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

Circular Construction Analysis

Heilongjiang Cold Land Building Science Research Institute

ENGLISH VERSION

APRIL 2025

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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.

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Cite as:

Rudolf, B., Müller, K. (2025). Circular Construction Analysis: Heilongjiang Cold Land Building Science Research Institute. 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.

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Cover image: Heilongjiang Cold Land Building Science Research Institute, Harbin

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1. PROJECT BACKGROUND

About Sino-Swiss ZEB Project

In order to jointly address global climate change and to strengthen cooperation between China and Switzerland in the field of emission reduction in the construction industry, the Ministry of Housing and Urban-Rural Development of the People' s Republic of China and the Swiss Federal Ministry of Foreign Affairs signed a Memorandum of Understanding (MoU) on 24 November 2020. The Memorandum is about the development of cooperation in the field of building energy efficiency. Within the framework of this MoU, the Swiss Agency for Development Cooperation (SDC) initiated and funded the Sino-Swiss Zero Emission Building Project. The project aims to support China in formulating the technical standard of zero carbon buildings and long-term roadmaps for reducing carbon emissions in the construction industry. Switzerland contributes by sharing know-how and use cases of zero emission building demonstration projects in different climate zones, while carrying out various forms of capacity building activities, so as to ultimately promote the carbon-neutral development of China' s construction industry.

Introduction of Zirkular

Within the duration of Sino-Swiss ZEB Project (15. March 2021 – 30.Nov. 2025), various experts and educational institutions from Switzerland have been involved in an exchange on the 10 selected demo projects. The Zirkular GmbH was also invited to give technical suggestions to the Harbin demo project and draw up a report on the renovation topic, incorporating existing information as well as including additional data.

Zirkular GmbH is a constituent element of four sibling companies based in Switzerland that are organized in form of a cooperative. The group of companies specializes in sustainable architectural projects, with a particular focus on building within existing structures. The group of companies can look back on over 25 years of experience in construction with existing structures and is regarded as a pioneer in this field far beyond the borders of Switzerland.

The range of services offered by the group includes:

- Denkstatt sarl: Urban and site development,
- unterdessen: interim use,
- baubüro in situ: architecture,
- Zirkular: specialist planning for circular construction.

The area of circular construction encompasses in particular the search for and procurement of dismantled components and their transfer to a new use with all associated processes such as determining and testing performance characteristics, organization of selective dismantling, documentation, management and logistics.

The overarching objective for each project handled within the group of companies is to comprehensively address the various dimensions of sustainability through a holistic approach, with a view to generating socially and ecologically acceptable solutions in a cost-effective manner. With these skills in mind, this report examines the approach to the renovation of the "Harbin demo

2. INTRODUCTION

2.1. Goal

The aim of this report is to examine the DP Harbin on the basis of existing documentation, to assess individual aspects from a Swiss perspective and, if necessary, to provide further solutions for future developments.

2.2. Working process

The basis of this report is the analysis of the existing documentation of the finalized renovation project. Based on this data, we developed a list of possible topics to pursue, this list was discussed with the project leading implementor - intep-skat consortium and then followed up. The project documentation provided by the project team are a comprehensive overview of topics, regarding the applied strategies in this complex refurbishment project and the decisions that have been taken along the way.

In this report, just special relevant topics are chosen and developed further, instead of reviewing every single aspect of the refurbishment process. As each topic depends on various parameters, relevant aspects are singled out and analyzed with an in-depth look. Finally, additional topics that are relevant in the Swiss context are added and addressed.

The DP Harbin represents a particularly exciting project in the field of climate-friendly construction, as it is the only refurbishment project among the 10 selected demo projects of Sino-Swiss ZEB Project.

Until now, though the development towards low-emission buildings has focused heavily on new construction, but we now clearly know that dealing with existing buildings is just as important and must not be neglected (key factor: embodied emissions).

2.3. Summary

As will be noted below, all the issues discussed must be analyzed on a case-by-case basis, as each renovation project is unique.

Our office applies an ‘in situ’ practice, where each project is based on specific parameters to achieve a financially viable, environmental and social optimum.

Reliable industry solutions and tools are fundamentally important to achieve these optimal solutions. Verified data is required, such as data on the greenhouse gas parameters of materials or the efficiency of appliances.

The ‘sustainability’ targets to be achieved must be agreed on at the beginning of the project so that they can be measured and evaluated (there is no one-size-fits-all strategy in building refurbishment).

For DP Harbin, the main target was to minimize the operating emissions as a ‘low-carbon’ or ‘nearly zero carbon building’.

In conclusion, we can say that the DP Harbin is a flagship project in terms of climate-friendly construction, which - as it stands - could also have been implemented in Switzerland.

Note: The operation values obviously vary considerably between countries and cannot be conclusively assessed - as far as we could judge within the scope of this work-, as we noted later in the report.

However, it must also be said that such demo projects often shed light on individual aspects, such as ‘only’ the operating emissions in our case; a comprehensive, holistic view is rare and also difficult to realize in practice. In Switzerland, the consideration of the emissions related to the construction is currently gaining in importance, as it has been recognized that - when calculated according to the consumption principle (Scope 3) - the embodied emissions are roughly the same; with an upward trend, as operating emissions are decreasing but construction activities are continuing (when considered at country level in Switzerland).

In our view, the following aspects could play a supporting role in the future development of climate-friendly refurbishments:

Overall life cycle assessment of construction & operation

- The life cycle assessment should cover the entire life of a project; construction now and operation beyond 2050.
- Data for the life cycle assessment
- Life cycle assessment data (production and disposal, transport, energy) should be verified by a suitable body on behalf of the public sector in order to obtain a comparable data basis.

Dynamic limit values

- The limit values for construction and operation are to be linked to the climate targets of the global community and/or the national decarbonization strategies, whereby the necessary reduction path for net zero 2050 can be created.

No fossil fuels

- Where possible, fossil fuels should be avoided altogether for new installations. If this is unavoidable or if, for example, the carbon intensity of the electricity mix means that fossil fuels currently offer a better solution in terms of overall efficiency, their substitution should be taken into account in planning as soon as the situation changes.

Components and materials

- Components and materials should be considered and optimized for their life cycle, so that topics such as design for disassembly (maintenance, servicing, repair), waste and disposal (composites, pollutants) and durability can also be evaluated.

2.4. Sustainability as a question of definition

In Switzerland, sustainability is literally enshrined in the Federal Constitution:

> "It [The Swiss Confederation] shall promote the common welfare, sustainable development, internal cohesion and cultural diversity of the country."
>
> (BV, Art. 2 Zweck, Abs. 2).

Sustainable development must then, of course, be defined and broken down into construction projects. The 3-dimensional model is the most widely used definition of 'sustainability' :

According to the 3-dimensional model, the 3 areas of society, environment and economy must be taken into account for sustainable projects, whereby it should be noted that none of the areas may be neglected for an effectively sustainable action, whereby the weighting of the respective topics is of course not defined.

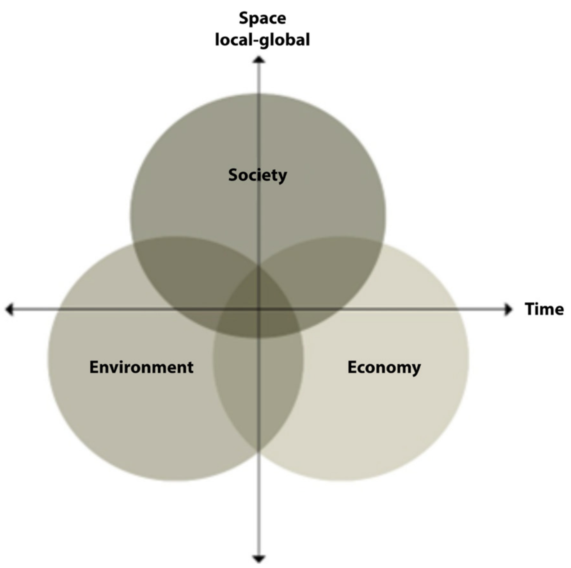


Figure 1: 'Sustainability' 3-dimensional model-Modell, Source: 'Lehrplan 21'

If, for example, the scientific urgencies of the various areas are taken into account, such as the CO2 budget, biodiversity decline or social justice, it would be appropriate to prioritize the aspects of these areas more highly.

Unfortunately, in Switzerland - as in most countries - the bottom line is that sustainability is practically never taken into account to the extent that would be necessary according to a 'precise' interpretation of the constitution and the urgencies.

Although interesting pilot projects are being realized time and again, the entire construction industry is only moving very slowly in a sustainable direction.

If social aspects are taken into account, there is even a trend away from social justice (rising housing prices, demographic trends in cities, social responsibility, etc.).

Unfortunately, economic development and the supposedly resulting increase in prosperity are always given the highest priority, so that other aspects have to be consistently subordinated to this.

2.5. Overview of the project and the normative basis

2.5.1. DP Harbin

We know from the introduction document of DP Harbin that the Demo Project Harbin is an existing public building in a severe cold area (Harbin City, Heilongjiang). It was built in 1995, and later once reconstructed to a hotel. There are 7 floors above ground and 1 floor underground. It has a total floorage of 8' 455.22m². The building had no external thermal insulation system. The interior decoration has been severely damaged and partially removed, and therefore can not be used. The main structure of the building has been tested by the Heilongjiang Cold Land Building Science Research Institute, and it is complete with no major safety hazard. Existing doors and Windows, heat supply, water supply, elevator, thermal insulation, fire protection, electrical appliances, strong and weak electricity, and exterior facade need to be replaced or transformed, internal space needs to be rearranged and repaired, and parts of the structure need to be renovated."

Implemented key technologies when renovation:

- The listed street façade was clad with internal thermal insulation (VIP = vacuum insulation panels)
- The rear façade was insulated with rock wool on the outside
- the roof was insulated with extruded polystyrene
- Thermal bridging issue: Efforts have been made to mitigate the thermal bridging issue at the junction of partition walls, floor slabs, and external walls.
- HVAC / Building technology
- Mechanical ventilation with heat recovery
- Air source heat pump
- Photovoltaic power

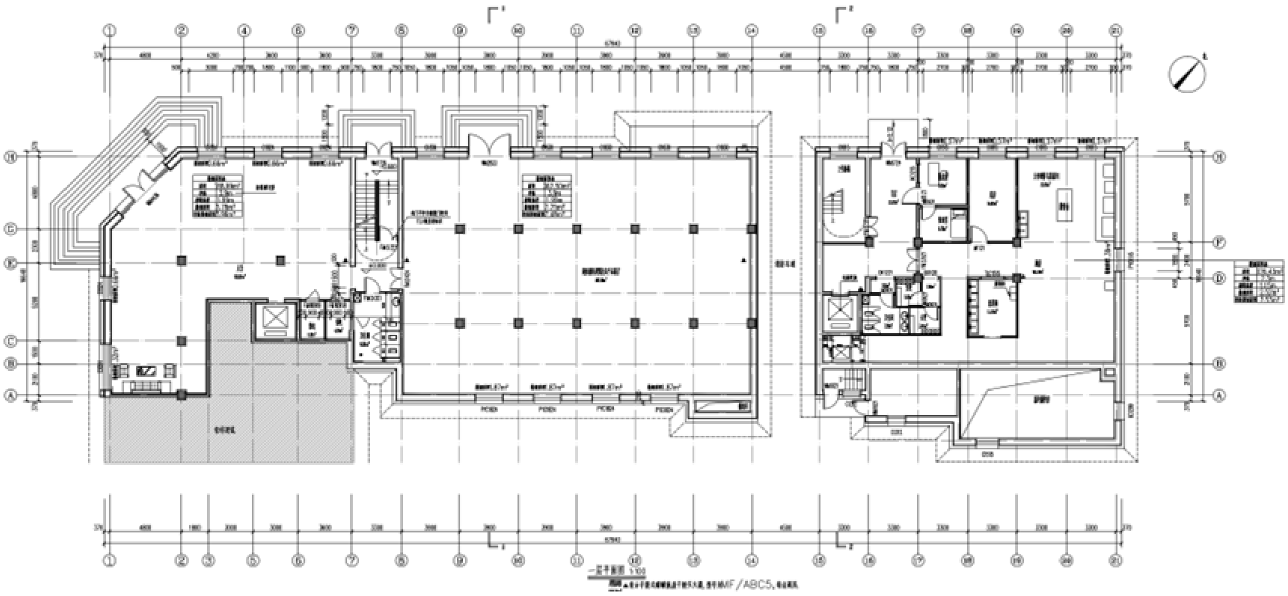


Figure 2: Main floor, Source: Heilongjiang Cold Land Building Science Research Institute

Figure 3: View from entrance (visualization), Source: Heilongjiang Cold Land Building Science Research Institute

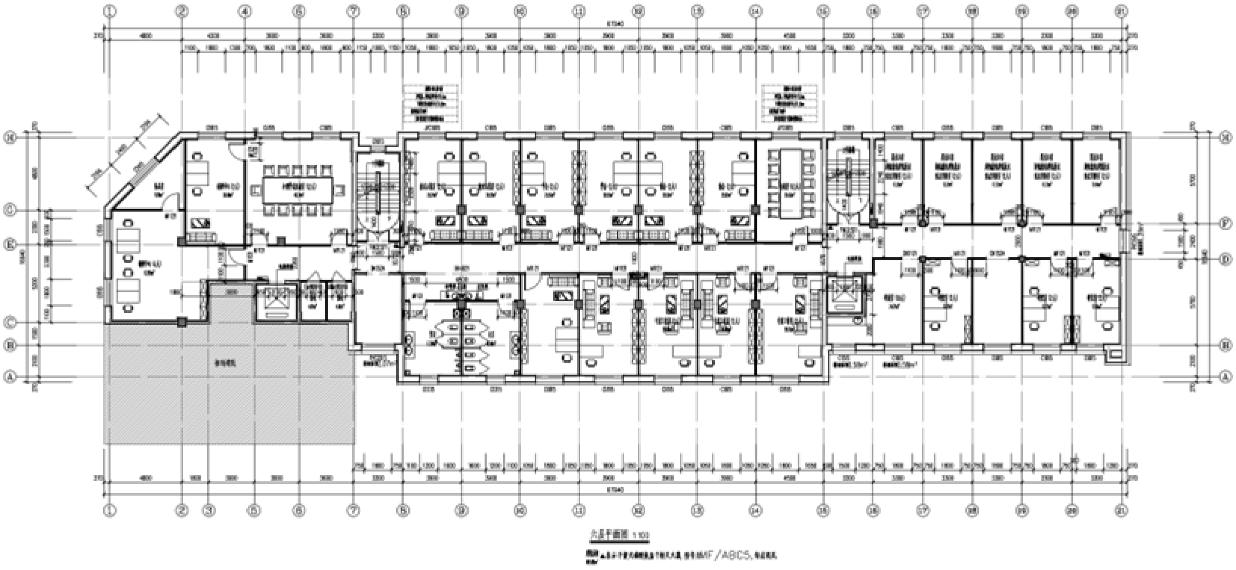


Figure 4: Upper floor, Source: Heilongjiang Cold Land Building Science Research Institute

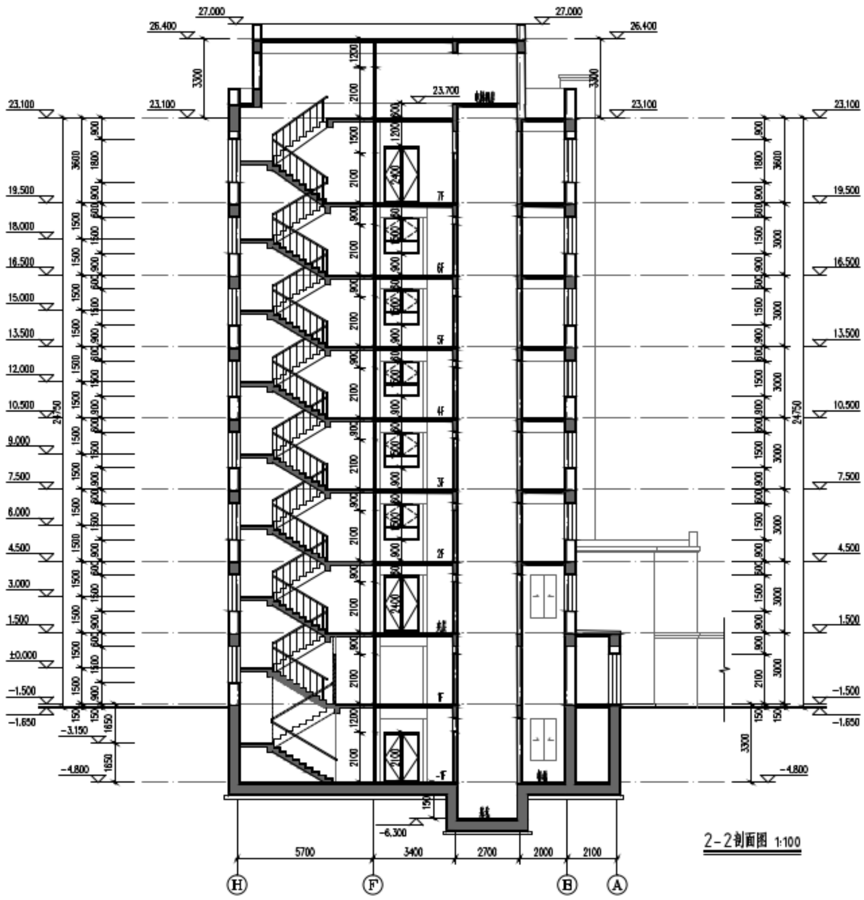


Figure 5: Cross-section, Source: Heilongjiang Cold Land Building Science Research Institute

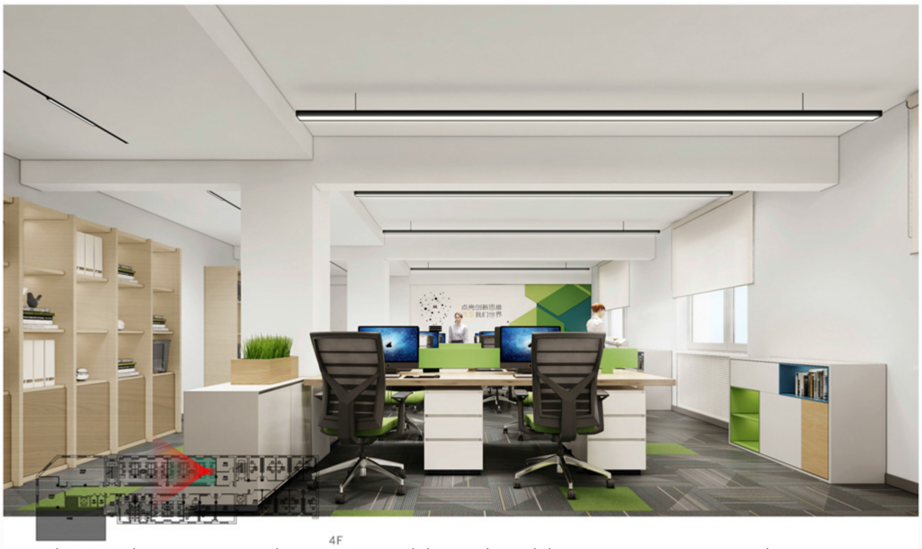


Figure 6: Upper floor (visualization), Source: Heilongjiang Cold Land Building Science Research Institute

Figure 7: Elevation Street View, Source: Heilongjiang Cold Land Building Science Research Institute

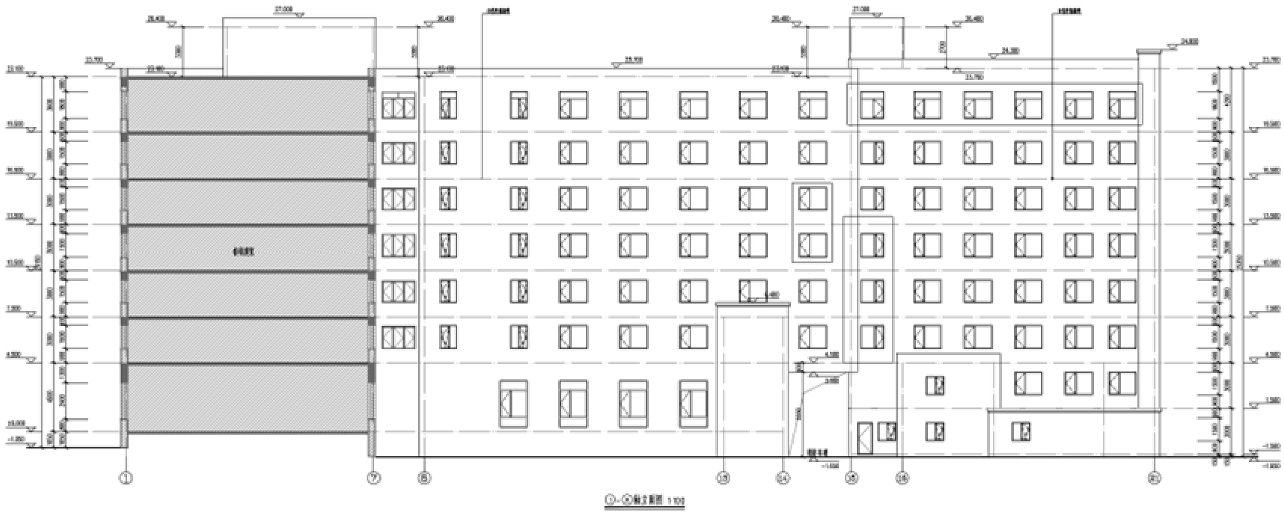


Figure 8: Elevation Rear View, Source: Heilongjiang Cold Land Building Science Research Institute

2.5.2. Technical regulations China

In the beginning Zirkular laid out the various basics in order to gain an overview, as we had no previous contact with the Chinese construction industry. Below we list a selection of the regulations relating to the DP and the development towards climate compatibility and sustainability.

Local Standards applied

- Design standard for energy efficiency of ultra-low energy public buildings in Heilongjiang Province

ZEB – Zero Energy Buildings

- General CODE for energy efficiency and renewable energy application in buildings, GB55015-2021
- Voluntary national standard of nearly-zero energy buildings, GB/T 51350-2019

ZCB – Zero Carbon Buildings

- National Standard for building carbon emission calculation, GB/T 51366-2019
- Technical standards for zero carbon buildings (Exposure Draft), GB/T xxxxx - 202x

The latter draft 'Technical standards for zero carbon buildings' is a comprehensive and far-leading standard in terms of sustainability, which strives for a holistic view by not 'only' addressing operating energy and operating emissions, but also other important aspects such as economic added value, questioning the spatial program, the environment (microclimate), possible natural ventilation, daylight yield, shading, demolition & deconstruction, sufficiency (reduction of unnecessary; e.g. purely decorative layers), simple form, 'passive design', recycled materials,

deconstructable constructions, maintenance & repair, durability, local materials (transport), CO2 life cycle for insulation and more.

Even a pure focus on greenhouse gas emissions does not cover the entire necessary range of sustainable construction and it is very welcome that this standard takes a comprehensive view and deals with many relevant topics.

This standard is closest in scope to the topics covered by the 'Swiss Sustainable Building Standard (SNBS)'

2.5.3. Technical regulations Switzerland

In Switzerland, standards in the building sector have been developing since the 1960s, with the focus in the early days being on the absence of structural damage and comfort.

Operating energy was limited from the 1970s due to the energy crisis, harmonized in the 1990s and supplemented with restrictions on fossil heat carriers from 2014.

Currently, the statutory regulations in Switzerland no longer correspond to the state of the art in terms of climate protection and other ecological aspects and are currently being revised.

MuKEn 2014 à Energy laws & regulations

The legal regulations in Switzerland are regulated at communal level (by the cantons). The cantons have harmonized their regulations; the current version is 2014 (MuKEn = model regulations of the cantons in the energy sector).

Quantitatively, only the operating energy is limited, whereby there is a requirement for the maximum proportion of non-renewable energy (heat generation must be largely renewable - i.e. not fossil).

However, the harmonization from 2014 has not yet been implemented throughout the country and it is still possible to put new fossil heating systems into operation.

As a result, there is a major discrepancy between scientific urgency, political objectives and actual implementation.

The model regulations are currently being revised (MuKEn 2025), whereby the grey emissions from construction are now also to be capped. In the current draft, they amount to 780 kg/m² for new 'administration' buildings and thus roughly correspond to the Swiss average for 'normal' new buildings. The idea is primarily to sensitize the construction industry and thus enable a future reduction in the limit value.

SIA 380/1 Heating Requirement

The standard describes the requirements of the existing MuKEn in detail (for verification and enforcement).

It is possible to fulfil the requirement by means of individual component requirements (U-value limit values per component) or system verification (heat requirement balancing of the building similar to the 'Technical Standard for Near-Zero Energy Buildings [GB/T51350-2019])'.

SIA 2040 Efficiency Path

In addition to operating energy and emissions, the fact sheet from the Swiss Association of Architects and Engineers also deals with construction and building-internalized mobility. Strict limit and target values are formulated for this purpose.

The regulations are not enshrined in law (exceptions are municipal requirements, e.g. in design plans for sites).

The limit and target values from 2017 are no longer up to date.

The information sheet is currently being revised and will now become the SIA 390/1 'Climate path' standard. SIA 390/1 provides for limit and target values to be specified in future, which are necessary according to the reduction pathway for greenhouse gas emissions in accordance with the 1.5°C target (Paris Agreement) and will be regularly tightened in future.

Minergie - Ecobau - SNBS

Three harmonized building labels and the SIA standard exist in Switzerland that are comparable in their approach and scope to 'Technical standards for zero carbon buildings':

- GEAK 'Building Energy Performance Certificate of the Cantons' with 'Plus' option for refurbishment proposals with regard to energy efficiency.
- Minergie(-P)/(-A) with the addition of ECO as an award for comfort, efficiency and climate protection with an addition for pollutant-free materials (ECO).
- SNBS for comprehensively sustainable buildings

SIA MB 2040 'Efficiency path' and SIA 390/1 'Climate path' for ambitious CO2-reduced buildings with life cycle assessment.

3. EVALUATION AND INPUTS FOR DP HARBIN

3.1. Introduction

DP Harbin is the refurbishment of a listed building (heritage protection). The procedure for this building is basically transferable to other refurbishments, including refurbishments of non-listed buildings (which usually makes it easier).

3.2. First inputs and suggestions

3.2.1. Project phases

As informed by Chinese partner, the project phases for a refurbishment project in China are similar, but are handled more stringently.

China:

- Schematic Design
- Preliminary Design
- Construction Design

Switzerland:

- Strategic planning
- Preliminary studies
- Preliminary and construction project, authorizations
- Tender planning and tendering
- Implementation planning & realization

According to the documents, the 'DP Harbin' refurbishment was realized within 2 years and 2 months. A comparable project in Switzerland would probably take around 5 years from the feasibility study to completion.

3.2.2. Aspects of sustainability in architectural projects

To date, there are no sustainability targets, such as CO2 limits, in Switzerland unless they are agreed in addition to the 'normal' legal requirements.

In addition to SIA 112, which defines the phases, SIA 112/1:2017 'Sustainable construction - Building construction' provides assistance in integrating sustainability aspects into an architectural project. The standard does not describe limit values or the like, but provides information for understanding within the planning team and promotes integral planning.

Phases	Subphase	Goals
1 Strategy planning	11 Formulation of needs Solution strategies	Needs, goals and framework conditions defined, solution strategy determined.
2 Preliminary study	21 Feasibility study	Procedure and organization determined, project planning principles defined, feasibility demonstrated.
3 Project planning	31 Preliminary project 32 Construction project 33 Authorisation procedure	Concept and profitability optimized, project and costs optimized, project approved, costs and deadlines verified, construction loan approved.
4 Invitation to bid	41 Tenders, contract awards	Readiness for awarding reached.
5 Realisation	51 Implementation planning 52 Execution 53 Commissioning, finalization	Ready for execution. Building constructed in accordance with specifications. Building accepted and put into operation, final invoice accepted, defects rectified
6 Operation	61 Operation	Operation is ensured and optimized.

Figure 9: SIA 112:2014 "Model construction planning"

The standard is based on the 3-dimensional model mentioned above and defines the following structure:

Society division	▪ Infrastructure ▪ Solidarity ▪ Social contacts ▪ Usability ▪ Design ▪ well-being ▪ participation
Business division	▪ Location ▪ Equalization ▪ Compaction ▪ Marketability ▪ innovation ▪ Capacity to act ▪ Life cycle costs
▪ Environment	▪ Mobility ▪ Sufficiency ▪ Biodiversity ▪ Durability ▪ Material cycles ▪ Production ▪ Operation

3.3. Building envelope / heating

The calculated heating requirement of the Harbin DP after the refurbishment measures is very low - especially for a refurbishment project with listed building (es culture heritage) requirements. It is significantly lower than a comparable project would have to achieve according to Swiss regulations:

Comparison of heating requirements “Qh”

DP Harbin “Heating Demand”(according to “Report on Energy Efficiency Assessment of Low Energy Buildings” from 22.10.2023)

= 33.7 kWh/m^2

Switzerland “limit value” (MuKEn2014 / SIA 380/1 for retrofit)

= 65.7 kWh/m^2

(Assumptions: Ath/AE = 1.4, Annual mean temperature = 4.6°C)

For a comparable pilot project in Switzerland, the strictest label for building envelopes ‘Minergie-P’ (Passive house) could be applied. This requires compliance with a maximum of 90 % of the legal limit value for a refurbishment, i.e. around **59 kWh/m²** in this case.

Even a new Minergie-P building of the same size in a climate region with an average annual temperature of 4.6°C, as in Harbin, is likely to have a demand of around **46 kWh/m²** (70 % legal limit MuKEn2014).

DP Harbin’s heating requirements are therefore much lower than we would expect.

Since a Minergie-P building envelope is at the limits of technical and financial feasibility and a low value such as DP Harbin in Switzerland can hardly be achieved, we assume that the difference lies in unequal calculation models and boundary conditions, such as the consideration of other energy consumers (for example, the designed energy consumption according to “Demo Project Harbin Summarizing Report EN v1.0” is 50.7 kWh/m^{2}a) and is therefore not directly comparable.

The so-called ‘performance gap’ must also be considered and should also be mentioned for this project (see also 2.6 Performance gap).

3.3.1. Thermal insulation

The low heating requirement of DP Harbin is primarily an effect of the low U-values of the thermal insulation (“Report on Energy Efficiency Assessment of Low Energy Buildings”):

- Roof: U = 0.11 W/m2K (XPS 30 cm)
- Exterior wall 1: U = 0.16 W/m2K (20 cm Rock wool)
- Exterior wall 2: U = 0.11 W/m2K (2, resp. 3 cm VIP & Further insulation).
- Windows: U = 1.0 W/m2K

Similar values are used in Switzerland. The minimum limit values for components against outside air are:

- Refurbishment: U ⩽ 0.25 W/m2K
- New construction: U ⩽ 0.17 W/m2K

For a pilot project, it would be conceivable to aim for U-values of 0.11 W/m2K, although this would probably only be applied to “simple” surfaces, such as a flat roof.

It is known from practical experience with VIP insulation that various aspects have a detrimental effect on the effective insulation performance when

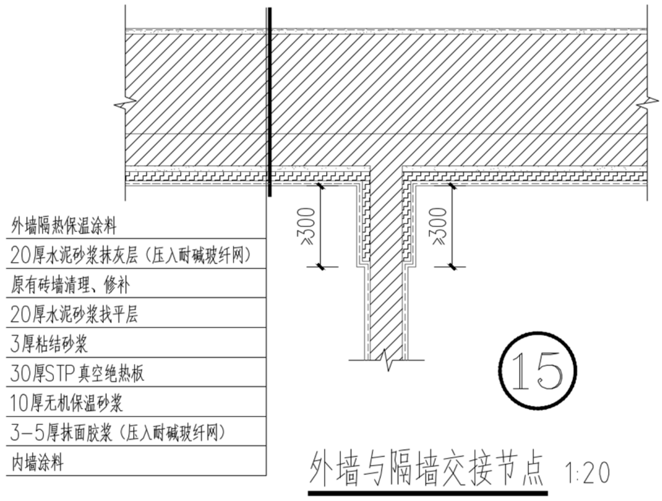


Figure 10: External wall with internal VIP-insulation and internal wall connection with flank insulation, Source: Heilongjiang Cold Land Building Science Research Institute

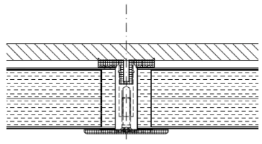
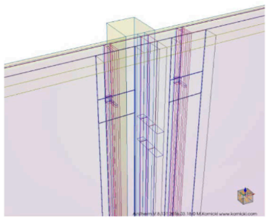
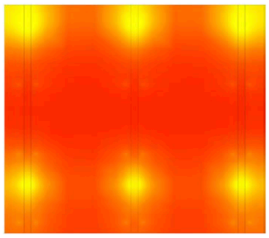
	▪ The VIP sandwich elements were installed (clamped) between stainless steel sheets to protect them. ▪ 1.5mm Stainless steel sheet ▪ 20mm VIP ▪ 20mm VIP ▪ 1.5mm Stainless steel sheet
	The thermal conductance is calculated using 3-dimensional modelling of a representative section of the façade
	The influence zones of the clamps and brackets (for the substructure of the curtain wall cladding) are clearly visible.

Figure 11: Section of the wall structure, Source: Amstein+Walthert AG

applied to the building, such as small parts / edge effects, fastening, standard formats / supplementation with normal insulation or the lack of workability.

For example, in a completed project in Zurich with 40 mm VIP (λ = 0.007 [W/mK]) and a theoretical, undisturbed U-value of 0.15 [W/m^{2}K], an effective U-value of 0.38 [W/m^{2}K] was achieved after taking all influences into account. The actual, calculated U-value was therefore around 250 % higher than the theoretical value possible on the undisturbed panel.

This was a sobering realization for the project, as the cost of the wall construction with VIP was significantly higher than with a conventional wall construction and the limit values could not be met after all without further measures.

In order to verify the calculated U-values of the VIP insulation in the demo project in Harbin, it would be very interesting to carry out a U-value measurement of the renovated building in operation (see also 2.6 Performance Gap).

Ecological optimum insulation

As an energy and emission-relevant component, thermal insulation has ecological and economic optimization potential when considering its construction and operation.

The effort required for production can be compared with the potential savings during operation:

- The ecological cost of producing and disposing of thermal insulation increases linearly with increasing insulation thickness.
- The ecological cost of manufacturing and disposing of the heating system decreases with increasing insulation thickness.
- The ecological effort in operation to cover the heating requirement decreases hyperbolically with increasing insulation thickness.

The most effective ecological insulation thickness therefore depends specifically on the property in each individual case.

For a ‘net zero’ pilot refurbishment project in Switzerland, which requires interior thermal insulation, various insulation materials would be evaluated, such as.

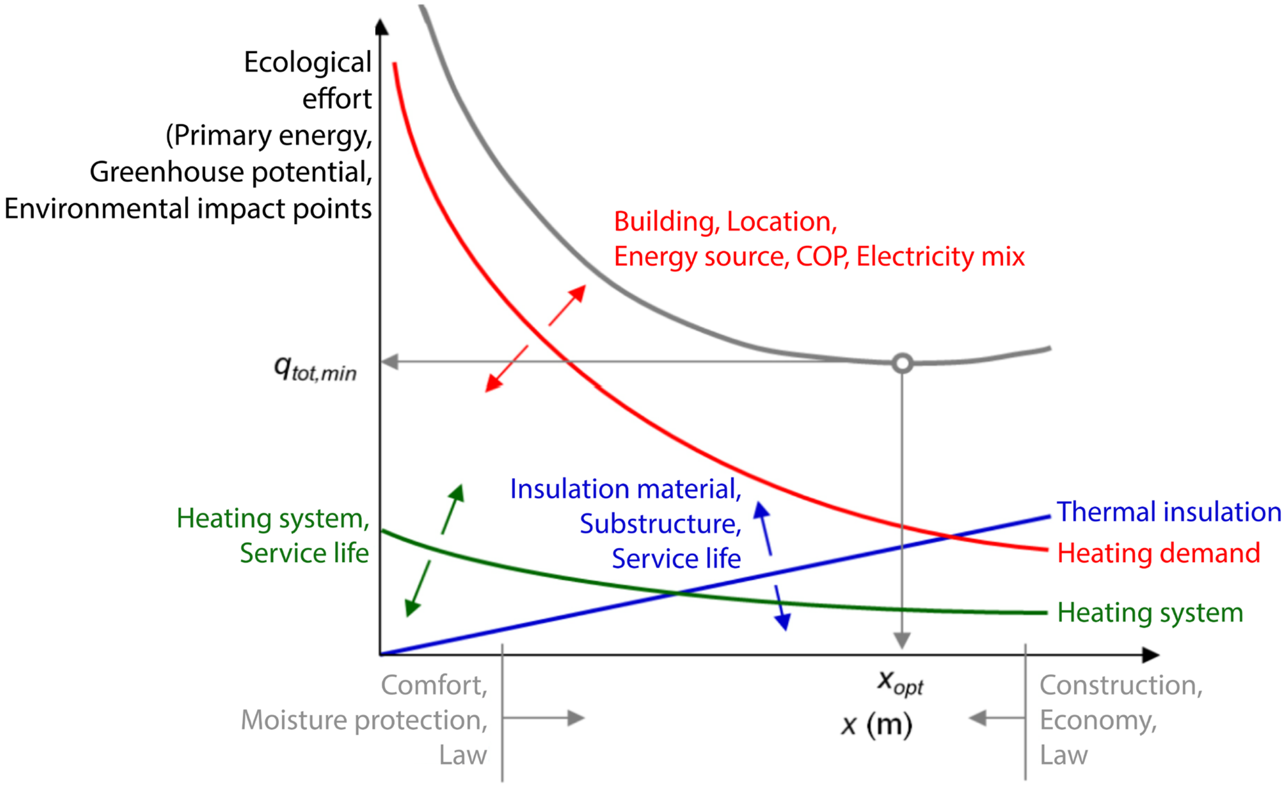


Figure 12: Ecologically optimized insulation thickness, Source: Federal Office of Energy, source: https://www.hslu.ch/-/media/campus/common/files/dokumente/ta/ta-forschung/zig/zig-berichte/schlussbericht-optimale-daemmstaerken.pdf/?la=de-ch

Figure 13: Calcium Silicate Insulation, Source: Xella Multipor

Monolithic, mineral insulation (e.g. calcium silicate)

[Diffusible & capillary-active, durable/robust, medium insulation performance]

Figure 14: Foamglas, Source: Baufachzeitung

Foam glass

[Absolutely insensitive to moisture, durable/robust, medium to good insulation performance]

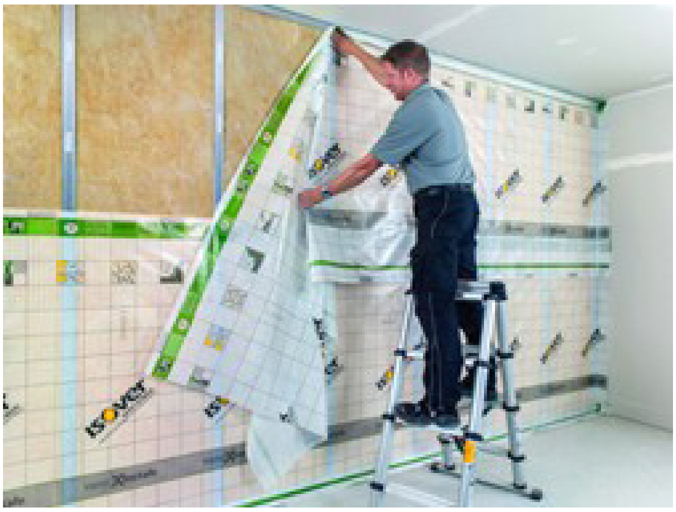


Figure 15: Glass Wool with vapor barrier, Source: Isover
Organic or mineral fiber insulation with vapor barrier (e.g. cellulose, wood fiber, rock/glass wool)
[Large selection, good insulation performance, sensitive to moisture]

Figure 16: Aerogel fleece, Source: Agitec Spaceloft
High-Performance Insulation (e.g. VIP, Aerogel, PIR)
[Cost-intensive, very high insulation performance, depending on the product, tricky in terms of processing, durability, moisture protection or grey emissions]

To determine the most suitable option, various parameters would be compared, analyzed and weighed up:

- Building physics behavior
  - Thermal and moisture protection (e.g. also thermal bridges)
  - Thermal mass
- Land consumption
  - Insulation thickness / U-Value
- Life cycle assessment
  - Construction vs. operating emissions
  - Environmental impact (e.g. method of ecological scarcity)
- Costs
  - Material costs - loss of space - energy savings
- Durability & usability
  - Life expectancy
  - Robustness
  - Risk of damage by users (screws or similar)

In most cases, the analyses with a high weighting of the environmental impact lead to the conclusion that insulation that causes as few emissions as possible during production would be the best from an ecological point of view. This could be cellulose made from recycled paper or straw, for example.

The lowest possible U-value is usually not expedient for the overall balance, as the greenhouse gases from heating with renewable energy (e.g. heat pump with certified green electricity) are very low (the current CH consumer mix is 0.125 kg CO2/kWhEl. while a certified mix of electricity products from renewable energies is 0.0016 kg CO2/kWhEl.) and the production emissions for the insulation can outweigh these if the insulation thickness is high.

According to information from the DP team, VIP was the only possible option for the interior insulation due to the limited space available. This is of course a tough criterion, as there are no comparable insulation materials in view of the low thermal conductivity. Aerogel products (λ = 0.016 W/mK) or PIR Premium Plus (λ = 0.018 W/mK) come closest, but these have more than double the conductivity.

The Zirkular team has not yet been able to gain any direct experience with a renovation project using VIP or other high-performance interior insulation. Recently, however, we have planned various interior thermal insulation projects using calcium silicate. These tend to be realized with thinner insulation thicknesses than the U-value specifications would require (e.g. 10 cm). This was also possible, for example, due to monument preservation requirements, as greater insulation thicknesses can lead to building physics risks (cooling of existing walls, moisture protection). In particular, this also applies to the known, sensitive moisture situation in terms of building physics with regard to wooden beam ceilings with interior thermal insulation.

With regard to the potential to reduce operating emissions, there is also the important factor of changing the energy mix over time.

As extensive efforts are being made to decarbonize heating (e.g. district heating) and electricity, operating energy is becoming less relevant and greater attention must be paid to construction emissions.

With regard to thermal insulation, this aspect goes even further in terms of biogenic or recycled materials.

3.3.2. Thermal bridges

Thermal bridges can account for a significant proportion of transmission heat losses in energy-efficient construction and not all details can be optimized in renovation projects.

In the case of external thermal insulation, a large proportion of potential thermal bridges can be resolved if a closed insulation perimeter can be realized. However, external insulation naturally has a major impact on the architectural appearance.

With internal thermal insulation, there are inevitably many situations where the insulation has to be interrupted, e.g. at the floor slab and internal wall connections. These areas are, on the one hand, thermal weak points in terms of heat flows and, on the other hand, critical points for moisture damage, as the internal surface temperature can drop to the dew point.

The roof edge is a typical structural detail that can have thermal bridges. It can be seen from the plans that the situation was resolved well at DP Harbin.

With external thermal insulation, the insulation perimeter is continuous and a constructive thermal bridge can be avoided.

The insulation perimeter cannot be extended for internal thermal insulation of the external wall. In Switzerland, the internal thermal insulation of the wall on the ceiling would be extended as flank insulation on the ceiling. This is exactly how it was implemented at DP Harbin:

The constructive thermal bridge cannot be avoided when changing the insulation perimeter from internal insulation (wall) to external insulation (roof), but the heat flow can be effectively reduced by the 600 mm flank insulation.

For windows, the position of the window in the reveal and the reveal insulation are decisive with regard to thermal bridges

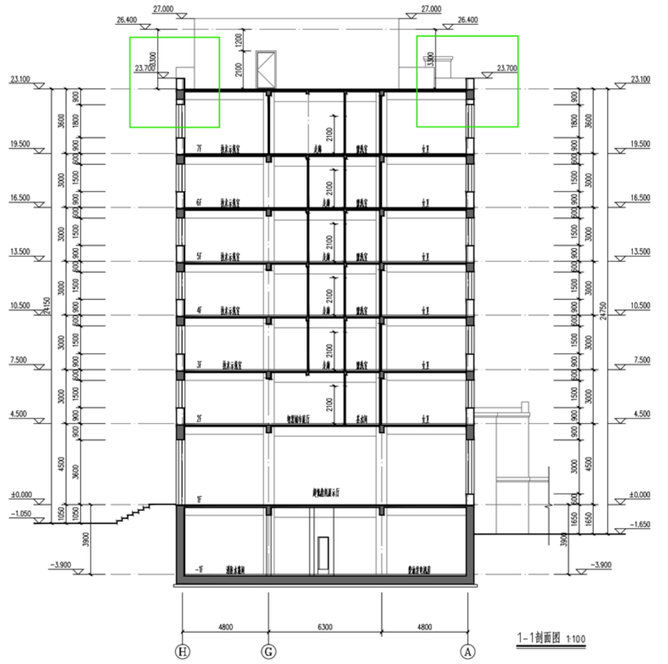


Figure 17: Cross-section with roof edge situation, Source: Heilongjiang Cold Land Building Science Research Institute, Color-Marking: Zirkular

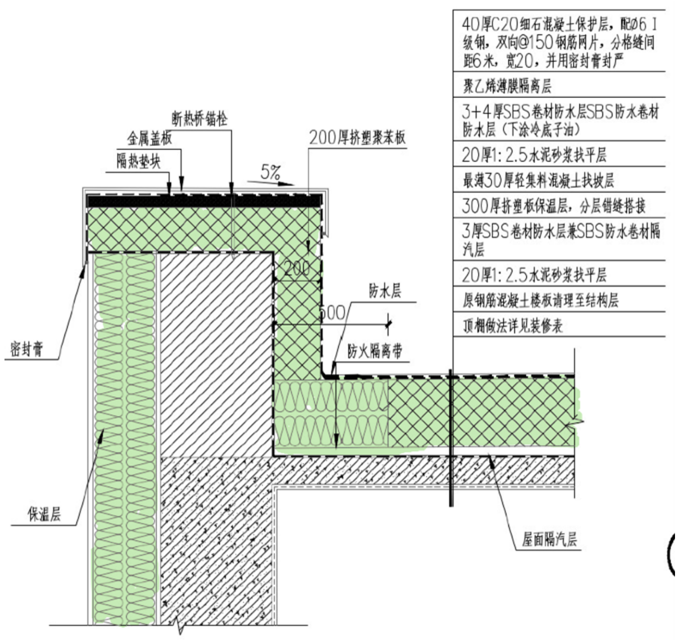


Figure 18: Detail of roof edge external thermal insulation, Source: Heilongjiang Cold Land Building Science Research Institute, Color-Marking: Zirkular

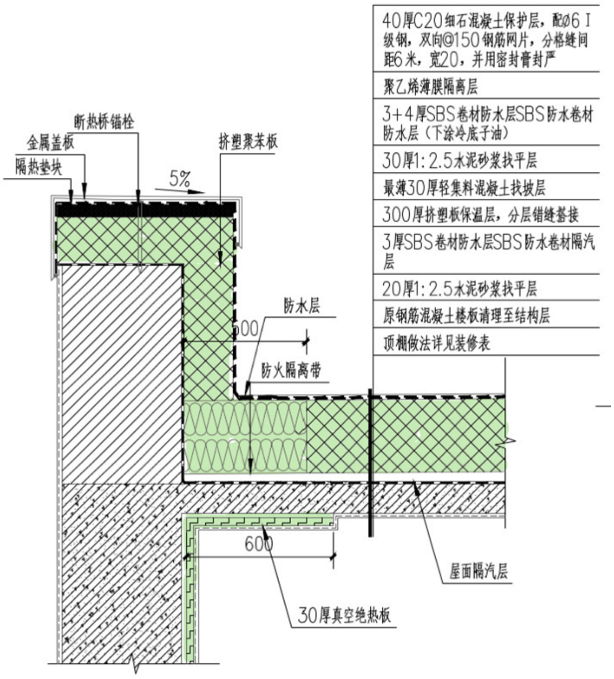
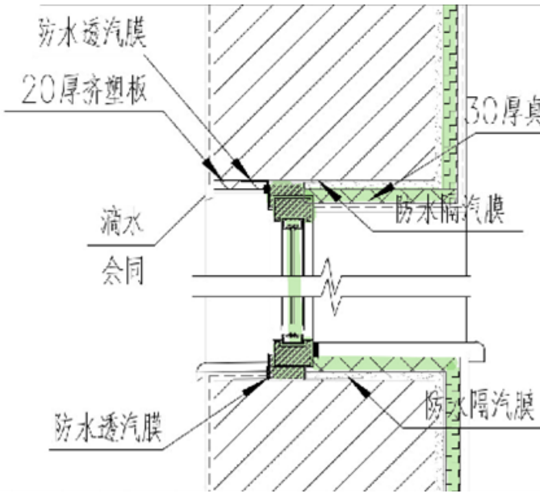
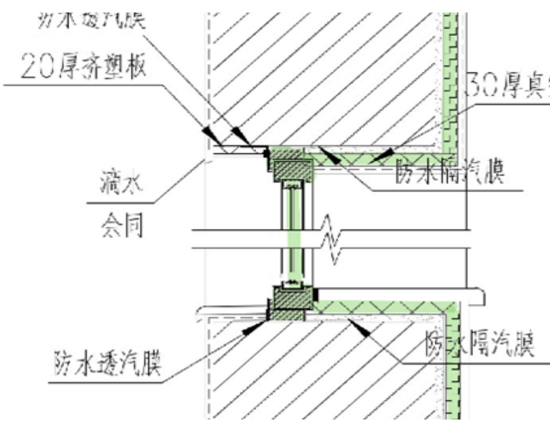


Figure 19: Detail roof edge interior thermal insulation, Source: Heilongjiang Cold Land Building Science Research Institute, Color-Marking: Zirkular



If possible, it would be advantageous from an energy point of view to also insulate the base area of the window with external insulation.

There is a risk of having to increase the proportion of the frame for this and thus losing glass proportion.



In the case of the interior thermal insulation, the insulation perimeter could be realized throughout.

Figure 20: Example window installation, Source: Heilongjiang Cold Land Building Science Research Institute, Color-Marking: Zirkular

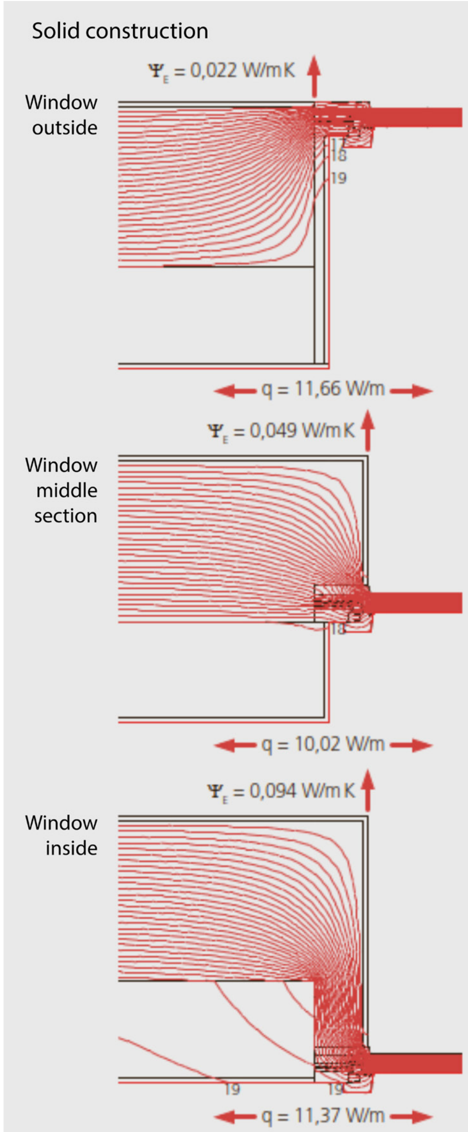


Figure 21: Example: thermal bridges windows, Source: ‘Energy-efficient Building’, Conference of cantonal energy directors

With regard to the window position in the reveal, the adjacent diagram shows that the transmission heat loss via the window stop is 4 times greater in the optimum position in terms of heat flow (outside) than in the worst position (inside).

3.4. Building technology

3.4.1. Heating

After the refurbishment, the building will be heated with air/water heat pumps placed on the roof of the building, with 1 x 17, 1 x 20 and 1 x 16 kWth (tot. 53 kWth) output (according to 'ZEB China_DP Harbin_Energy calculation report en').

This is also used in Switzerland as a 'standard solution', with the proviso of the location. Due to the low outside air temperatures, a correspondingly low COP or system utilization factor of the heat pumps is to be expected in winter. Accordingly, a geothermal probe heat pump, a solution with wood and/or adapted peak load coverage would probably be examined.

The use of district heating would also be a solution. According to the project information, this is also common in northern China, but the energy is billed according to the area to be heated (without taking into account the specific efficiency of the individual building), so that properties with a good building envelope are financially penalized.

At best, property-specific consumption billing based on the energy demand calculation could be a solution for future projects.

Heat dissipation by means of radiators

The high flow temperature required for the radiators (50° C in DP Harbin) is technically possible with the L/W heat pump, but with disadvantages in terms of efficiency, especially in view of the low outside air temperatures in winter.

The problem of high flow temperatures would be alleviated with underfloor heating. However, the floor heights and the high cost of accompanying adaptation work during refurbishments usually limit the possibilities for underfloor heating systems. However, underfloor heating systems with an installation height of just 25 mm are available on the market. If the floor cannot be activated, wall or ceiling heating systems are a viable solution.

Electric boilers for hot water

Direct electric heating systems are inefficient and are no longer permitted in Switzerland. Alternatively, integration into the heating system by means of fresh water stations (decentralized heat exchangers) or a heat pump boiler would be possible.

A heat pump boiler is an ecologically sound solution, particularly for small hot water requirements, especially as the heat pump boiler can be used more effectively to provide hot water during the warmer months of the year.

Figure 22: Air-source-heat pump on the roof after renovation, Source: Heilongjiang Cold Land Building Science Research Institute

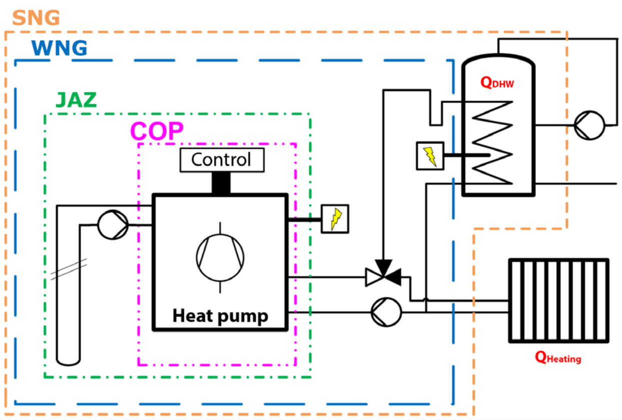


Figure 23: Various system limits of heat pump systems, Source: "Report on Field Measurements of Heat Pump Systems for the Heating Season 2021/22", Swiss federal Office of Energy

COP: Coefficient Of Performance

JAZ=SPF: Seasonal Performance Factor

(JAZ: Jahresarbeitszahl)

WNG=HUE: Heat Utilization Efficiency

(WNG: Wärmenutzungsgrad)

SNG=SE: System Efficiency

(SNG: Systemnutzungsgrad)

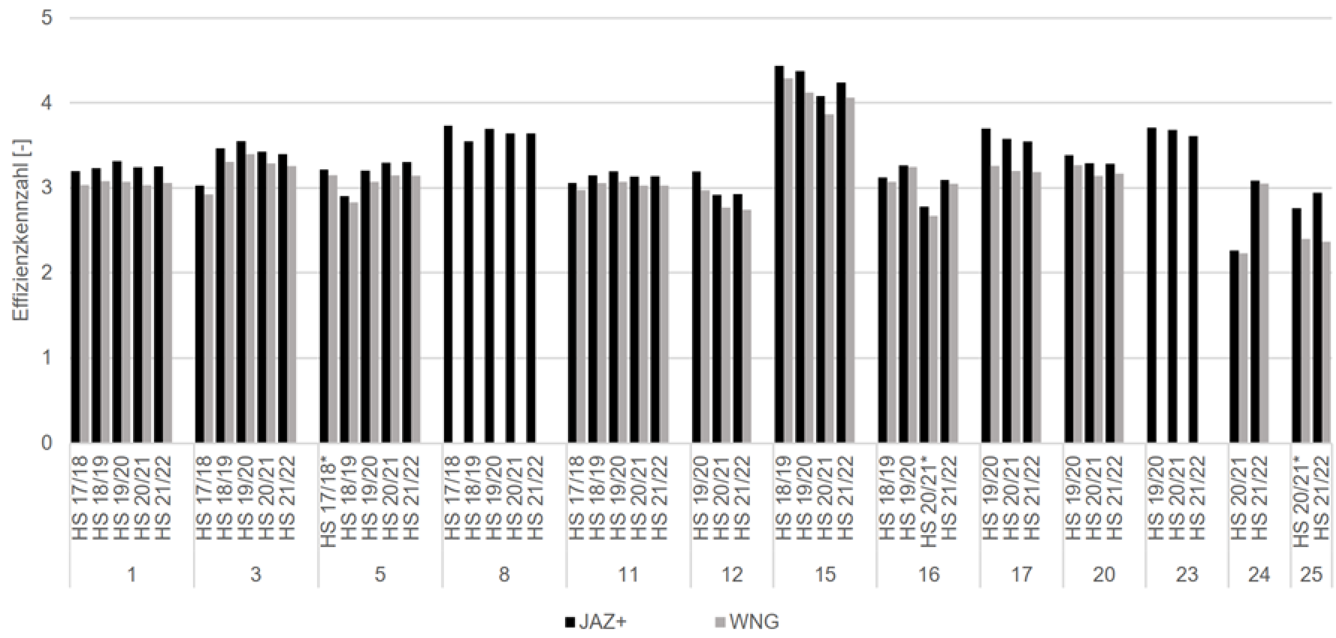


Figure 24: Annual seasonal performance factor (SPF) and Heat Utilization Efficiency (HUE) of air/water heat pump systems, Source: “Report on Field Measurements of Heat Pump Systems for the Heating Season 2021/22”, Swiss federal Office of Energy

3.4.2. Research on air-to-water heat pumps in Switzerland

The efficiency of heat pumps is being analyzed in various projects. Not only the COP is assessed, but also the extended system limit.

A field measurement study has determined the following values for air-to-water heat pumps:

The average outdoor temperature across all buildings was 12.2 °C in the 2021/22 heating season (so it is not 1:1 comparable with Harbin).

The evaluations showed that the majority of the systems are highly efficient and run robustly.

Major defects were only discovered very rarely. The greatest potential for optimization was identified on the control technology.

Examples of this would be

- Optimize heating flow temperatures (optimize heating characteristic)
- Avoid heating on summer days (partly also on days with T_AVG > 25 °C)
- Prevent heating and cooling on the same day
- Water treatment: Heat pump preheating for legionella circuits
- Water treatment: Charging time at the highest possible ambient temperature

Note:

Heat pumps in alpine regions (with comparably cold temperature conditions in winter) can be implemented without any special requirements. However, if you want to receive financial subsidies, you must provide project-specific proof that a COP > 3.1 is achieved with a bivalent system.

A bivalent system could also be interesting for DP Harbin. It has been shown that in very cold regions, systems with a combination of air source heat pumps and peak load boilers can be particularly economical with a coverage of 80 % via the pump and 20 % via the boiler with a control system specially adapted to bivalent operation.

3.4.3. Ventilation

As is often the case with refurbishments, there was not enough space in the DP Harbin to accommodate a fully equipped mechanical ventilation system with supply and return ducts.

A compound ventilation system was presented as “Swiss Technical Expert Input” of 5 Feb 2024.

A compound ventilation system has disadvantages, such as the installation and maintenance of active ventilation components (active overflow units) or the possible mixing of supply and exhaust air in corridors.

Considering the low requirements for available space and low material usage - which can be a noticeable saving in construction emissions - it is a good customized solution.

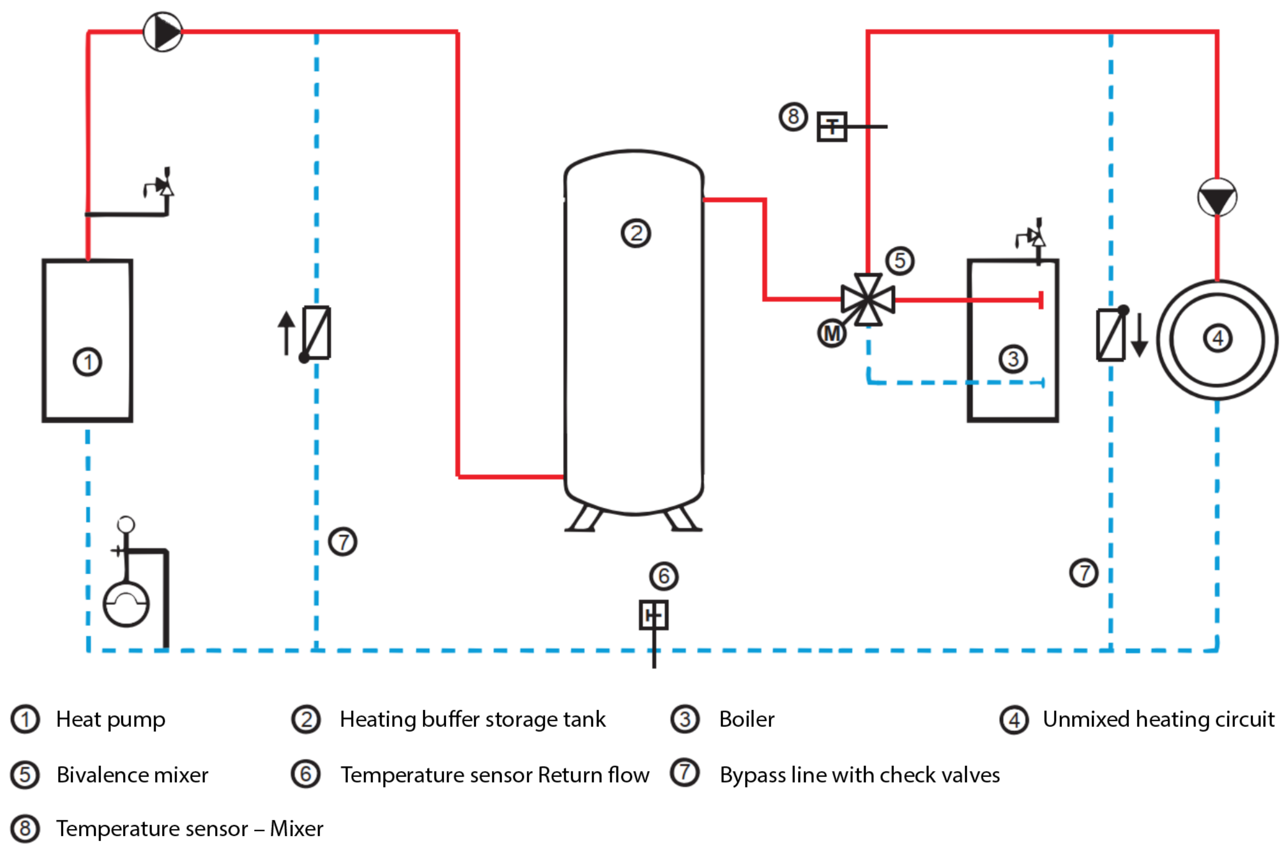


Figure 25: Bivalence mode for high water capacity boilers, series buffer tanks and by-pass lines with non-return valves (Bundesverband der Deutschen Heizungsindustrie - Federal Association of the German Heating Industry), Source: Federal Association of the German Heating Industry

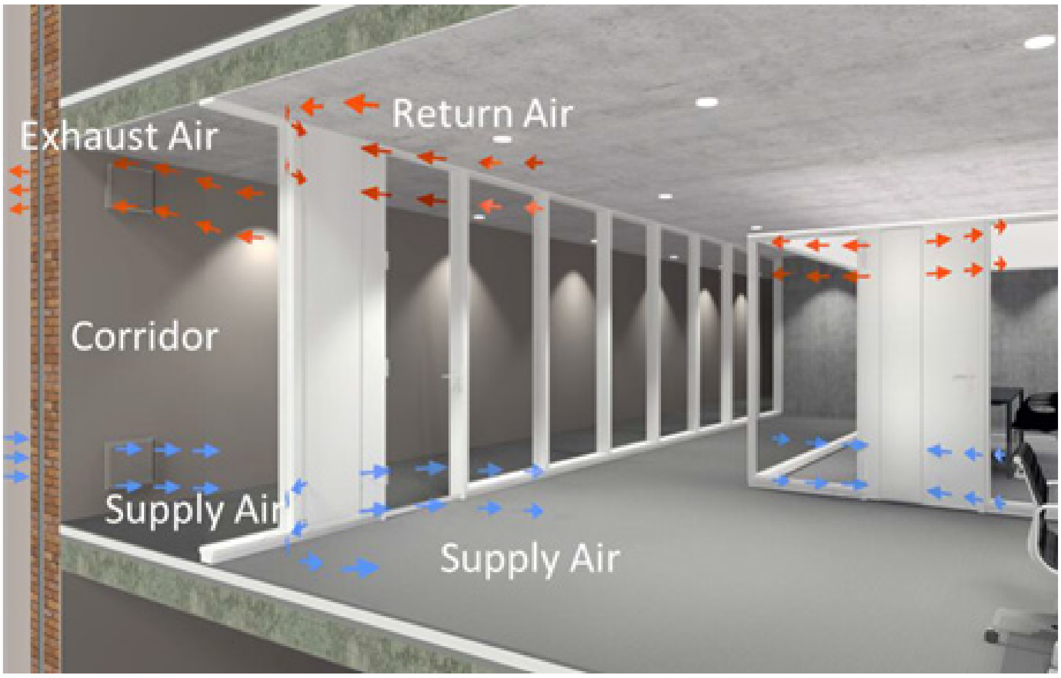


Figure 26: Air flow diagram in an office equipped with compound ventilation elements (Swiss Expert Technical Input, 05. Feb. 2024), Source: "Swiss Technical Expert Input Lighthouse Project: Harbin Retrofit Project" Feb 5th 2024

3.4.4. Air Conditioning

«1/3 of the area has heating but no cooling, 2/3 of the area has both heating and cooling.»

In administrative buildings, it may be essential to install mechanical conditioning due to the internal loads. In view of the provision of cooling by means of heat pumps and in-house electricity production via photovoltaics, it is possible to realize cooling in summer with low operating emissions.

The (automatic) external sun protection and the thermal inertia of the rooms support the thermal insulation in summer.

Optimizing the thermal mass in combination with natural night-time cooling can help to reduce the cooling capacity requirement. In a solid construction, the paneling of walls, ceilings and floors is particularly important here (exposing the reinforced concrete structure).

We assume that the requirement for cooling, as well as the proof of comfort (overheating), has been proven mathematically by means of dynamic simulation.

Figure 27: Lecture Hall (visualization), Source: Heilongjiang Cold Land Building Science Research Institute

3.5. Life cycle assessment

Greenhouse gas emissions from operation - production

As already mentioned, regulations and technical developments have significantly reduced operating emissions (greenhouse gas emissions GHG) in recent decades. However, production emissions ("grey emissions" GHG) have remained virtually unchanged.

In Switzerland, according to the consumption principle - considering the entire life cycle, i.e. construction and operation - approximately the same amount of greenhouse gas emissions are currently generated every year by the construction and disposal of buildings as by the operation.

The grey emissions are distributed among the various element groups as follows (generic Swiss building):

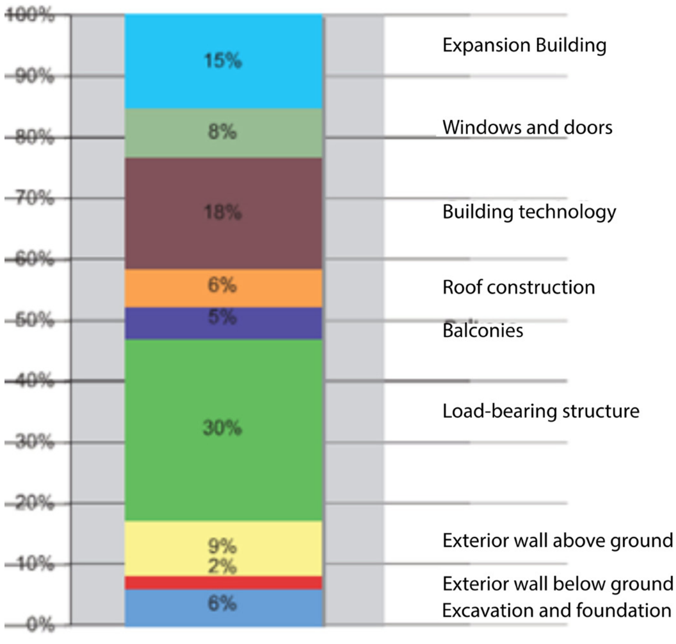


Figure 30: GHGE Construction of generic building Switzerland, Source: SIA 2032:2010 "Gray energy of buildings"

The distribution shows that the most effective measure in terms of construction emissions is the preservation of a building, as around a third of the emissions can be "avoided" by preserving the supporting structure compared to a new one.

This means that the greatest potential for GHG savings exists in the preservation of existing buildings and is practically always preferable from an ecological point of view.

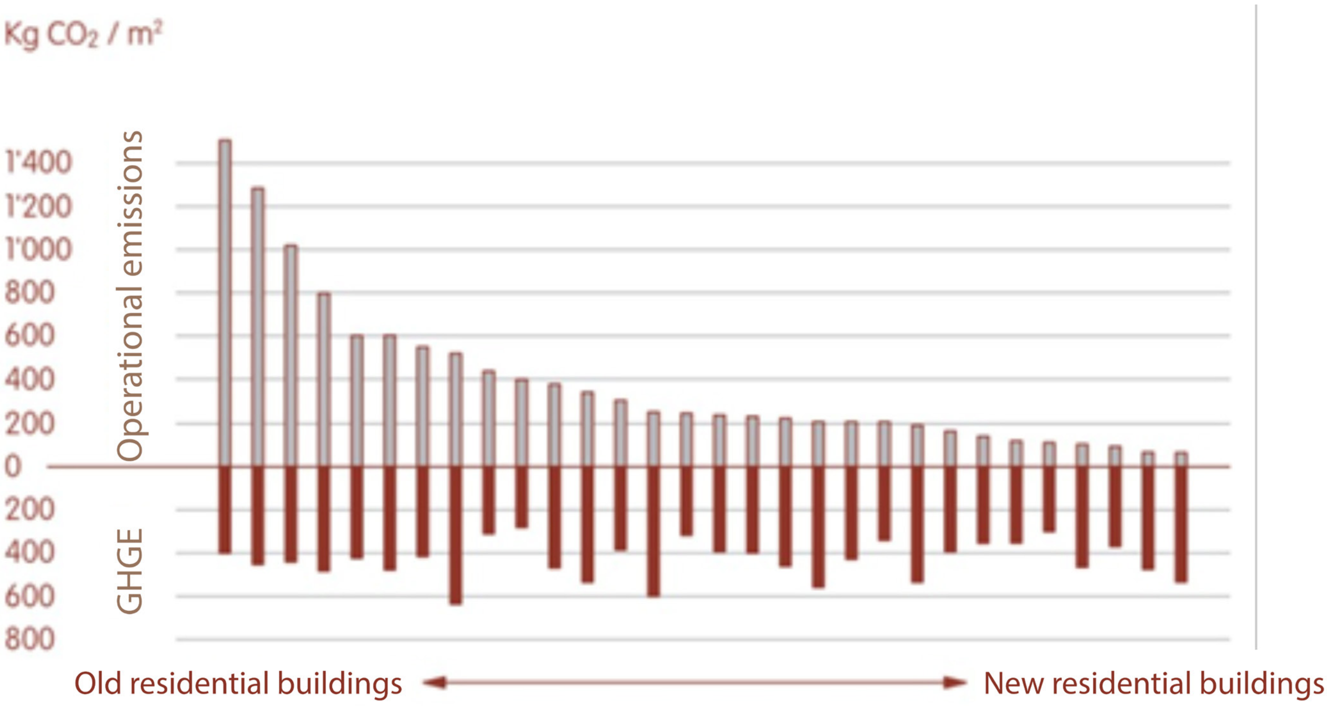


Figure 28: Operation versus Construction (GTHG), Source: "Reuse in Construction", Salza 2020, report prepared on behalf of Federal Office for the Environment

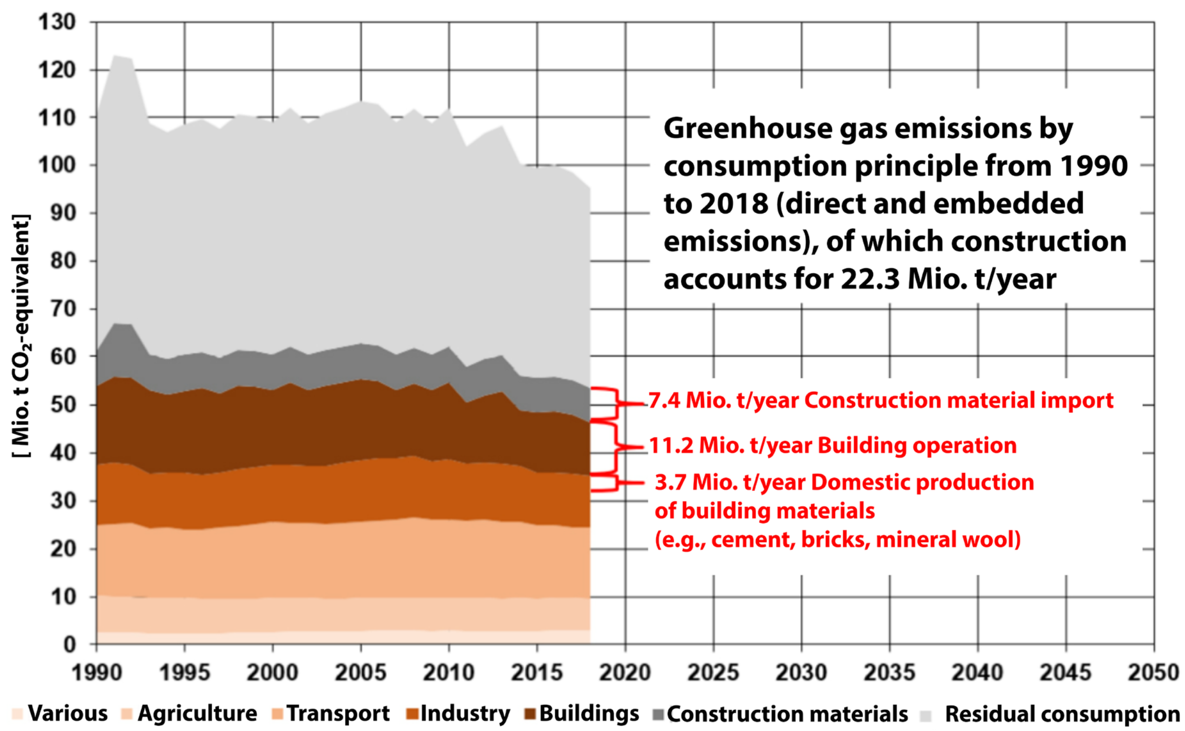


Figure 29: Source: Office for Buildings, City of Zurich

3.5.1. Greenhouse gas emission limits

China

- Operation
  - «Low-Carbon» 25 [kg/m^2a]
  - «Nearly Zero Carbon» 18 [kg/m^2a]
- Construction
  - «Whole Process Zero Carbon Building» 350 [kg/m^2]

Switzerland

- Operation
  - SIA 2040: 6 [kg/m^2a]
  - SIA 3910/1: 5 [kg/m^2a]
- Construction
  - MuKEn2025 new construction «office building» 780 [kg/m^2] (13 [kg/m^2a])
  - Minergie-Eco Retrofit «office buildings» 480 [kg/m^2] (8 [kg/m^2a]) (property-specific limit value for a "similar" building)
  - SIA 2040 & SIA 390/1 Retrofit «office building» 300 [kg/m^2] (5 [kg/m^2a])

Operating emissions are strongly linked to the carbon intensity of the heat carrier. The differences are clearly visible when comparing electricity. Today, China still has a carbon intensity that is about 4 times higher than in Europe, but this is expected to change significantly in the coming decades.

This makes it clear that dynamic limit values are required to reflect the changing situation and to be able to track the path to net zero.

The fact that construction emissions outside of labels will be given limit values and become legally binding is still under development and will probably not be implemented in Switzerland for another 5-10 years.

The standardized method of calculation and the standardized and verified material data have provided important insights from working with the labels.

3.6. Energy Performance Gap (EPG)

In Switzerland, it is becoming increasingly apparent that there can be a significant discrepancy between calculated heat demand and actual measured heat consumption.

A study has analyzed 35000 residential buildings. It has confirmed the existence of the EPG in Swiss residential buildings, whereby buildings with a low a low energy standard (class G) consume around -40 % less weighted energy for heating and hot water than calculated (negative EPG), while efficient buildings (class B) consume +12% more (positive EPG).

We have read that energy efficiency is also being monitored at DP Harbin. It will be exciting to see how the temperatures and energy flows develop in comparison to the planning.

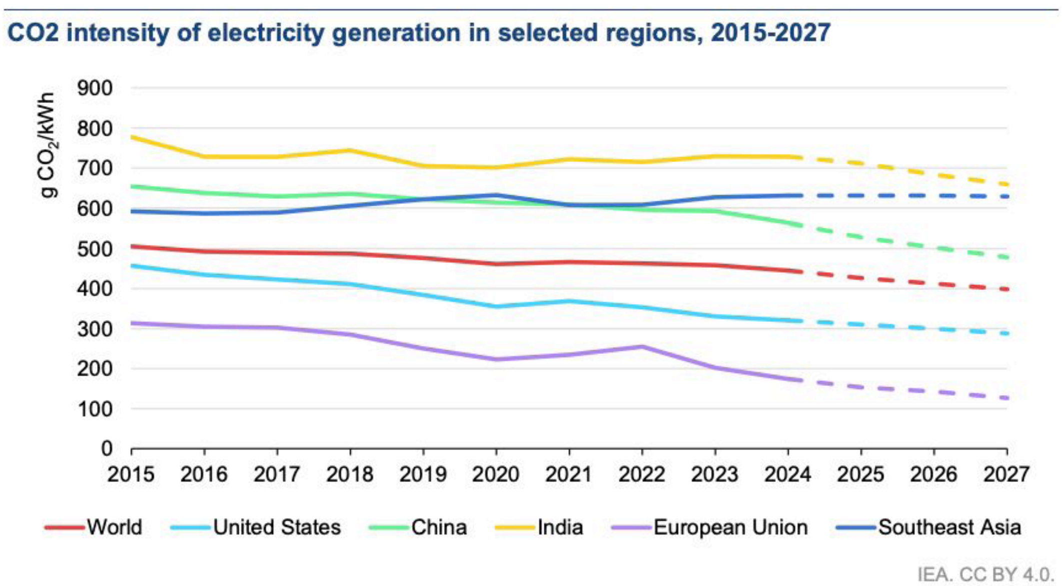


Figure 31: Intensity of electricity generation in selected regions, 2015-2027, Source: IEA

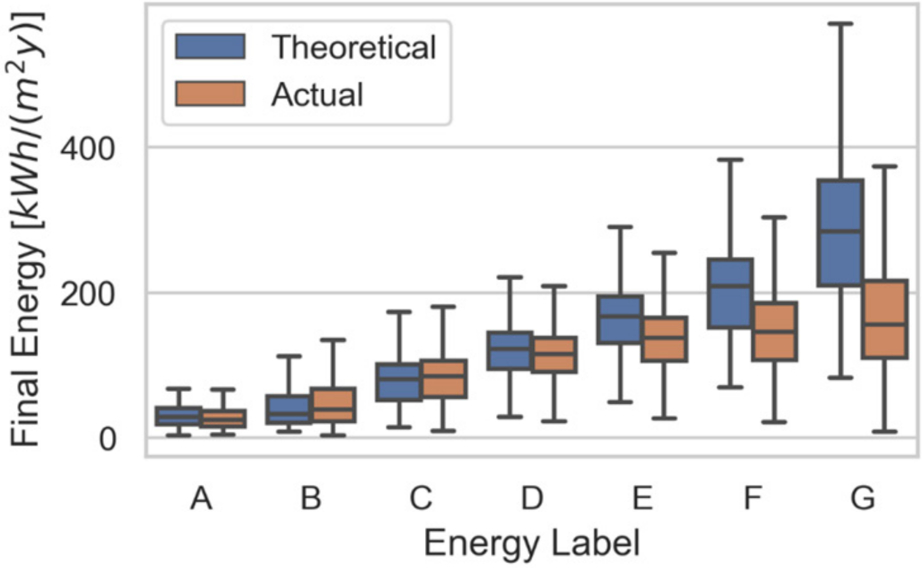


Figure 32: Energy performance gap for retrofits, Source: literature study final report, City of Zurich, 2022
https://www.stadt-zuerich.ch/content/dam/web/de/aktuell/publikationen/2022/studien-netto-null/energy-performance-gap-in-standsetzungen-studie.pdf

3.7. Design for Disassembly / Adaptability

A key factor influencing the life cycle assessment is the durability or life expectancy of the various components, as well as the flexibility potential of utilization.

Repairs, adaptations and additions will occur in every building.

In this respect, it is also known that the operating costs, viewed over the entire life cycle, always exceed the construction costs.

As a basic principle, the aspects of ISO 20887: 'Sustainability in buildings and civil engineering works - Design for disassembly and adaptability - Principles, requirements and guidance' can be applied:

General

These principles apply to assemblies and systems within a constructed asset that can be disassembled at the end-of-life, or renovated, with the potential for components to be used for other purposes.

Ease of access to components and services

Ease of access in design allows for a material, component, or connector of an assembly, especially those with the shortest anticipated life cycle, to be easily approached, with minimal damage to and impact on it and adjacent assemblies.

Independence

Independence is the quality that allows parts, components, modules and systems to be removed or upgraded without affecting the performance of connected or adjacent systems. Reversible connections are a very important point here.

Avoidance of unnecessary treatments and finishes

Choice of finishes can limit the options for reusing or recycling the substrate, particularly if potentially hazardous substances are included. To support disassembly, finishes that can prevent the substrate from being re-used or recycled should be avoided.

Supporting re-use (circular economy) business models

This principle is concerned with supporting the market for re-used, refurbished, remanufactured and recycled materials and products now and in the future, in support of circular economy business models. Design approaches to provide resources for future construction works should facilitate the use of secondary materials and resources in buildings and infrastructure.

Circular economy business models can be: Reusability, Refurbishability, Remanufacturability, Increased recycling.

Simplicity

Simplicity is the quality of an assembly or system that is designed to be straightforward, easy to understand and meet performance requirements with the least amount of customization.

Standardization

Standardization is concerned with the use of common components, products, or processes to satisfy a multitude of requirements.

Practices that can support the principles are:

- When possible, materials and components, which can be easily, safely, and more cost-effectively replaced or removed and transported, should be used.
- A means of handling components during disassembly should be provided. Handling during disassembly can require points of connection for lifting equipment or temporary supporting devices.
- Components that are sized to suit the intended means of handling should be used. Various possible handling options at all phases of assembly, disassembly, transport, reprocessing, and reassembly should be considered.
- Spare parts, and on-site storage for them, should be provided, particularly for custom-designed parts, to allow broken or damaged components to be easily disassembled and replaced, and to facilitate minor alterations to the design.

Application

Nowadays, with the constant optimization with regard to short construction times, these topics are unfortunately not established in the application.

In our Zirkular projects, for example, we try wherever possible not to install the electrical cables in the structure so that they are easily accessible..

Figure 33: Example of surface-mounted electrical installation, Source: baubüro in situ «K118»

3.8. Drafting a standard process for retrofitting

In addition to the points mentioned so far, our group of companies mentioned at the beginning is trying to include the type of use and users in order to achieve sustainable solutions in building refurbishment.

In order to establish a standard process for the refurbishment of listed and other existing buildings, we recommend the following steps:

First, Overarching objective:

Creation of a climate reduction pathway and derivation of cross-project targets from this. (e.g. SIA 2040)

Second, Project based solutions:

- Technical/ structural as-built analysis and scenarios derived from this for the conversion / further use / refurbishment of the building.
- Analysis of the building' s current use and scenarios derived from this regarding possible uses and users of the building.
- Phase-appropriate feasibility and variant studies (see 2.2.1)
- Ideally, solutions are found with a low level of intervention and use close to the original use.
- Ideally, solutions should be found with suitable users who accept or appreciate certain imperfections in the building.

Third, Structural solutions:

- Life cycle analysis of construction and operation, taking into account space efficiency.
- Emission-optimized choice of materials as well as reparability and deconstructability of the structures

Fourth, Monitoring and post-occupancy evaluation.

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