让我们共同打造气候中和的未来
Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Zero Emissions Building Design with Low Carbon Building Materials

Experiences from Switzerland

ENGLISH VERSION

JULY 2024

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC

中华人民共和国
住房和城乡建设部

IBEE 环能科技

intep

skat

让我们共同打造气候中和的未来
Building a climate-neutral future together

This report has been produced within the framework Sino-Swiss Zero Emissions Building Project; an international collaboration funded by the Swiss Agency for Development and Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development.

Authors:

Gianrico Settembrini, Lucerne University of Applied Sciences and Arts

Marvin King, Lucerne University of Applied Sciences and Arts

Sina Buettner, Lucerne University of Applied Sciences and Arts

Contributions and review:

Dr. Feng Lu-Pagenkopf, Intep Integrated Planning

Roland Stulz, Intep Integrated Planning

Jilong Zhu, Intep Integrated Planning

Yin Li, Architectural Design & Research Institute of Zhejiang University (UAD)

Design and layout:

Intep-Skat

Cite as:

Settembrini, G., King, M., Buettner, S. (2024). Zero Emissions Building Design with Low Carbon Materials - Experiences from Switzerland. Sino-Swiss Zero Emissions Building Project Technical Report. Intep-Skat: Zurich

The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

Implementation partners:

Intep Integrated Planning

Skat Consulting

China Academy of Building Research

WeChat:
SinoSwissZEB

Web:
zeb-china.org

Contents

1. ZEB DESIGN WITH LOW CARBON BUILDING MATERIAL

In research and teaching, the holistic consideration of the life cycle of buildings and building components is a central component, with circular construction as an essential aspect that is always topical.

1.1. Introduction

The all-changing perspective: "Earthrise" shows our planet in its full beauty, the consciousness of a closed system first had to emerge at the time. ("The Overview Effect").

On 24 December 1968,an astronaut on the Apollo 8 mission to the moon, "Bill Anders" took a photograph that was essential for our society. The first photo of the Earth: "Earthrise" (as it was called) shows our planet in its full beauty; the consciousness of a closed system has emerged at that time. As we know today, our resources are limited and exhaustible.

In Switzerland, buildings are responsible for over a quarter of CO2 emissions (and about 40% of energy consumption). Nevertheless, industry operates under the guise of "sustainability" with a massive demand for resources and energy. Excessive consumerism and a society that has gone off tracks. If our current society is to persist, we must prevent valuable material from becoming waste and the environment from being destroyed. The question is: How do we want to live?

Figure 1: View of the earth from the moon. ©NASA

The mindset in the construction sector also needs to change. In the picture (Figure 3), the artist Erwin Wurm shows us an essential step. Among other things, he is concerned with (immoderate) consumer behavior and a society that has gone off the tracks. The mindset in the building sector needs to shift towards "counting calories or CO2" - but the range of possibilities is much broader.

Figure 4 is an analogy of the phrase "How much does your building weigh?" by the early 21st century architect and sustainability pioneer Buckminster Fuller.

1.2. Initial Position

How much waste does Switzerland produce each year?

In Switzerland today, about 24 million tons of waste are produced per year (equivalent to 2860 kg/year p.p.). This can be divided into four categories (construction waste, municipal waste, hazardous waste and sewage sludge/ FOEN 2008). At almost two-thirds, construction and demolition wastes account for by far the largest share. It consists largely of mineral materials, such as concrete or bricks. If these materials are properly separated, they can be reused after processing. It should not be forgotten that 80% of Swiss construction waste can already be recycled (all downcycling).

The deconstruction of a single-family house alone is estimated to generate about 400 tons of construction waste. This corresponds to the weight of no less than 36 buses.

1.3. Embodied Carbon Emissions in Swiss Buildings

Firstly, carbon emissions in general will be examined. Switzerland failed meeting the 2020 CO2 emission target. But if we see the different sectors in the graphic the building sector reduced the CO2 emissions since 1990 significantly.

However, the building stock is currently still responsible for 24 percent of greenhouse gas emissions. There is still a long way to go to net zero. For several years now, the transport sector has accounted for the largest share of emissions. Although there has been slightly downward trend over the past

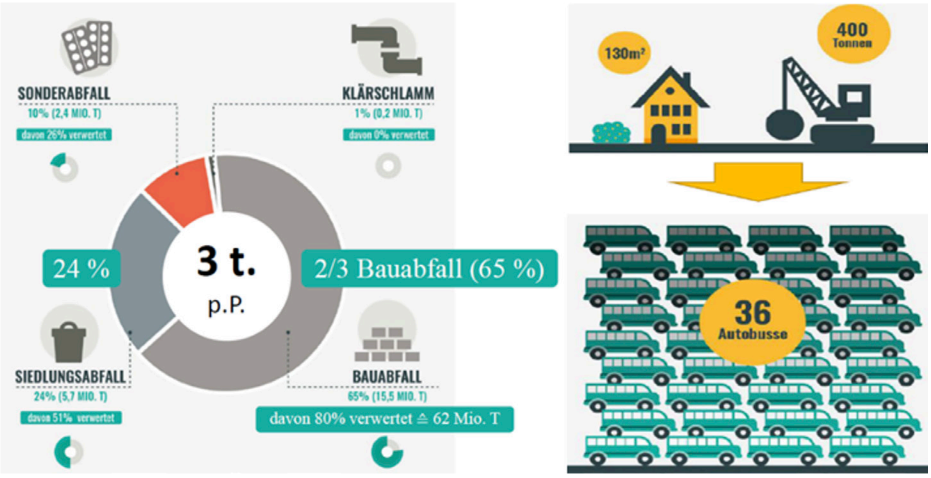


Figure 2: Waste generated in Switzerland: Breakdown of Waste and Comparison, source: HSLU

10 years, emissions remain only slightly below the level recorded in 1990. Due to the measures to contain the coronavirus pandemic, emissions from the transport sector in particular have decreased significantly from 2019 to 2020.

Within the framework of the Paris Climate Agreement, Switzerland has committed to halving greenhouse gas emissions by 2030, compared to 1990 levels (from 53.7 to 26.85 million tons of CO2 equivalent). From 2050 onwards, Switzerland aims to achieve neutral in terms of net greenhouse gas emissions.

The 19% of "other emissions" includes the emissions from agriculture, waste and synthetic gases.

We see this trend in the graphic above. The circles symbolize the constant reduction of CO2 emissions over time. Additionally, the graphic illustrates the relation between the embodied carbon emissions (in green) and the operating carbon emissions (in grey). The green part becomes larger over time, the embodied carbon importance grows constantly.

Figure 3: How much does your Building weigh? Counting CO2 instead of calories (©Skulpturenpark Waldfrieden/D, Erwin Wurm FatHouse)

1.4. The biggest levers for sustainable construction

The linear principle of "produce-consume-dispose" of our economic model must be replaced by closed, lean material cycles. Circular building is multifaceted and concerns not only materials but also, for example, energy and water management. It goes much deeper than simply extending the life of buildings through maintenance or conserving resources through the reuse of building components. The "greenest building" is always the one that has never been built - but it is important to show a constructive way by rethinking ingrained paradigms (note on "biggest levers for sustainable building").

The most diverse levels of scale and a condensed overall picture are required: Accordingly, reference is now made to further impulses on various hierarchies:

Scalelevels

How do we plan sustainable cities?

- Reduce land consumption
- Reuse structures
- Plan cool urban spaces

How do we construct sustainable buildings?

- Create biodiverse living spaces
- Promote sufficiency
- Avoid demolition

How do we construct sustainable details?

- Repair instead of replace
- Use little material
- Use resource-saving building materials

1.5. Overarching Holistic Approach

Developing overarching holistic approaches to solutions means not stagnating but moving forward (it' s about setting IMPULSE). In interdisciplinary projects at the HSLU, we analyze the challenges and opportunities of holistic sustainable building from a constructional, ecological and economic point of view and discuss possible solutions to promote the renovation rate together with the construction and real estate industry.

Solution variants for the implementation of a new CO2 law will be sought with federal offices (SFOE/FOH/FOEN) and the scale effect as a driver for increasing the renovation rate and a high CO2 efficiency will be developed within the framework of cluster projects. In addition, the effects and interactions of complex overall systems of buildings are considered and strategies for maintaining the value of real estate are developed with institutional investors. Recommendations for action provide practical instructions for building owners and planners in times of climate change. The transformation to new business models and circular value creation are also being developed.

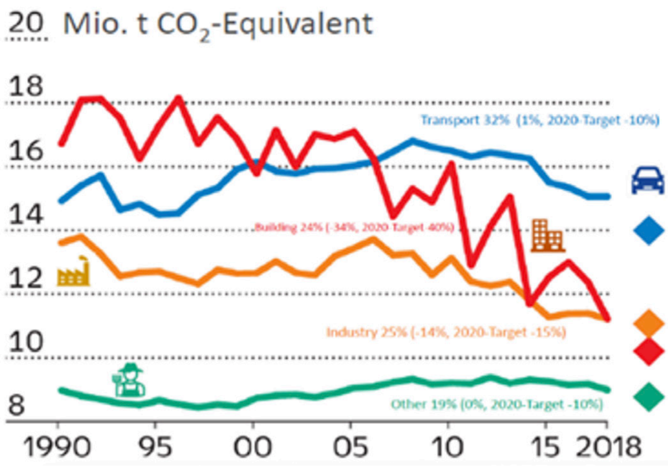


Figure 4: Greenhouse Gas Emissions by 2020: Total 43.4 Mio. t CO2-Equivalent (©BAFU, Treibhausgasinventar der Schweiz, Stand 2020)

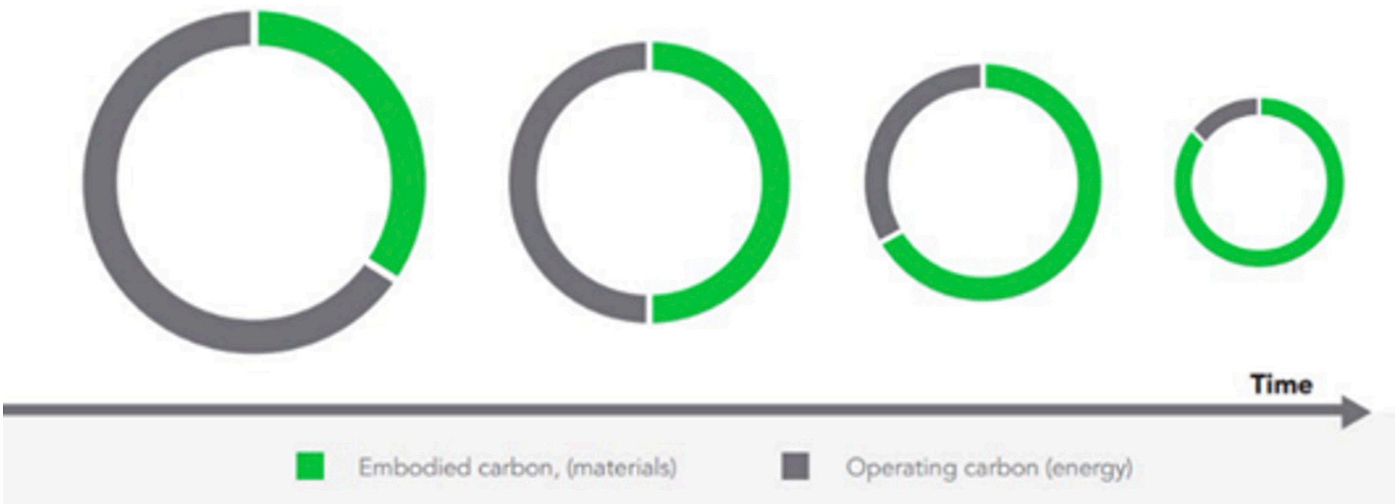


Figure 5: Development and trend of greenhouse gas emissions in the life cycle of buildings, broken down by operation and construction (©The Embodied Carbon Review, One Click LCA Ltd, 2018)

1.6. A sustainable building is not possible without a Life Cycle Assessment

Only the calculation of a life cycle assessment ensures that projects or measures in the circular economy really contribute to a reduction in environmental impact. A life cycle assessment includes all relevant environmental impacts over the entire life cycle of products.

In this way, the potential CO2 emissions and grey energy calculations can serve as a decision-making basis for building owners in early planning phases, as is currently the case here with timber hybrid high-rises in Suurstoffi/Rotkreuz.

Figure 7 compares the results of the 4 buildings with timber construction on the left and with conventional massive construction on the right. The difference between the buildings are much greater than the 5% indicated. What is the reason for that?

One factor contributing to the difference in emissions between the construction method is the size and compactness of the building. However, the main aspect is the windows(green part of the columns in the graphic). In the left square, timber elements with simple windows are used, while in the right square, a close cavity façade with a two-layer glass façade is implemented.

Figure 6: Four buildings in timber-hybrid construction on the Suurstoffi site, Risch-Rotkreuz/ZG (©HSLU, Comparison of construction methods: Timber hybrid and solid construction based on)

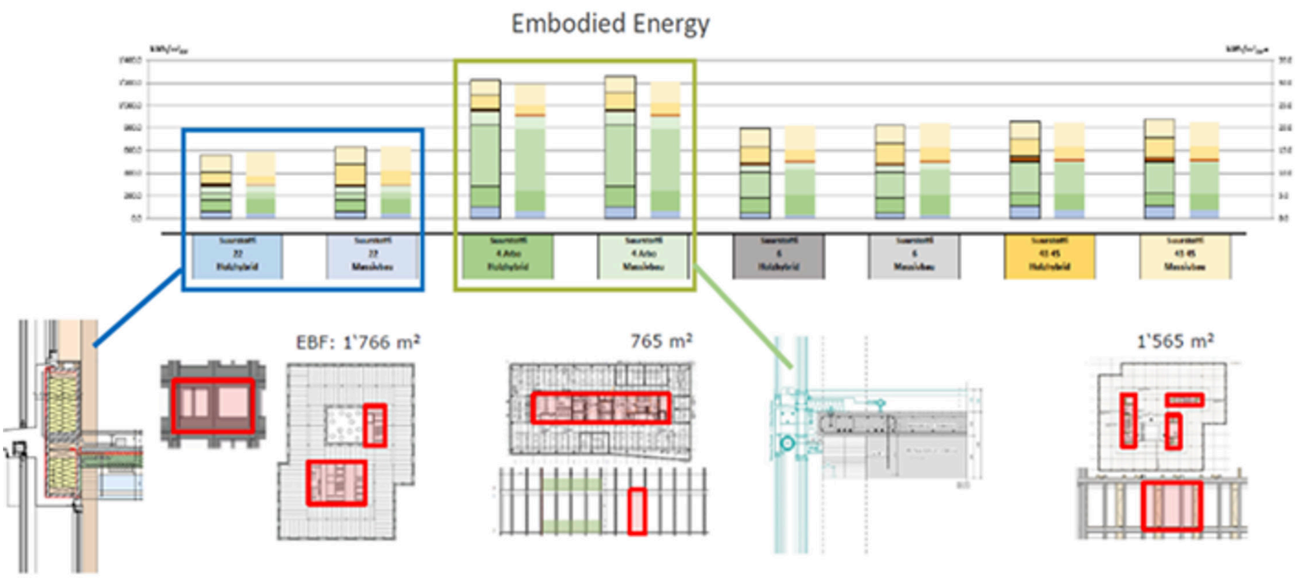


Figure 7: Embodied Energy of the Buildings (©HSLU, Comparison of construction methods: Timber hybrid and solid construction based on four buildings, 2022)

1.7. The Swiss Calculation Tool for Embodied CO2

The tools currently do not include a circular concept to extend the lifespan of building components.

Until now, houses have been constructed, used and then demolished again, resulting in various types of waste. In future, this linear concept could be replaced by a circular concept in order to avoid such waste.

Now we will take a closer look at the calculation. In the picture is the basic principle of a life cycle assessment. We have to look at all materials in a building and multiplicate their weight with their environmental factor. The environmental factor is calculated in “KBOB 2022” (CBPP) per building material.

1.8. Implementation in Practice

Further IMPULSEs at the level of buildings and components are important to find circular solutions within the construction industry. The holistic life cycle consideration of individual components plays an essential role in the development of an innovative façade system,.

In an interdisciplinary team, a completely mineral façade system (pure clay product) was developed. Components with a potentially shorter service life were avoided. The outcome is a diffusion-open and ecologically sound alternative to the compact façade (such as EPS/polystyrene from petroleum-based insulation materials) without going into all the advantages such as the healthy living climate and storage mass.

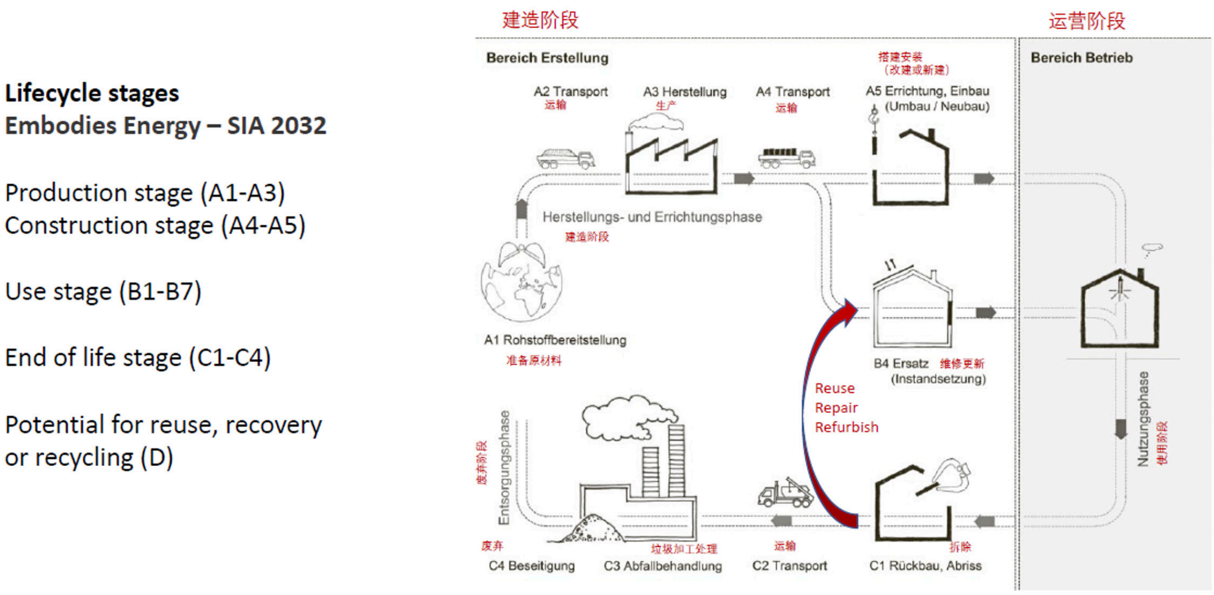


Figure 8: Lifecyclestages Embodies Energy (©SIA 2032 - Graue Energie - Ökobilanzierung für die Erstellung von Gebäuden, 2020)

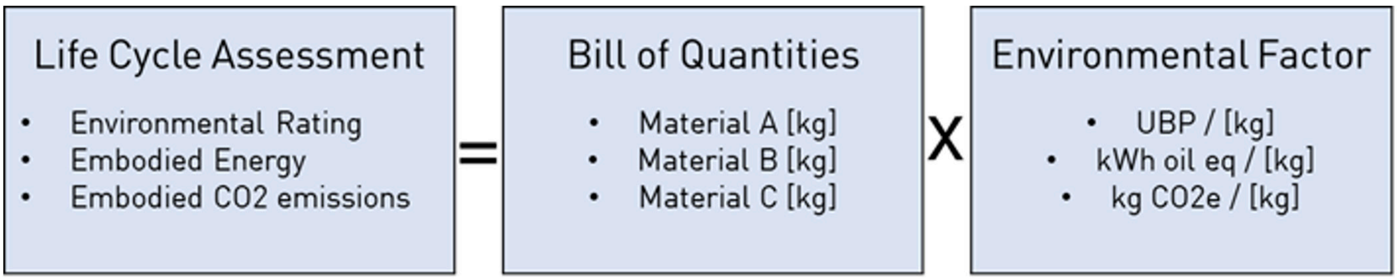


Figure 9: Calculating the Life Cycle Assessment, source: HSLU

We are currently in the process of further developing this open, deliberately non-patented system for renovations, which is ideal for combining with other sustainable materials such as wood and clay.

Brick is one of the oldest building materials. The basic element of brick is clay. In its manufacturing process, clay is prepared, shaped and then fired. Brick is not made with cement but with lime mortar, allowing bricks to be disassembled and reused. Already today, a certain amount of recycled clay roof tiles is used in the production process.

A current project with the city of Zurich focuses on alternative ventilation materials and low-tech solutions, demonstrating possibilities for reducing grey energy compared to current practice. This endeavor is important because building technology accounts for 25% (PEnr) or 20% (GHG) of the expenditure within the "construction" sector. The ventilation distribution (with system separation and accessible pipe routing as shown here) is responsible for approx. 50-65% of the grey energy, greenhouse gas emissions and total environmental impact of ventilation systems. Here, too, sensible alternatives are needed.

1.9. Conclusion

Back to the question posed at the beginning: "How do we want to live?"

We can come back to this basic formula for a life cycle assessment:

- Quantity
- Environmental factor
- Reference area (that is important for the comparison with the operation)
- Lifespan

An important component of the life cycle assessment is the life span of the components.

Figure 10: Completely mineral Facade System; right: Building technology / system, source: HSLU

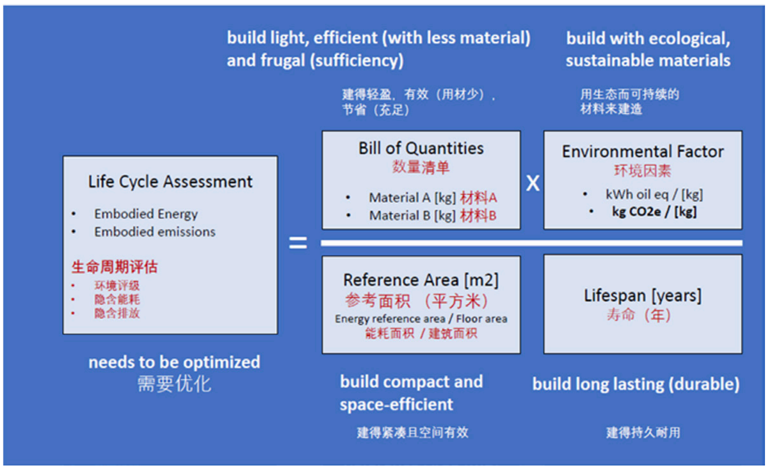


Figure 11: Calculating the Life Cycle Assessment: Basic Formula for Planners, Source: HSLU

2. A SHORT INTRODUCTION TO CIRCULAR CONSTRUCTION

2.1. Linear, Recycling and Circular Economy

Currently, the predominant economic model is linear: raw materials are purchased, processed, used for a certain time and then disposed of. This approach leads to increasing amounts of waste, but also the depletion of resources (picture on the left). The Circular Economy (CE) aims to counteract this process.

2.2. 10 R’ s of Circular Economy

Instead of throwing away materials and components, the goal is to keep them in the life cycle for as long as possible. There are various approaches to this (see the 10 R’ s above), which have different levels of impact. The ones with the highest impact are “refuse”, “reduce” and “redesign”, which should be considered in the early planning phase. Other approaches should also be considered, such as:

Often people are confused with the difference between “reuse” and “recycling”. The two terms are therefore briefly explained below.:

- Reuse: The component is reused as it is, e.g. a window is removed and reinstalled in the new building (no loss of raw materials).
- Recycling: The materials are reprocessed into new products, e.g. recycled concrete - here you always have a proportion of primary raw material and only a certain proportion of secondary raw material (with recycling, 100% of the material never gets back into the cycle, there is always a loss, plus energy for the manufacture of new products, etc.).

That’ s why “reuse” has a higher impact than “recycling” and should be consider first.

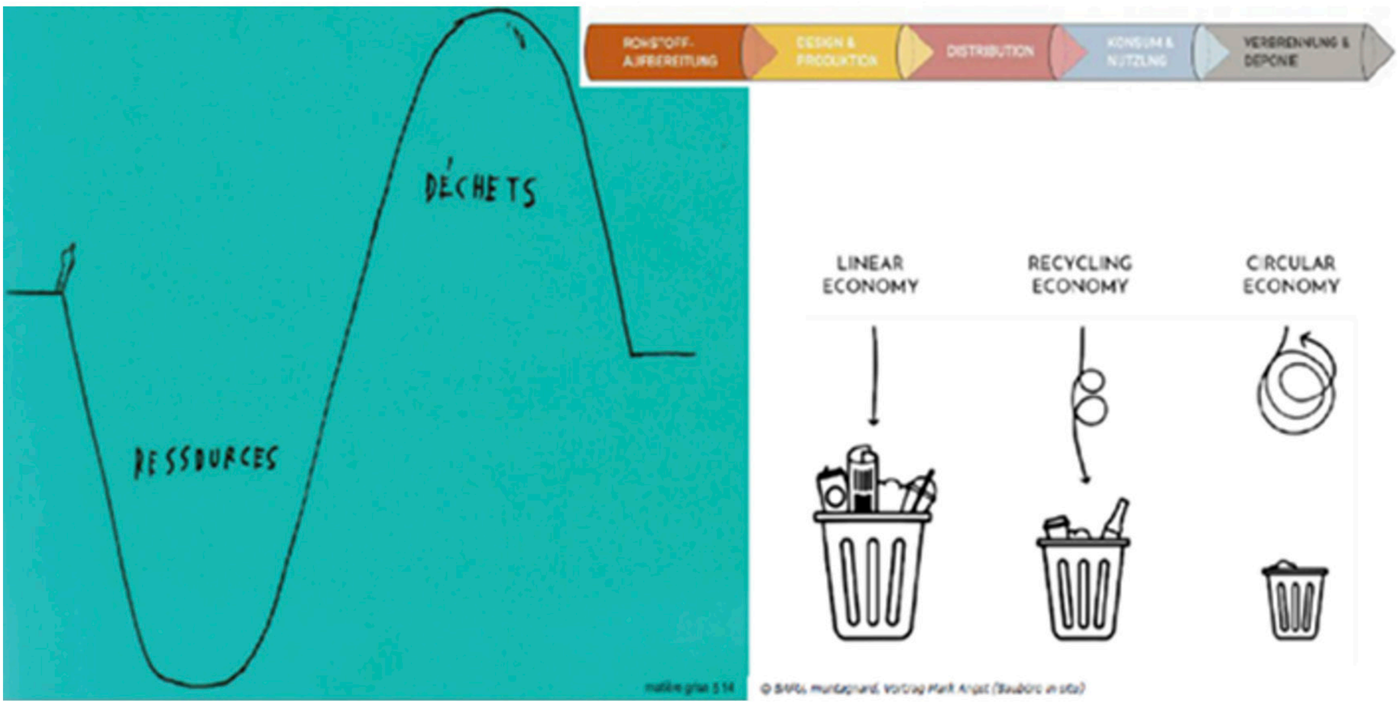


Figure 12: Compilation of Linear, Recycling and Circular Economy, Source: HSLU

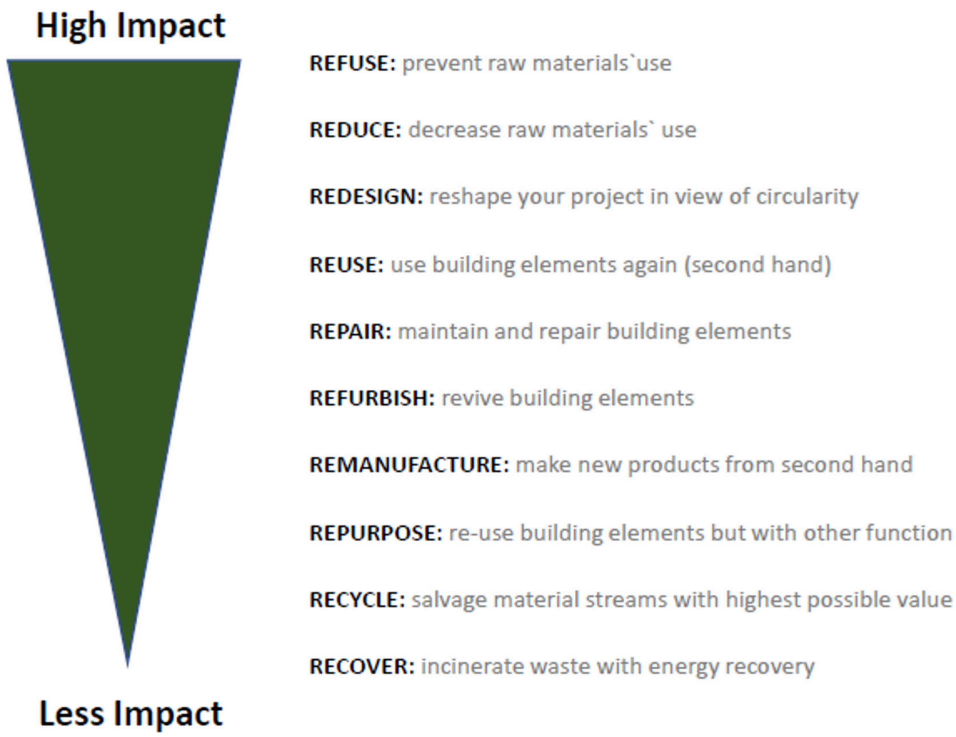


Figure 13: The 10 R’ s of Circular Economy, Source HSLU

2.3. Case Studies of Buildings - Refuse, Reduce

Figure 14 shows an example of Refuse and Reduce. This is a building from Baumschlager Eberle which is located in Lustenau, Austria.

What characterizes this building?

This compact office building operates without heating, cooling, or active ventilation systems. Every second ventilation sash is running automated. In summer, the building is naturally cooled at night.

In winter, the internal gains from employees and appliances are enough to heat the building. In this example, the building technology which typically accounts for20-30% of the embodied CO2 in buildings has been “reduced” to a minimum by adding thermal mass.

The picture on the left shows the wall construction and the two pictures on the right provide a view of the interior.

Figure 14: Burohaus 2226, Lustenau, Austria, baumschlager eberle, 2013

2.4. Case Studies of Buildings – Reuse

The picture below shows an example of “reuse”. The building office in situ is known in Switzerland for incorporating circular solutions into its buildings. In the building in Lysbüchelareal in Basel various structural elements have been reused.

The façade of the inner courtyard was constructed by using windows from surplus or reserve stocks from around ten Swiss window manufacturers. If they had not been used here, they would have been disposed. The thermal insulation mats and the wood for the facade elements are also partly from existing stock.

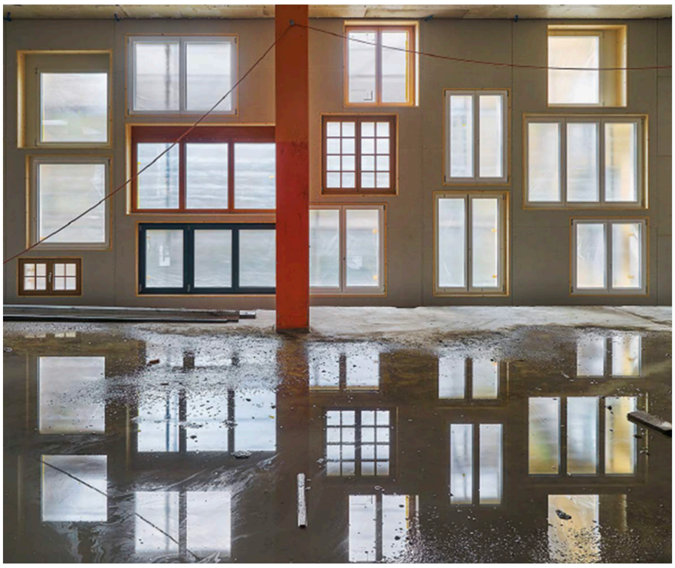


Figure 15: Lysbüchelareal, Basel, Switzerland, Baubüro in situ, 2020

Figure 16: Lysbüchelareal, Basel, Switzerland, Baubüro in situ, 2020

2.5. Case Studies of Buildings – International Projects

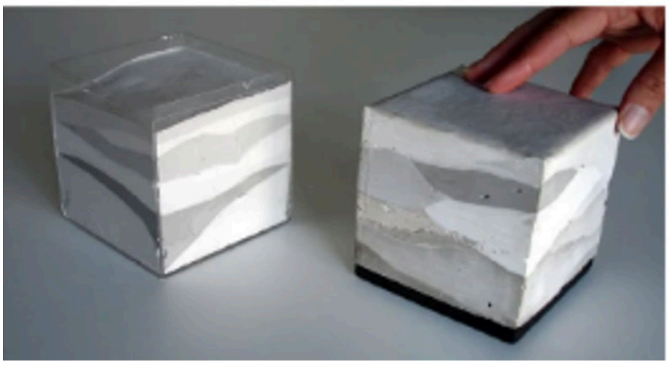
The following example comes from Chicago, USA: the SOS Kinderdorf at the Lavezzorio Center. It's a good example to show creativity as they worked with materials which were available for them. Concrete donations were collected for the building. The architects worked with the material they received through donations. The result is a unique façade design, which defines the building of the SOS Children's Village.

Below is an example from the Netherlands: This is a temporary building. The planned building will not be erected before 2030, which is why the open space was used temporarily. The temporary use is a 2-storey pavilion that can be completely dismantled and rebuilt elsewhere later. The uses include several conference rooms, a restaurant and a vertical greenhouse in which vegetables and herbs are grown for the kitchen. The building reflects many different approaches to circular construction, which are briefly presented below.

Here is a look inside the building: Old doors were used to cover the counter and the ceiling while old paving stones were used for the floor, which gives a special atmosphere to the room. (example for reuse of materials)

Here is a look inside the building: Old doors were used to cover the counter and the ceiling while old paving stones were used for the floor, which gives a special atmosphere to the room. (example for reuse of materials)

On the present scheme is an overview of the approaches taken in the building (Reduce, Refuse, Redesign, Reuse) – description in the picture.



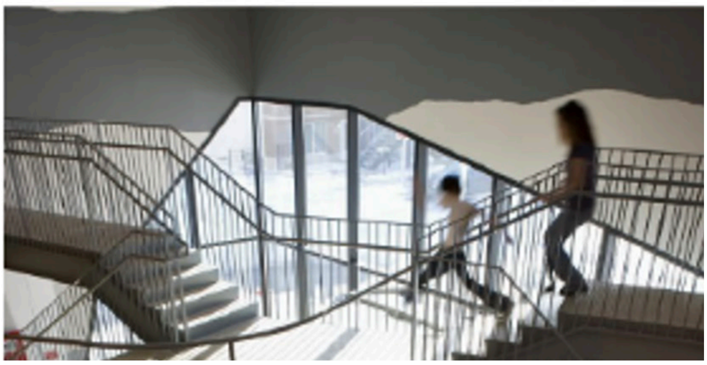


Figure 17: Lavezzorio Center, SOS Kinderdorf, Chigaco, USA, 2008, Source: Lavezzorio Center

Figure 18: The Green House, Utrecht, Netherlands, 2018, Source: the green house Urrecht

Figure 19: The Green House, Utrecht, Netherlands, 2018, Source: the green house Utrecht

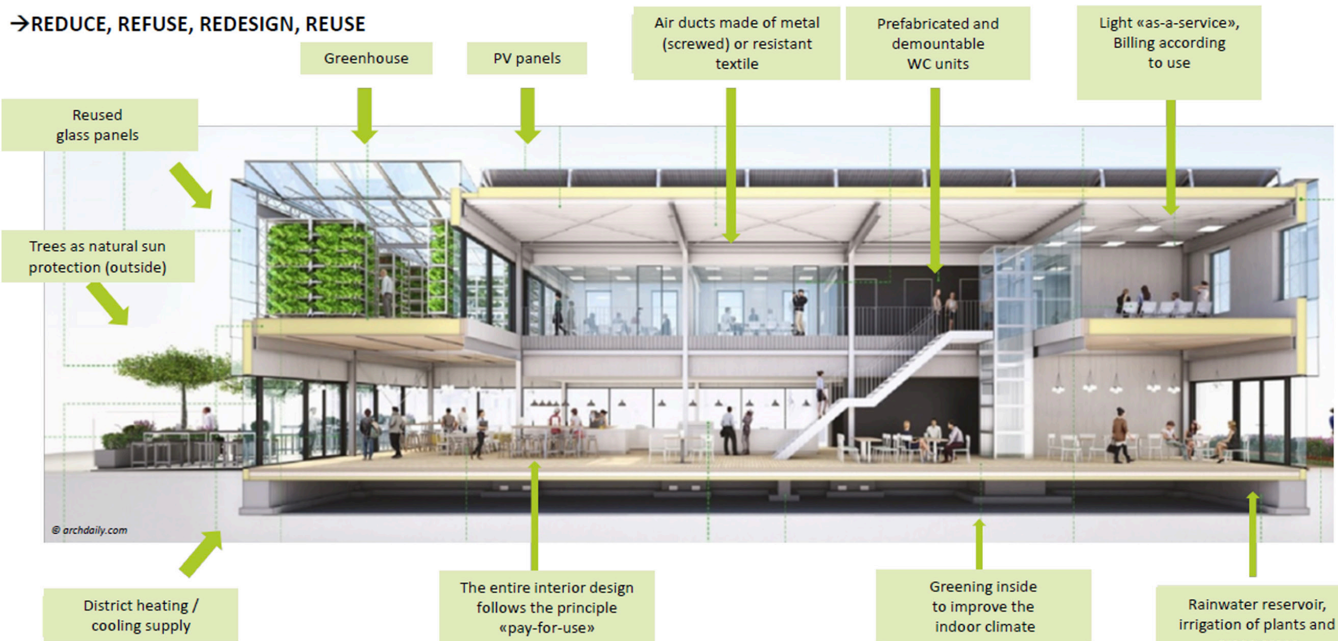


Figure 20: Reduce, Refuse, Redesign, Reuse, Source: HSLU

2.6. Potential of Reuse – How much CO2 can be Reduced?

Below is another lighthouse project in Switzerland which is another example from building office in situ. The architects' aim was to use only reused building components and to supplement these with natural materials such as straw, clay and wood where necessary. For example, they used.

- Reuse steel beams and stairs
- Façade with insulated aluminum windows and red facade slabs from Winterthur and Zurich, complemented by natural building materials such as wood, straw and clay

As a result, a saving of 494 tonnes of CO2 was achieved through reuse.

Here are pictures of the building. The picture on the left shows the assembly of the stairs. The top centre picture demonstrates a wall construction with re-used windows and façade cladding and a new wall construction made of straw and wood. The lower centre picture displays a view into the interior. The picture on the right shows the addition of a storey to the existing building, which has been retained.

Figure 21: Kopfbau Halle 118, Winterthur, Switzerland, 2021 (©baubüro in situ, 2021)

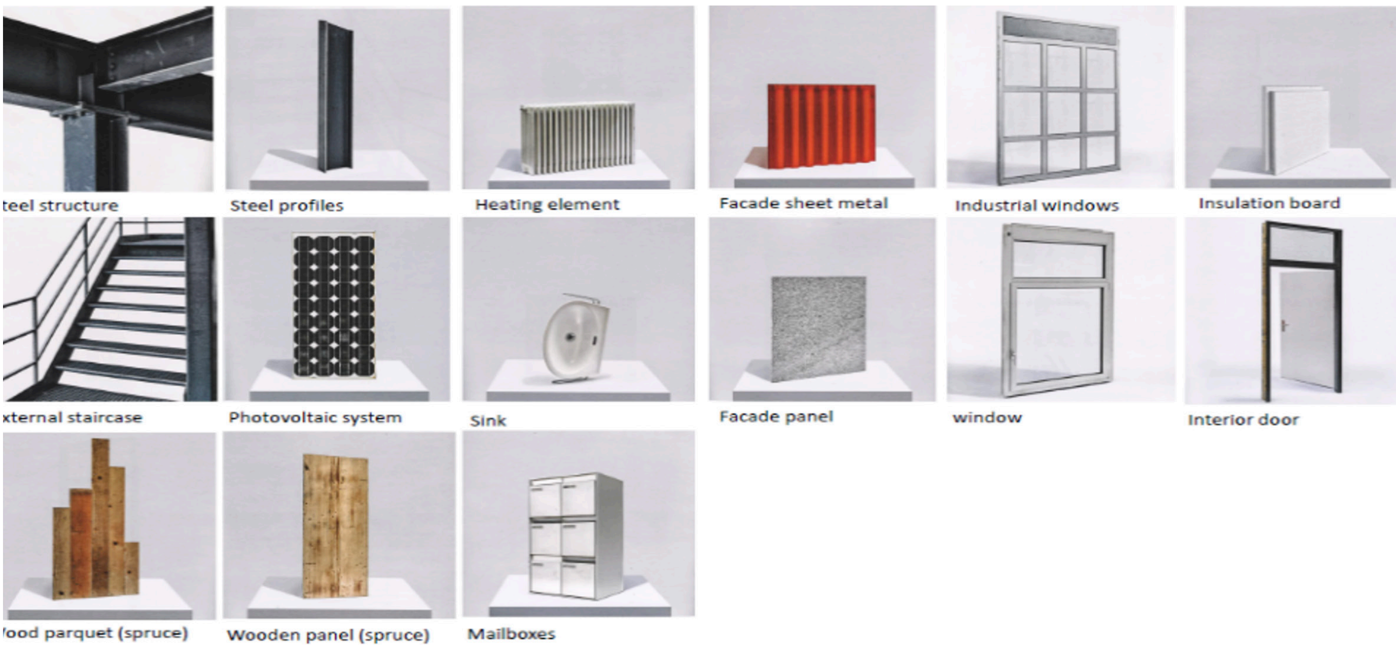


Figure 22: CO2-Emissions from the Reuse of Components (©Bauteile wiederverwenden, 2021)

2.7. Halle K118 – Reused Elements

Figure 23 shows where the reused components came from. In order to keep the transport routes as short as possible, the search was conducted at companies, second-hand platforms and construction sites in central Switzerland.

Below is an overview of the reused components.

On this illustration you can see an overview of how the CO2 emissions of a reused component are made up and which processes have the biggest influence. Three components have been selected and illustrated as examples (steel structure, façade panel, heating element). The situation is similar for the other components as well!

The blue bar shows the emissions generated during dismantling, the green bar the emissions for transport, the red bar the emissions for reprocessing and the yellow bar the emissions for reassembly. This can vary depending on the component: The steel structure.

On this illustration you can see an overview of how the CO2 emissions of a reused component are made up and which processes have the biggest influence. Three components have been selected and illustrated as examples (steel structure, façade panel, heating element). The situation is similar for the other components as well!

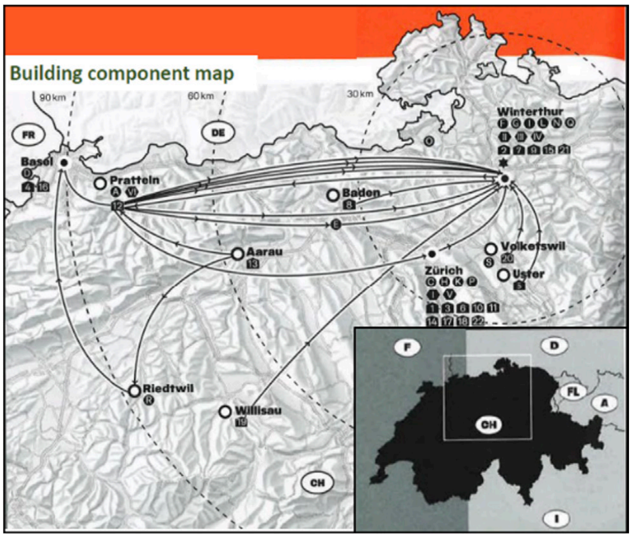


Figure 23: Building Component Map, Switzerland

The blue bar shows the emissions generated during dismantling, the green bar the emissions for transport, the red bar the emissions for reprocessing and the yellow bar the emissions for reassembly. This can vary depending on the component: The steel structure (left-hand) requires more effort for dismantling and reassembly than the façade panel or the heating element. However, it is clear that transport accounts for the largest proportion of emissions for all three components. This means that the aim of reuse should be to keep transport routes as short as possible in order to achieve the greatest savings potential.

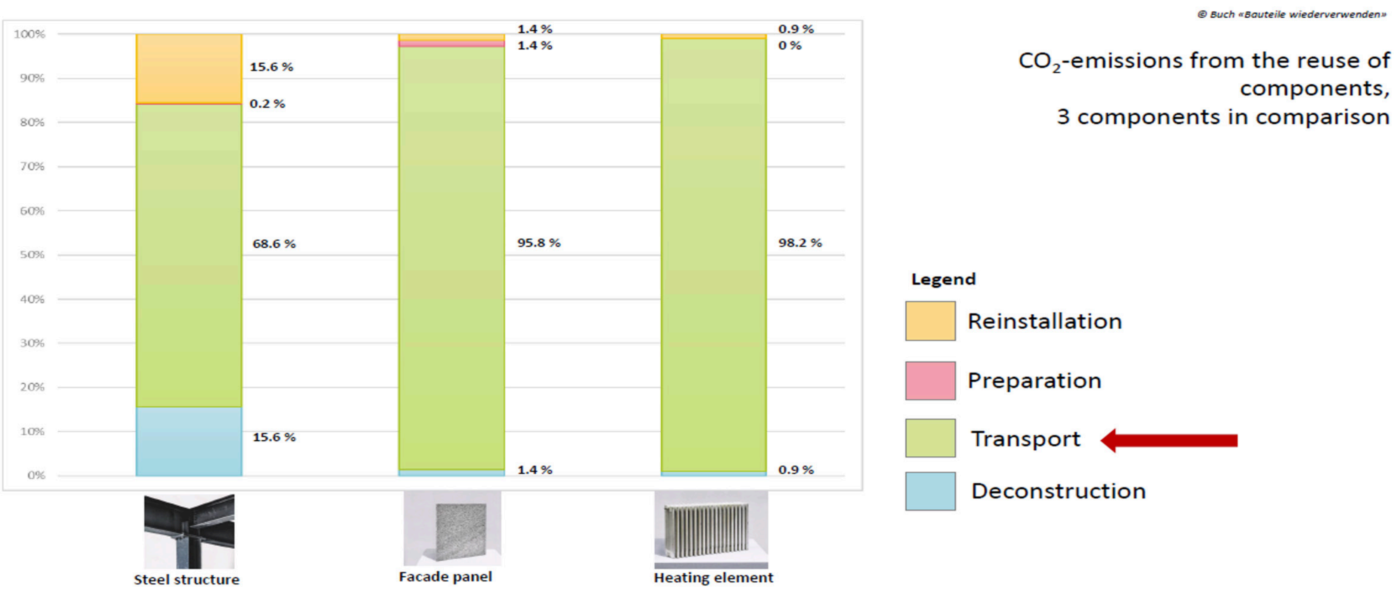


Figure 24: CO2-Emissions from the Reuse of Components (©Bauteile wiederverwenden, 2021)

2.8. Savings per Component

Let's take a quick look at how much emissions could be saved by reusing these three components compared to a new component.

The grey part shows the emissions that occurred during reuse. We looked at this on the previous page and it includes dismantling, transport, processing and reassembly. It is clearly visible that between 98 % and 85 % of the emissions could be saved with these three components - the other components, which were reused, also behave similarly here. So we can conclude: In terms of CO2 emissions, reuse is worthwhile!

2.9. Potential of Reuse

How much could be saved overall by reusing all the components?

On the left you can see the emissions of the building K118 with reused components, while on the right you can see the emissions by using only new components for the building. The reuse saved a total of 494 t of CO2 in this project and reduced emissions by 59 %. For the reuse of the building components, i.e. the dismantling, transport, preparation and reinstallation, only 1% of the emissions occur. For the new materials and components, i.e. the wall structures made of straw, clay and wood, 40% of the emissions still occur.

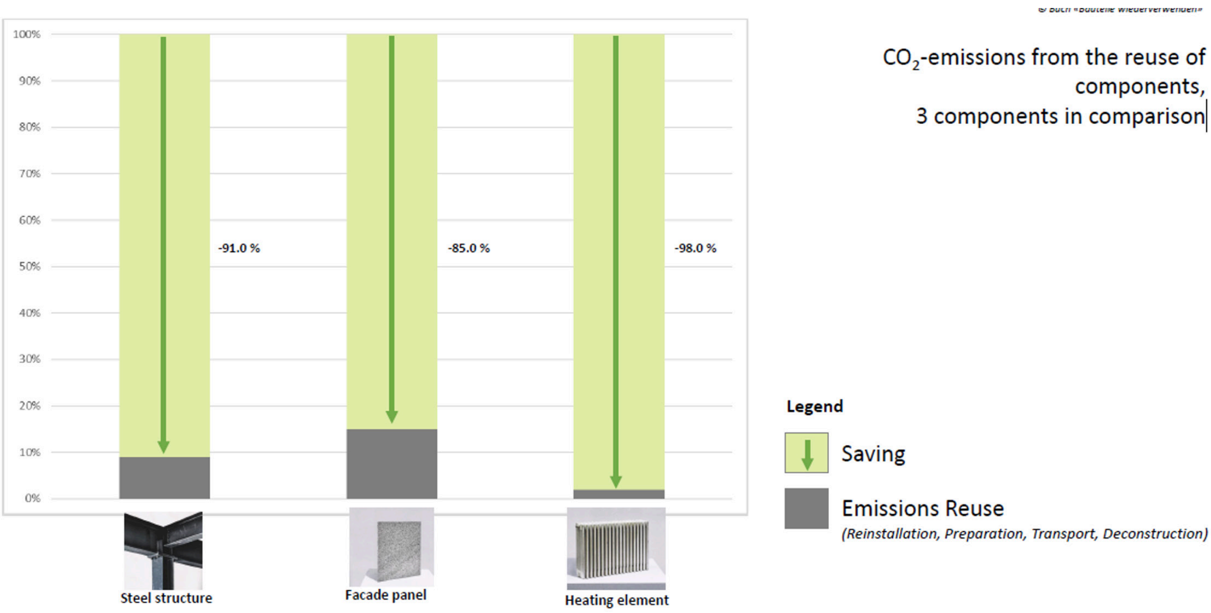


Figure 25: CO2-Emissions from the Reuse of Components (©Bauteile wiederverwenden, 2021)

Figure 26: Potential of Reuse (©baubüro in situ, 2021)

让我们共同打造气候中和的未来
Building a climate-neutral future together

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development
and Cooperation SDC

中华人民共和国
住房和城乡建设部

IBEE 环能科技

intep

skat