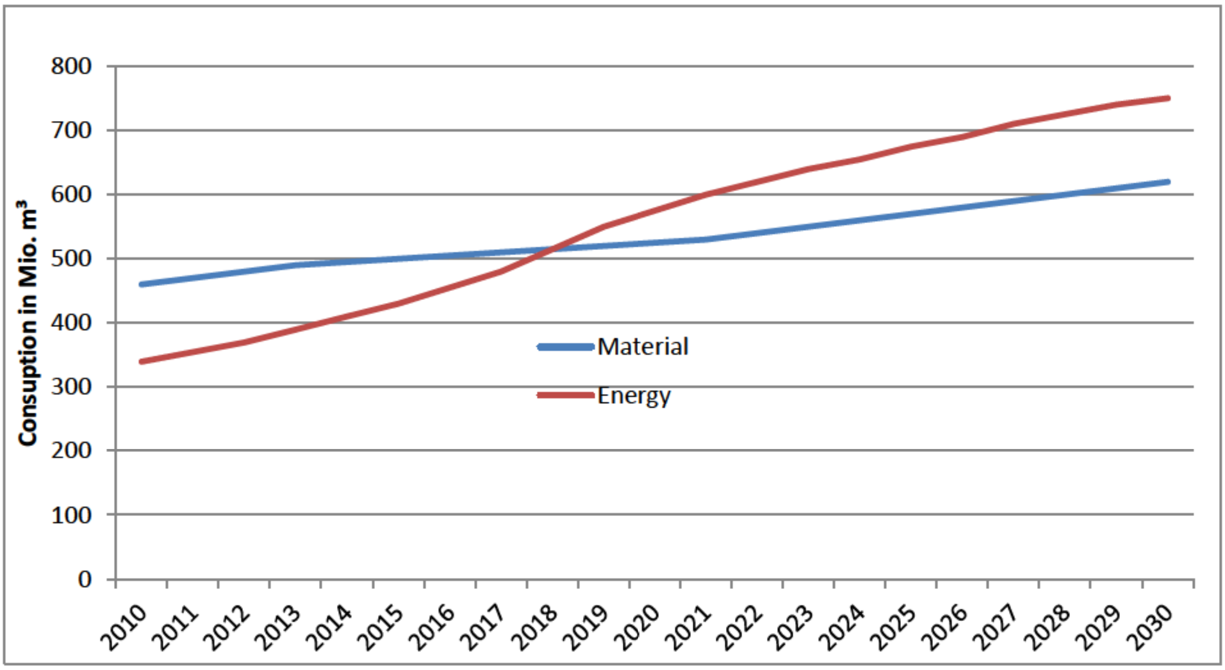


Fig. 1: Consumption of wood for energetic and material use in Europe [1]

As shown in [1] the consumption of wood for material use will rise slowly in the future, whereas the consumption of wood for energetic use will rise dramatically. In Germany wood for energetic use already exceeds the material use in the year 2012, as actual calculations from Mantau in [2] show.

This fact causes a rising share of fresh wood thermally used, and a shortage and in long run rising cost for raw material supply of the timber construction sector. The use of good quality, recovered wood not only as energy source reduces this economic pressure. Old buildings can provide the necessary dimensions and quantities of wood. Other sources rely on much smaller dimensions and are less useful. The scope of the paper is a check of the quantities and qualities of recovered wood. Additionally there are other fractions a building consists of, which are only side products in this study.
There are various studies in EU market, which quantify the usage of wood in market shares [3],[4],[5].Up to now no exact evaluation is confirmed on how much recycled wood exists in our building stock and how high the potential of reuse or recycling is from this material source. There is already a small amount from recovered wood used in the production of particle boards or wood fibre products but it is a small share. Explicit calculations on quantities of recovered wooden material in building sector have not yet been done. Therefore the amount of wood contained in a historic cottage in the Alps, dedicated to demolition, was evaluated. It is an example for construction with a long life cycle with numerous repair intervals, changes, building extensions,

and a conglomerate of different materials.
Material recycling, reuse and energy recovery are theoretically possible as end-of-life scenarios for wooden products. Different end-of-life options are useful for different cases.
Another problem exists for use scenarios of the recovered wood. Recycling and even reuse of materials can only be done when the material does not contain harmful substances. Timber has been treated with poisonous chemicals since the beginning of the 20th century, to reduce the risk of mould or to impregnate it against insects. This fact decreases the possibility of reuse and even recycling of reclaimed wood nowadays. For reuse purposes the contaminated wood has to be identified and its amount has to be quantified. Additionally the type of chemical treatment has to be analysed for bio hazardous substances and human-hazard toxicity of treated timber construction. These quantities have to be sorted out and regarded according to the rules for hazardous wastes, in Germany the recovered wood regulation [6].
Reuse of construction parts is problematic because of a wide spread of unplanned demolition. For optimal reuse the available construction parts have to be identified and classified at least for different end-of-life scenarios. Construction wood and engineered wood products can be dismantled easier than most other parts, because they are used in dedicated layers, they are often used in modular assemblies and they are light-weight. The wooden parts are mostly serialized and the dimensions of certain parts are identical. All these themes make wood suitable for reuse. After the planned dismantling process of removable parts, the rough demolition of monolithic portions can take place. Such fractions may contain smaller amounts of wooden bits and pieces which are reserved for recycling or thermal use.

2. Case study

Aim is a realistic assessment of the material fractions to overcome rough estimations and theoretical scenarios for end of life. Exemplary investigations and calculations are done on an existing cottage in the Alps, which is located in a sensi tive natural environment. The ecologic most beneficial disposal phase of the old alpine hut is main objective.
The existing cottage is used as a case study for end of life evaluation because it is devoted to rebuild and thus has to be dismantled and demolished in a planned way. The owner, the Munich chapter of the German Alpine Club needs detailed information about the building masses, because he has to tear down the building and to treat all demolition waste carefully due to fact that the site is located in a nature reserve. Additionally all material has to be brought to the valley by helicopter flights and therefore masses are a very important parameter for the construction costs.
Here the methods of building survey, classification of components, parts, materials and documentation for reuse, recycling and disposal of existing constructions are presented.
Used methods for that were: research with existing planning material, survey on site to measure and verify exact sizes and to check the jointing and tectonics of the building, as well as the technical status of the material. Material samples were taken to examine the construction for hazardous substances.

2.1 The Höllentalangerhütte

The Höllentangerhütte is located in the northern Alps close to Garmisch-Partenkirchen. It is situated at a height of 1387m above sea level and can only be reached through a small and steep foot path. For logistics and supply items an additional cable car with a maximum payload of 200 kg exists. Water and energy supply are organised self-sufficient for the cottage. Concerning the water supply, it has an own source which is roughly 50 meters higher. The energy for operating and especially the kitchen of the cottage is supplied by a diesel engine which is run by bio diesel provided with the cable car.

Fig. 2: Höllentalanger cottage.

The cottage contains bedrooms for 80 people, the flat for the landlord, sanitary facilities, a kitchen and a restaurant. The most important issue is the huge amount of visitors who climb up the Höllental gorge each summer.

The cottage was built and completed in different stages, as shown in figure 2. In Table 1 the floor areas of the cottage are outlined.

- The oldest part was built in 1893 as a wooden log house (red line).
- A two-storey timber building containing bedrooms was built in 1909 with a post and beam construction (blue line).
- An additional building was erected in 1925 for the kitchen and restaurant with a post and beam construction on a stone masonry cellar (yellow line).
- Sanitation facilities were built in 1963 as an additional stone building with masonry walls from light-weight concrete blocks (grey line)

Table 1: Floor areas of the cottage.

	Numbers	Unit
Gross external volume	1650	m³
Net floor area	511	m²
Use space	446	m²
Built area	331	m²
Envelope area	1381	m²
Roof area	471	m²
Building footprint	331	m²
Exterior walls	477	m²
Basement / cellar	48	m²
Fire wood storage	54	m²

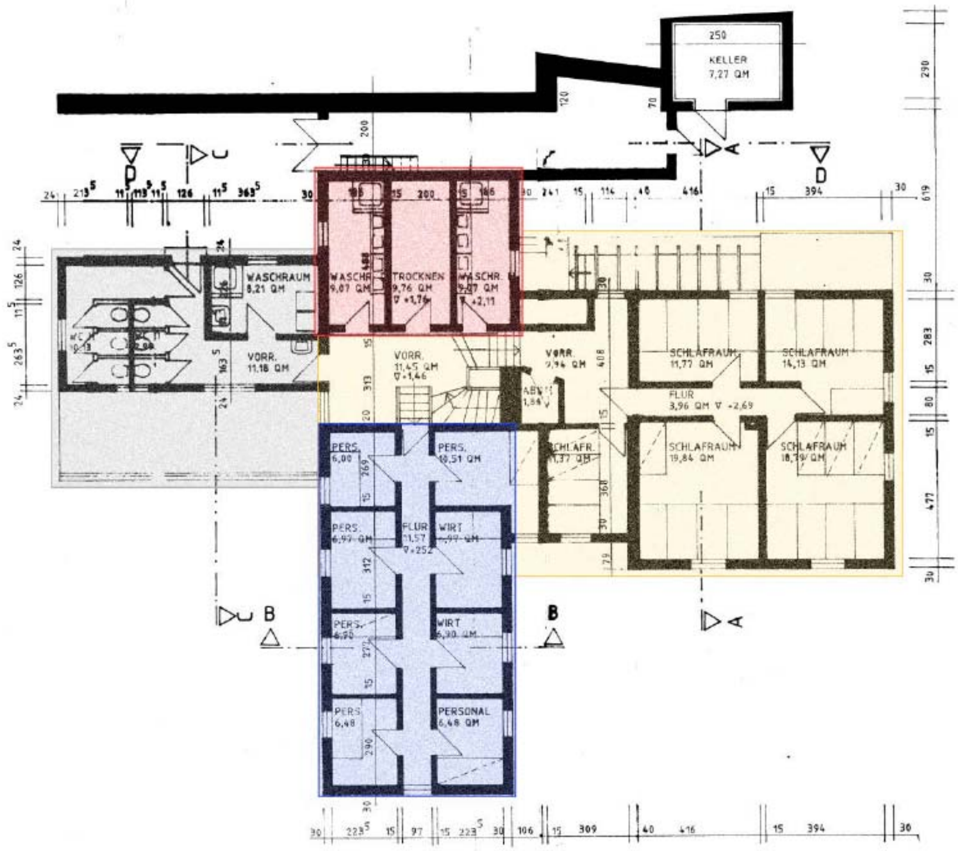


Fig. 3: construction stages of Höllentalangerhütte

The existing fabric of the cottage does no longer fulfil today's technical and functional requirements. Additionally it lacks protection from avalanches, ergonomic work environment, spatial and architectural potential to reuse the existing substance in its actual state. Hence as much material and components should be reused and selected for recycling on-site. Critical questions arise from the quality of the material (moisture content, chemical treatment, moulder, etc.).

2.2 System boundaries

The system boundaries count for the construction of the building and all attached materials. All flexible interior, furniture as well as technical equipment or building systems are suspended from the examinations. Focus of the study is the primary loadbearing construction, the related claddings, surfaces of interior and exterior and the quality of the parts.

2.3 Measures

Basis for the examinations are an overall inventory analysis and documentation of existing construction with classification in qualities and quantities.
The work was divided in two parts:
The first part was of theoretical nature and based on a research in the archives for information about the history of the cottage, the development stages over the lifecycle with repairs, refurbishments and extensions. First calculations are done according to existing drawings to get knowledge about quantities and material usage.
In a second part a survey on site helped to check masses and make drawings of construction details with focus on materials. Damages of construction and possible use of harmful substances were also documented on site. Material samples were taken to analyse the content and in parts

also wood humidity.

3. Examinations

3.1 Research based on existing drawings

Initially, a theoretical review has been conducted according to existing drawings. This approach enables the examination of all parts of the building including hidden parts.
The results include the foundation as well as inaccessible constructions whose dimensions can only be guessed when they are hidden behind claddings or remain inaccessible for other reasons.
The goal of the theoretical evaluation is to get structured lists of absolute values of measures and cubature of buildings and materials.

3.2 On-site inspections and documentation

Through survey on-site the result of the theoretical examinations is verified, as far as the construction has been accessible. In parts with zero information the construction was inspected through openings or by removal of claddings. There are areas where interventions are forbidden, they have been inspected with an endoscope. Small scale drawings and sketches of components and joints are done to improve the documentation. Modifications and systematic deviations to the existing drawings are detected and also documented.
Tables with hierarchy of surface area list are combined with a components list, materials description and the amounts of the materials in volume and mass are the result of on site survey.

1	Bauteil	Material	Ausrichtung/ Lage	Länge [m]	Breite/Höhe [m]	Stärke/Dicke [cm]	Volumen [m³]	Verweis	Bemerkung
2	Außenwand		Haus 1, NO	1,50	2,80	25,00	1,05/0,74	AW zw. Wirtschafts- und Sanitärgebäude	Fenster: 1.1*1.1
3	Innenwand		Haus 1	1,50	2,80	25,00	1,05/0,47	IW zw. Wirtschafts- und Sanitärgebäude	Tür: 1.1*2.1
4	Außenwand	Betonsteine	Haus 1, NW	8,80	2,70	30,00	7,12/6,38	Haus 1 Betonsteinwände, AW Sanitärgebäude	Fenster: 1.5*1.0, 0.5*1.0, 0.5*1.0
5	Außenwand	Betonsteine	Haus 1, NO	4,00	3,00	30,00	3,6/3,3	Haus 1 Betonsteinwände, AW Sanitärgebäude	Fenster: 1.0*1.0
6	Außenwand	Betonsteine	Haus 1, SO	8,80	2,70	50,00	11,88/10,16	Haus 1 Betonsteinwände, AW Sanitärgebäude	Fenster: 0.75*0.6, 1.45*0.75; Tür: 1.0*1.9
7	Innenwand	Betonsteine	Haus 1	4,00	2,70	15,00	1,62	Haus 1 Betonsteinwände, Santärgebäude (Toiletten)	
8	Innenwand	OSB-Platten	Haus 1	4,00	2,00	3,00	0,24	Toilette Türen u. Trennwände	teilweise lackiert
9	Innenwand	Betonsteine	Haus 1	5,90	2,50	15,00	2,21/1,99	Haus 1 Betonsteinwände, Santärgebäude (Waschraum)	Tür: 0.75*2.00
10	Außenwand	Betonsteine	Haus 1, NO	3,30	2,10	27,00	1,87/0,98	Haus 1 Betonsteinwände, Werkstatt	Tür: 1.5*2.0
11	Außenwand	Betonsteine	Haus 1, NW	9,30	2,00	25,00	4,65/4,2	Haus 1 Betonsteinwände, Werkstatt	Fenster: 1.3*0.7, 1.3*0.7
12	Innenwand	Betonsteine	Haus 1	3,00	2,10	25,00	1,575/1,1	Haus 1 Betonsteinwände, Werkstatt	Tür: 1.0*2.0
13	Innenwand	Holzbalken	Haus 1, NO	2,50	3,50	15,00	1,31	Innenwand Urhütte NO	
14	Außenwand	Holzbalken	Haus 1, NO	2,50	3,50	15,00	1,31/1,22	Außenwand Urhütte NO	Fenster: 0.6*1.0

Fig. 4: Section of the component list

The following drawings show exemplary construction drawings of the existing cottage.

Fig. 5: Historic construction drawings

Additional to components list, moisture in the different parts is measured, damages of constructions and materials were traced out and material samples of four different constructions were taken to be analyzed in the laboratory.

3.3 Material testing

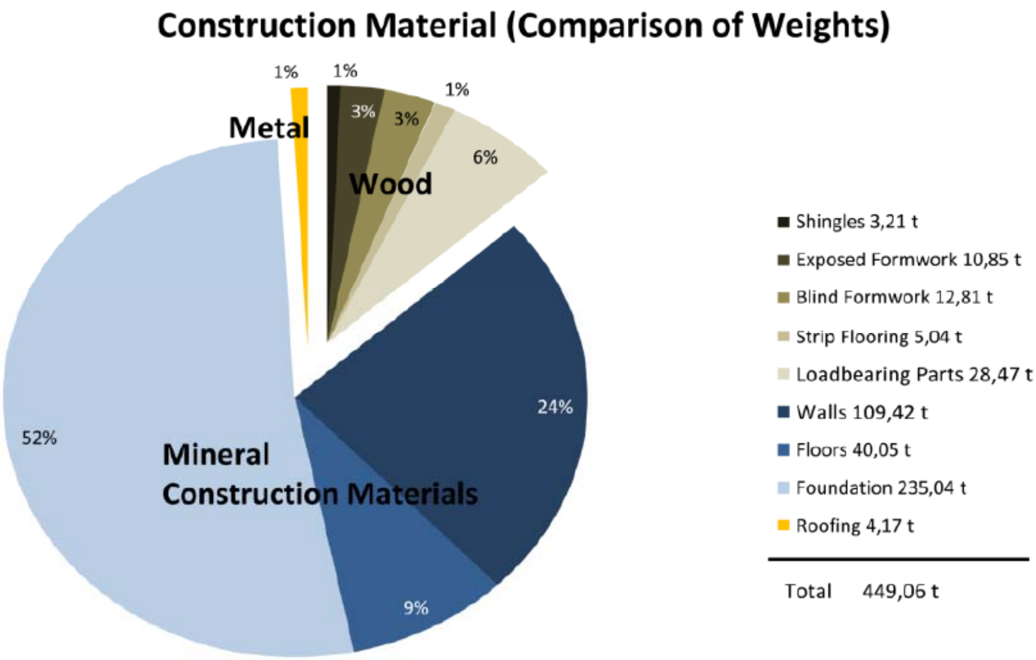
Material probes of the timber constructions were analyzed to test for harmful substances and to identify the kind of substances or formulations. This is done because wooden parts can only be reused if no harmful substances are detected in the material, according the national waste wood regulation.
According to German laws the term used wood (Altholz) means used wood from production and end user, as far as it is covered by the German life-cycle Resource Management Act.
The used wood is divided up in four categories, in order to decide which wooden material is usable for which waste scenario.
a) *Waste wood category A I:*
Waste wood in its natural state or only mechanically worked that during use was at most insignificantly contaminated with substances harmful to wood
b) *Waste wood category A II:*
Bonded, painted, coated, lacquered or otherwise treated waste wood with no halogenated organic compounds in the coating and no wood preservatives,
c) *Waste wood category A III:*
Waste wood with halogenated organic compounds in the coating with no wood preservatives,
d) *Waste wood category A IV:*
Waste wood treated with wood preservatives, such as railway sleepers, telephone masts, hop poles, vine poles as well as other waste wood which, due to its contamination, cannot be assigned to waste wood categories A I, A II or A III, with the exception of waste wood containing PCBs [7].

The material samples were analyzed made by the chemical laboratory of the wood science department (Holzforschung München), which is part of the Technische Universität.

Via pyrolysis and use of spectroscopy harmful substances like polycyclic aromatic hydrocarbon (PAK) and Pentachlorphenol (PCP) in coatings were detected. Thereby a reusing and recycling is not possible without a careful separation of the materials, which are non-toxic and toxic. Result of the analysis showed, that main part of the timber construction could be reused as further components. Only parts of the outside facade and materials included in the building erected in the nineteen sixty years of the last century contain critical substances. Most material from the original cottage is free of harmful substances and is also in good and dry condition.

4. Results

The cottage Höllentalangerhütte is an example for buildings mainly built from wooden material. Calculations of the material included in the building show the quantity of various materials. Analysis of material fractions in mass and volume show a high percentage of massive material in the cottage. The share of wooden material reaches a share of 38% in volume with very simple wooden constructions and a mass of 14 percent. Main mass is 63% concrete / stone. Complete analysis of construction is shown in figure 6.



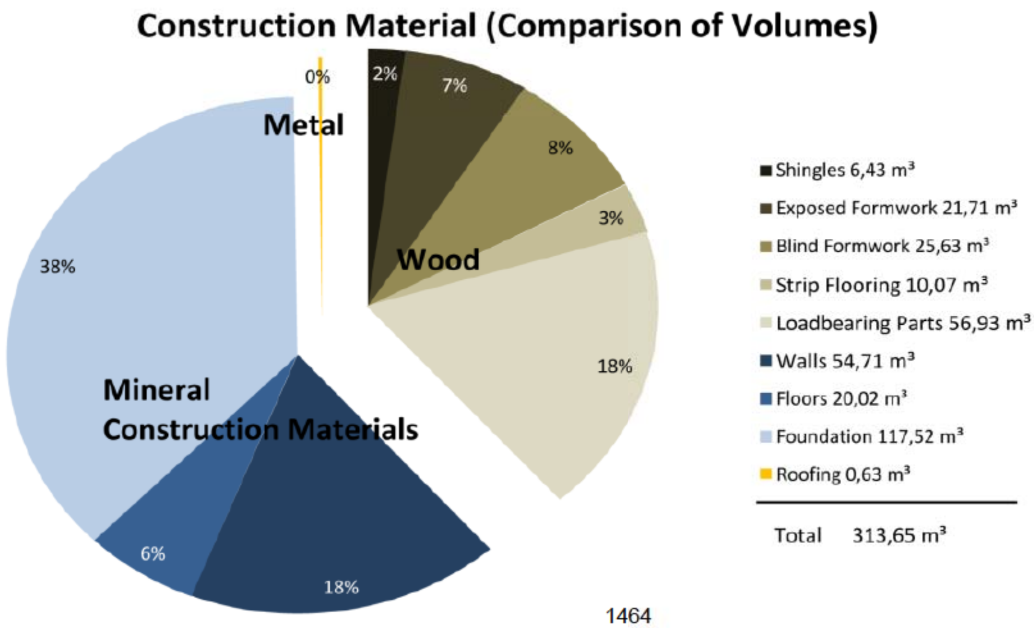


Fig. 6: Construction material – different fractions. Comparison of volume and mass

Figure 7 shows the share of harmful substances in the wooden material divided up in different building parts. The amount of contaminated wood is minor and the highest share is in the façade cladding and in a few interior claddings.

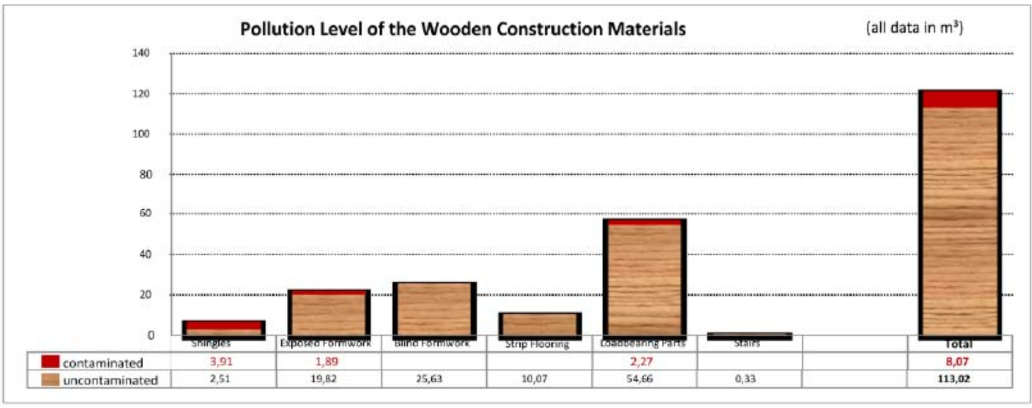


Fig. 7: Share of harmful substances in construction (in red)

Overall result of the analysis was, that mostly massive timber from which the cottage was built nearly a hundred years ago is reusable and available in reasonable sizes. Mainly the oldest material is of good quality. Reusing this material as beams, posts and floor is limited by size and quantities and in this case by the possibility to bring the material to other sites. Reusing the material for the new design of the Höllentalangerhütte was not deeply analyzed as the planning of the cottage is already nearly finished.
For future planning the reuse and recycling of existing buildings has to be integrated quite early in the planning process to be able to use the materials in the best way. Small scale drawings also show how components are built in and how jointing is done. This information is useful for dismantling.
With existing building documentation fictive mass calculation could be produced which then can be updated by partial surveys. In future architects contracts have to be enlarged to include also reuse of material in early planning stages.

5. Conclusion

The EU Directives on waste [8] as well as the national laws in many European countries aim at higher rate of reuse and recycling, which leads to reduced amounts of wastes to be landfilled. The basic principle in the European waste management directive is that materials should be primarily recovered for secondary use, and only as a secondary option, they can be utilized as energy.

For recycling of existing buildings exact calculation of actual mass and volume as well as building condition is necessary. Therefore drawings (as built) help to calculate overall quantites. They need to be checked on-site with survey. Survey on-site focuses on quality of materials. Only on-site qualities of wood and usage of harmful substances can be identified. These analyses are important to choose material for recycling without introducing critical substances in recycling process. For reuse the classification system has to be improved to the same level as the reclaimed wood classes regarding the contamination. This could be difficult, because the way of reuse is unclear and needs further development.

The Höllentalangerhütte, as a case study, reveals that more than 120 year old wooden construction still is in very good condition and could be reused in large parts. In parts where no maintenance and repairs were applied, like running water around broken rain gutter, construction is mouldered and cannot be reused. Problems for recycling arise in the usage of harmful substances in paints. Here exact material testing is necessary.

In general conclusion can be drawn that this Alpine cottage is an example for a simple building with a minimized construction which allows a high level of reuse. A reduced conglomerate of fractions makes separation easier and the additional economic effort could be limited.

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