Integrated planning for the realization of a public indoor pool with concepts of passive house technology

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to implement. This goal must be communicated early and specifically so that it is fully taken into account in all planning steps. Those aspects that have a significant influence on the energetic concept of the building must already be examined in the preliminary design phase. Orientation, compactness and zoning are to be mentioned here. These requirements have far-reaching effects on the energetic concept of the building and are particularly important for the economic implementation of the project. It is all the more important that all specialist planners discuss possible solutions together in this early phase. So are decisions regarding compactness and zoning from both design and building aspects

as also under Aspects the

Weighing up daylight supply and fire protection. In the indoor swimming pool project presented here (Lippe Bad Lünen), the zoning and compactness is largely determined by the use alone. Nevertheless, questions regarding the location of the ventilation units and the associated ductwork must be considered from the start. This was discussed on the basis of several basement variants in collaboration with the specialist planners. The given boundary conditions of the existing building to be integrated (location, cubature) influence both the solar gains and the possibilities for daylight supply in the hall area. Here, too, the results of the daylight examinations could only be effectively and inexpensively incorporated into the planning process through early, joint considerations.

The principles of energy-saving construction must increasing

The level of detail of the planning must be taken into account in order to avoid frequent correction runs. The planning with regard to airtightness and freedom from thermal bridges is particularly worth mentioning here. The coordination of the details by the specialist planners helps to identify and remedy collision points at an early stage. Only the integral planning process and the joint control of the planning status of all specialist planners are suitable for guaranteeing a high-quality starting point for the implementation of the construction project.

Special features compared to conventional buildings must already be conveyed in the tender rich in understandable details. All executing companies for the building envelope must know that a particularly airtight version can be realized, the quality of which is checked by means of a blower door test. All specialist planners have the special task of using detailed planning and descriptions (qualities, work processes, special measures) to convey each bidder's specific tasks and performance areas so that the bidder can calculate his offer clearly and in a cost-effective manner. On the part of the client, there must be a willingness to be more committed to

Process monitoring and quality assurance compared to standard projects.

2nd Summary and conclusions

With the planning of the Lippe Bad Lünen it was possible to implement an indoor pool with concepts of passive house technology. The basic investigation of the building physics and

technical conditions for the implementation of the Passive house concept in the public indoor pool (pool company Lünen and PHI 2009) was the basic foundation for this. Through the

thermal very high quality building envelope could the Transmission heat requirements can be significantly reduced relative to standard new buildings and even more clearly to existing bathrooms. The decisive thermal improvement of the building envelope, in particular the transparent components, results in higher minimum surface temperatures (see Figure 1), which makes it possible to increase the relative humidity in the bathroom.

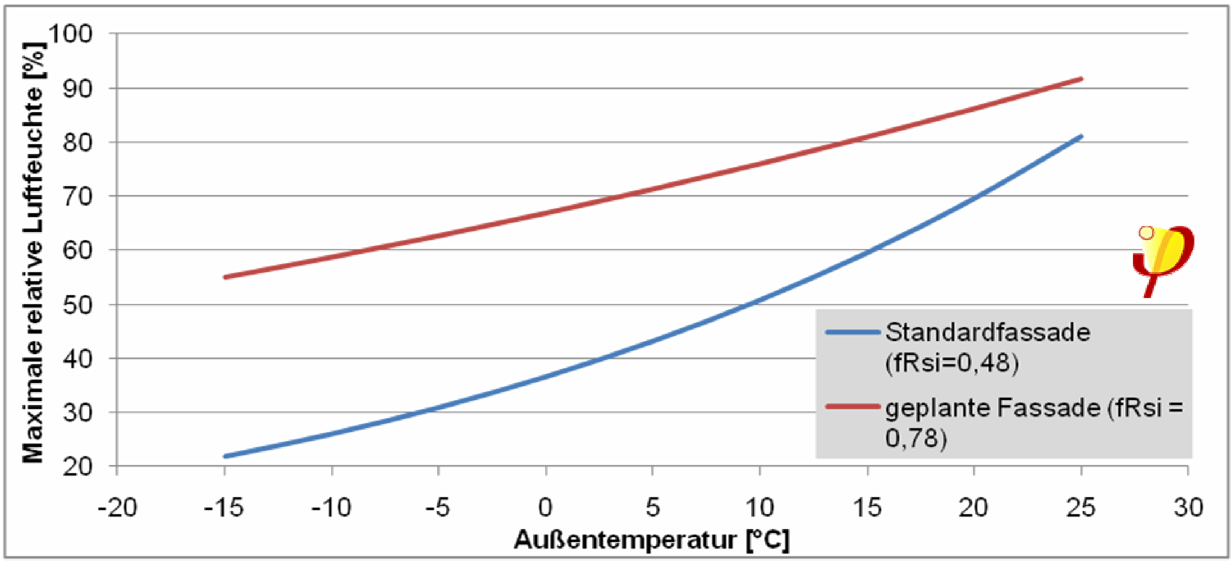


Figure 1: Maximum condensation-free room air humidity of a standard facade (aluminum Support system, double glazing, aluminum edge bond) and the planned facade depending on the outside temperature (source: PHI).

This measure significantly reduces losses due to evaporation of pool water. Through the consistent use of extremely high quality ventilation heat exchanger, as well as an intelligent ventilation control, the air volume flows and ventilation heat losses are significantly reduced.

Heating and water heating work consistently with low-temperature heat; highly energy-efficient electrical systems are used throughout (lighting, pumps, motors).

According to the current state of energy balance using a modified passive house project planning package (PHPP), the final energy requirement could be reduced to 549 kWh / (m²a) by these measures.

In connection with the two combined heat and power plants at the Lippe Bad site, one of which is operated with biogas and one with natural gas, the use of waste and condensing heat can be carried out at a low temperature (see figure
2) achieve extremely advantageous primary energy factors for heating and hot water production of less than 0.1. The result is a primary energy requirement of only 409 kWh / (m²a). It is expected that this value will decrease further in the further course of planning due to the specification of the plant technology.

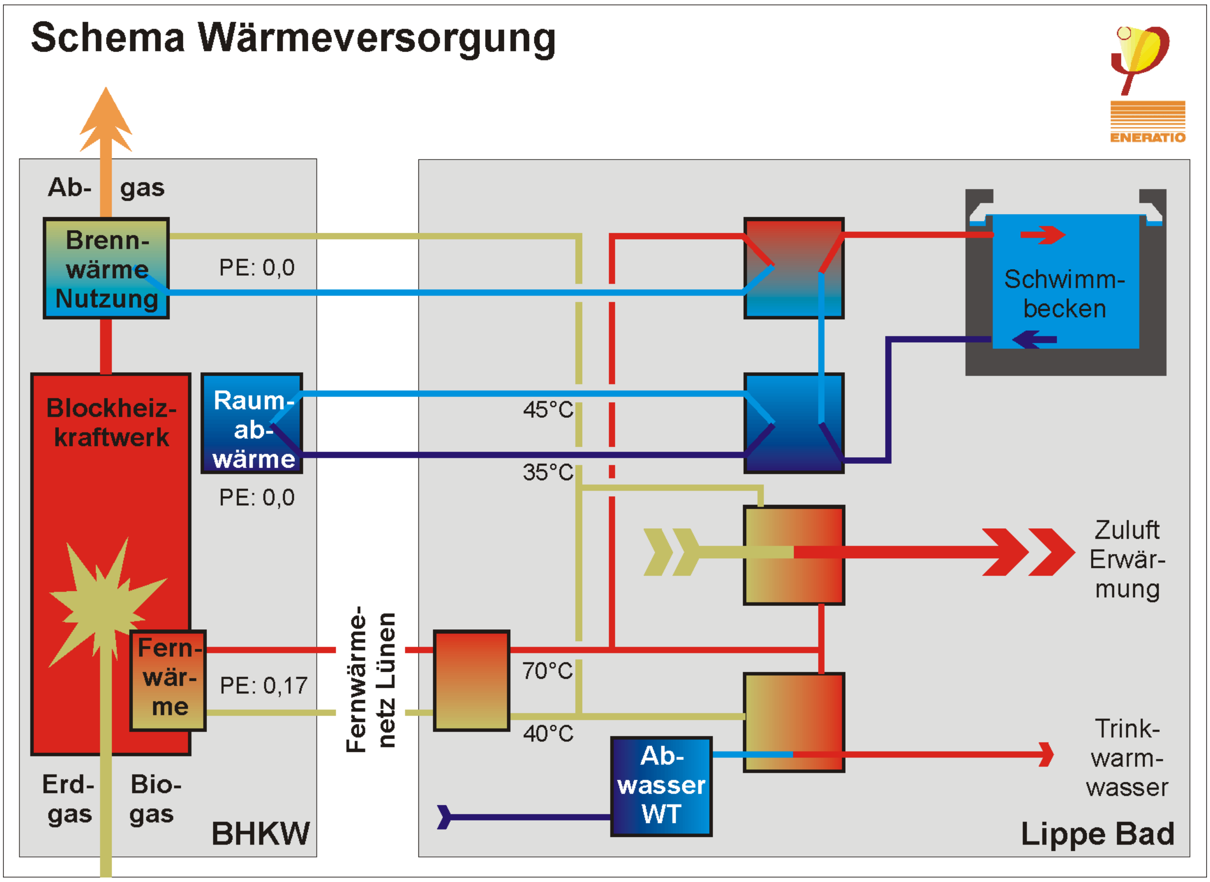


Figure 2: Scheme of heat supply via the combined heat and power plant (graphic: PHI)

The use of an ultrafiltration system proved to be an economical variant. Water recycling is possible due to the rinsing water that is generated almost continuously during ultrafiltration (see Figure 3). A large part of the rinse water is treated and reused as pool water. Another part substitutes fresh water for toilet flushing. Economical fittings and toilet and urinal flushing ensure further savings, so that a reduction in the drinking water requirement of approx. 67% is expected.

It could be determined that the use of passive house technologies does not result in additional expenditure in the area of fire protection. A well-thought-out and innovative cleaning concept, which is also based on the experience of the operator and which intervenes deeply in the design of the building and the system technology, is expected to result in considerable savings in operating costs, as well as savings in water and cleaning chemicals. The concept makes it possible to relocate cleaning work to a greater extent, sometimes also during the low-load opening times of the bath. As a result, the reduction in the total operating time also results in a reduction in the energy requirement.

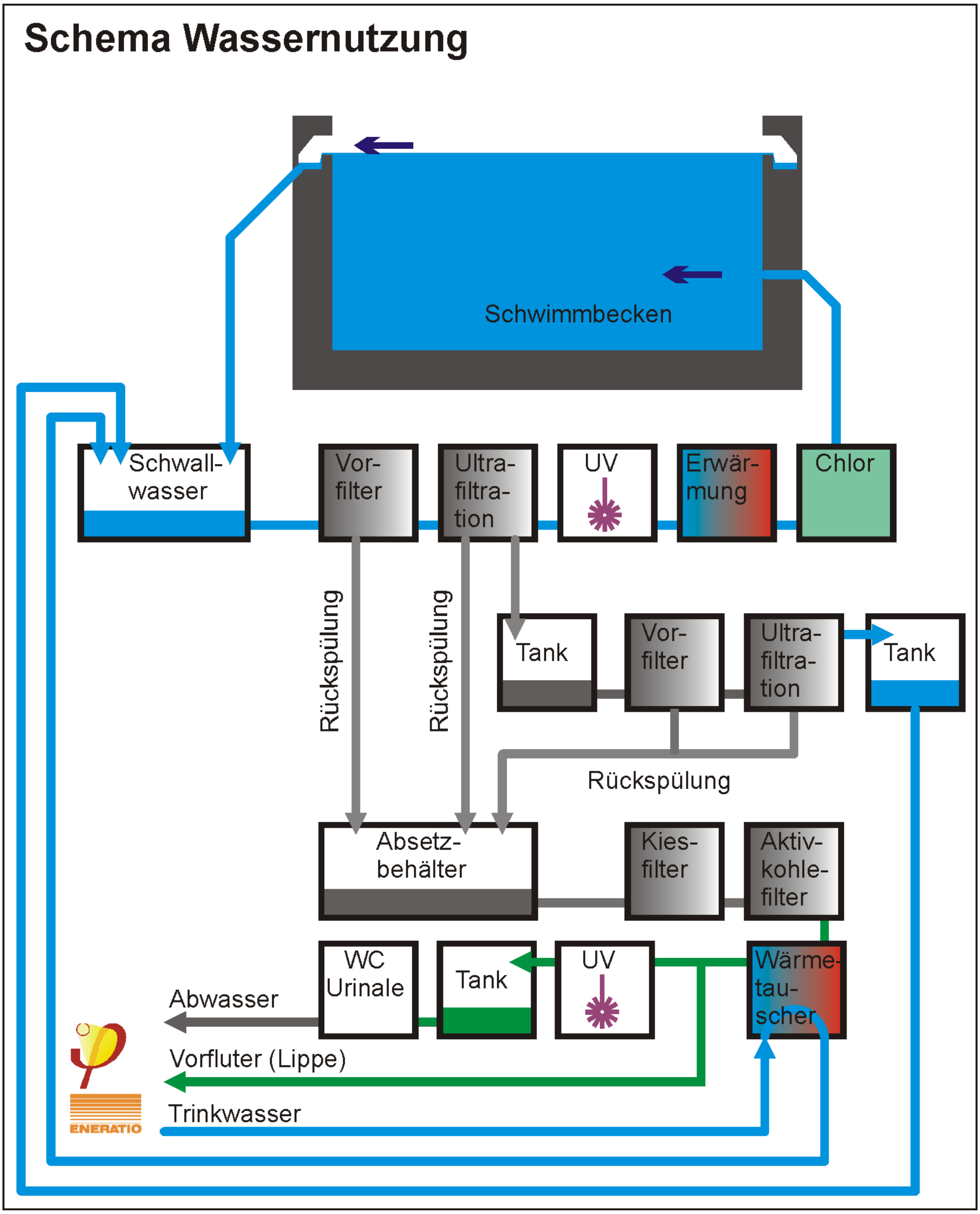


Figure 3: Scheme for filtration and water recycling (graphic: PHI)

In the integrated planning process, diverse approaches to energy and water saving could be formulated across the respective trade boundaries. The planning always developed imaginatively. Through the desired cooperation between science and practice

were innovative in the team

Solution approaches achieved and developed tangibly. Every member in the integrated

As a result, the planning team has learned and gained new knowledge. This clearly benefits the overall project.

The previous construction shows that quality assurance measures must be applied consistently and permanently. Many routine workflows in common construction practice, covering almost all construction trades, do not meet the requirement for execution quality and attention to detail that is inherently associated with passive construction.

Very detailed and transparent monitoring in bathroom operations is essential. This is the only way to further optimize operations and qualify the selected solution approaches. Particular attention must be paid to the relevant conditions where the current state of the art does not correspond to the operating regime of the Lippe Bad with a passive house concept. The functional proof of an indoor swimming pool with passive house concepts is expected with particular interest, as the ever increasing demands for the Lippe Bad project show.

3rd introduction

3.1 The integral planning as a project basis

The integral planning of an indoor swimming pool is much more than the preparation of strategies for minimizing the need for heat and electricity, because the use and handling of drinking water, chemicals for water treatment and hygiene, as well as the amount of wastewater that is generated, also affect operating costs and environmental conditions. Another indispensable component is the intensive involvement of the employees experienced in the bathroom business (knowledge and experience) in order to improve future working conditions and work processes and to create sustainable qualities that also promise savings in maintenance and renewal requirements.

Against this background, it becomes clear that the planning phase is of crucial importance for the implementation of innovative concept ideas. A planning service based on extensive knowledge and imaginative, taking into account the relationships between architecture, quality of use, technology requirements and costs is essential. Planning is fundamentally decisive for the success of the project and additional work is required in an integral planning process, because the construction and follow-up costs can only be influenced in the planning phase.

Looking at the life cycle costs of an indoor pool project, it can be deduced that additional services for a high-quality planning process are very economical, provided that sustainable operating cost savings are achieved without sacrificing the requirement profile and quality of use. While the life cycle costs on average of different building types (from residential buildings to administration buildings, hospitals to schools and kindergartens) are determined by 20% via the investment and 80% via the operating costs, the shares for indoor swimming pools are around 10% investment and 90% Operating cost. It follows that in medium-sized indoor swimming pool projects (investment € 14 million, useful life 40 years,

annual cost increase 1.95%,
Dismantling costs € 0.6 million) with 1% savings in operating costs by € 1.3 million lower life cycle costs. Another motivating factor is that the additional expenses for achieving new buildings that are energetically and functionally sustainable are generally very low-risk investments for the future. The passive pool innovation approach was based on the fundamental investigation of the building physics and

technical conditions for the implementation of the
Passive house concept in the public indoor pool [PHI 2009] extensively elaborated with requirements and solutions. This forms the very specific requirement profile for the integral planning to prepare the practical implementation for the Lippe Bad in Lünen.

The indoor pool cover according to passive house requirements is the first building block for energy saving. The transmission heat losses are significantly reduced and higher internal surface temperatures are achieved. With higher internal surface temperatures of the external components, the limit of falling below the dew point is shifted towards higher indoor air humidity. This is the second building block for energy saving, because with increasing room air humidity in the hall area, the evaporation performance of the pool water decreases, and regardless of other influencing factors, the required air exchange and thus the ventilation heat loss can be reduced. In this context, the execution of the indoor pool cover in passive house quality can be seen as an "entrance fee" in order to be able to tap further savings.

lies in the building and
Process techniques of an indoor pool and there are very extensive planning tasks to work out functional systems with favorable efficiency conditions.

<u>What are the criteria that determine success in the integral planning process?</u> To answer this question, the conditions, measures and functions based on the experience gained in the specific process are dealt with as follows:

Client

The builder must make an uncompromising decision to implement the innovation approach while minimizing life cycle costs. Only with this basis is he undoubtedly convinced of the advantage of the integral planning process and ready to guarantee additional framework conditions (more planning time, project teamwork, planning budget). Due to the special situation, because here the builder is not only the erector of the building, but also experienced operator and user (courses), he is essentially obliged to manage the project management. The building owner and his employees experienced in the company must meet the requirement profile (usage concept, specification, Specify special detailed requirements) and consistently accompany the planning process with quality and cost assessment, which usually takes place over several solution approaches to the requirement profile, until the decision for the design variant. The builder must take special care that no optimization measures stand in the way of determining the building, because the users

decide based on the perceived and Quality of use, whether they will use the indoor pool repeatedly and will also recommend it. In the integral planning process, therefore, favorable conditions for quality of stay and use must be combined in an imaginative and functional manner with approaches to savings (energy, water, chemicals, cleaning, operation).

Experience in project management, interdisciplinary technical and economic understanding and adequately measured processing time are prerequisites for the committed execution of these detailed client functions.

Planning team and project organization

In order to be able to select the planning team appropriately, the target catalog (main objectives, advanced objectives) and the pending planning tasks should be defined beforehand. The main objectives of the passive indoor pool project dealt with here were defined in great detail by the preparatory basic examination of the building physics and technical conditions for implementing the passive house concept in the public indoor pool [PHI 2009]. Extended objectives resulted from the demands on energy and water-saving systems for the process technology specific to the indoor pool, accessibility and the expanded demands on improved room acoustics, the cleaning concept and the operational management. The goal in the planning process is not the perfection of a single work, but rather the overall design, which largely fulfills the complex target catalog, for which varied evaluations and considerations have to be made. This is teamwork. All main trades must be part of the team from the start be represented competently, with separate specialists for advice and fine-tuning to be consulted for separate details in the ongoing planning process, provided that the special task processing cannot be performed by members of the core team in accordance with requirements. These specialists can also be practically experienced technicians from relevant specialist companies / product manufacturers, to whose core competence is processing the

heard individual detailed questions (concrete example: conditions and Control systems for sliding doors in public functional areas). In order to create the framework conditions for effective teamwork favorably, as few different planners as possible, but as many experts as necessary should belong to the team from the start of planning. With regard to the technical building equipment, this principle means, for example, to involve a planning office that is experienced in several areas and not to have the sanitary, electrical, heating and ventilation technology trades processed by different offices.

There are also extended requirements for the individual team members. First of all, it should be clear that the client expects above-average commitment to innovation from all team members, which every team member must be willing to perform. In addition, everyone needs to bring along a high level of basic knowledge, communication skills and attention to detail with a high quality of service. If the client cannot access proven planning companies based on other projects / experiences, he should speak to a spectrum of service companies based on the demands made on team members and select new project partners based on references, personal impressions and general economic conditions.

In order to be able to perform the planning tasks in terms of quality, time and costs, regular team meetings (e.g. weekly at the beginning, then every 14 days) must be moderated by the project manager (client). In the overall process, the use of a planning server is recommended so that all members can easily exchange documents and plans digitally and at the same time transparently document the development steps / plan status. The developer receives an overview of the ongoing activities and the progress of the individual specialist planners as well as overall via the individual updates in the planning server.

Important tasks of all planners are to convey the peculiarities compared to conventional buildings and technical solutions already in the tender rich in understandable details. All specialist planners have a special task, with the help of a well thought-out detailed planning and

Description (qualities, work processes, special measures) to convey to each bidder his specific tasks and performance areas so that the bidder can calculate his offer clearly and in a cost-effective manner. To this end, it may be helpful to consult texts and plans already drafted with several specialist companies during the preparation of the tender documents, in order to eliminate inadequacies or ambiguities in the solution approach and in the service description. Even at the planning stage, it should be worked out in which work steps and in what way the executing companies in general and in particular for quality assurance are to be supported and monitored.

3.2 Project description

As part of a swimming pool concept for Lünen, Bädergesellschaft Lünen mbH is building a central indoor swimming pool on Konrad-Adenauer-Straße. The annual number of visitors to the new indoor swimming pool is forecast to be around 230,000. The bathroom is designed for sports and movement in the water. Basic aspects of planning are:

a) Reduction of operating costs through

- Construction of the new building and upgrading of the existing building with passive house components

high-quality insulated, thermal bridge-minimized building envelope high quality of

the building envelope with regard to airtightness efficient system technology,

cheap hydraulics use of renewable energy

- Increase in air humidity (thereby reducing evaporation and thus saving energy when heating pool water)

- Reduction of energy requirements for artificial lighting

- Water management

Bath water treatment by ultrafiltration process Backwash water use

Water-saving fittings and flushing systems

- optimized cleaning concept

b) consideration of the needs of people with disabilities through

- structurally supported integration of handicapped visitors in all areas (traffic areas / door systems / changing rooms / sanitary areas)

- stepless accessibility of all visitor areas

- Planning coordination in advance with disability organizations

c) Comfort and acoustics

- High internal surface temperatures

- favorable indoor air humidity (on average approx. 64%)

- low indoor air speed

- appealing material and color design

- good room acoustics due to low reverberation times and avoidance of flutter echoes

3.3 Building law basics

The planning law basis for the construction project was created in September 2009 by the development plan Lünen No. 201 V + E (section Lippe Bad).

The plan area is shown as area for public use. The stipulations of the development plan are adhered to by the planned development.

3.4 Optimization of the concepts for an ecologically sustainable and future-oriented location in Lippe Bad Lünen

Stapelmann und Bramey AG was commissioned by the Bädergesellschaft Lünen mbH to prepare the following plans for the future Lippe Bad Lünen:

Land use planning,

Open space design, traffic

planning,

Supply and disposal planning,

Construction management, open space architecture, traffic and access systems.

With this, Stapelmann and Bramey AG is contributing to the realization of the pioneering and stimulating project "Lippe Bad Lünen" with concepts of passive house technology.

The project also acts as an initiator for the development of the former Lünen heating plant, into an ecologically sustainable and future-oriented location. The area development with coupling of living, water and recreation is a building block to achieve the urban planning goals of the city of Lünen.

The guiding principles for the passive house indoor pool can be extended to the idea of an ecologically high-quality location. To realize this vision is it
It is necessary to bring in qualities in supply and disposal, in traffic planning as well as in the design of open spaces that take this idea into account. For this reason, the waste water is disposed of in the separation system. The entire surface water of the sealed areas and the pool water to be drained from the indoor pool are throttled and discharged into the area adjacent Lippe via an underground rainwater retention basin. Only the wastewater accumulating in the indoor pool is fed to the municipal mixed water sewer and thus to the public sewage treatment plant, where it has to be cleaned with a comparatively high amount of energy.

In the future, the surface sealing associated with the construction of the new Lippe Bath will reduce the groundwater recharge rate in these areas, but the surface water is not fundamentally lost for the groundwater in this area, because the rainwater accumulating on the traffic and roof areas and the post-treated pool water of the indoor pool will be on returned to the groundwater at a location near the lip. The heat supply is operated by a biogas CHP and a natural gas CHP integrated in the Lippe Bad Lünen. Both CHPs are operated with downstream flue gas condensing technology, which significantly improves efficiency. For the heat consumption of the Lippe Bad excess heat produced in combined heat and power (CHP) is always in the district heating pipe of the city of Lünen fed, and is thus available to meet the needs of many other heat consumers in the city of Lünen.

In the area of traffic planning, space savings and the reduction of noise are crucial for ecologically sustainable development at the location. The goal of the overall planning is also the improved accessibility of the indoor swimming pool (central location) and the entire lip triangle for non-motorized private transport, for public transport, school

and sports traffic. The motorized Individual traffic tends to be reduced. This is a reduced claim for sealed Parking facilities (Number the Parking spaces) and a Traffic noise reduction (fewer individual car arrivals and departures). The latter is further reduced by the successful concentration of traffic facilities in the northern area of the planning area. This keeps the southern and western surroundings of the bath largely free of traffic noise, which promotes the recreational function of the area and, in particular, favors the conservation and development of the protected fauna.

The ecology of the open space lives in particular from the comfort and this above all from the townscape, in particular from squares, from monuments, from the distant view. The monument is the sculptural indoor pool in its form and function. In contrast, the Lippe-Bad-Platz was designed. The flat and wide square with the solitary building is the basis and foundation for the entire Lipreieck area, with its function and architecture as more sustainable Identification and Orientation point, as a new landmark, shaping the location and thus the city of Lünen. The square itself should be the linchpin, the center, the meeting point of the entire lip triangle.

Other factors that played a role in the planning of open space architecture contribute to comfort, but above all to the energy-saving function and use of the Lippe bathroom. These are the inclusion of the surroundings (river Lippe and its dike landscape), the use of the existing topography and the lighting of the area.

In order to unite these characteristics, it was necessary to prepare the partial area of the Lippe bath uncoupled from the total area of the lip triangle. For this purpose, a project-related development plan was drawn up by Stapelmann and Bramey AG, which contains the following planning objectives in detail and ensures long-term planning law:

Design of the urban planning goal of the city of Lünen, formulation of the edge areas of the main dike of the Lippe as a quality feature, Consideration of the existing green and open space structures, functional transport

links,

Measures to ensure high quality architecture and to integrate existing architecture and

Utilization of solar and regional energy as well as environmental heat as a contribution to the sustainable and ecological integration of the indoor pool in the city of Lünen.

The site plan fulfills the functional requirements in an outstanding way and the building law requirements for the passive house indoor pool innovation project are met.

3.5 Project management

On the basis of the spatial program specified by the Lünen spa company, the design of the Lippe bath was drawn up in 2009 and coordinated with the client and the bodies involved (spa advisory board, school committee, disabled advisory board). The task of further planning was to adapt the bathroom to the requirements of a passive house standard, both in terms of the building envelope and the technology.

Due to the complexity, the path to a general contractor was not followed for the construction of the Lippe bathroom with components from passive house technology. The variety of details and the necessary monitoring of the execution qualities have contributed to the fact that an integrated working planning team was added at the start of the project, supplemented by individual specialist site management.

With the support of the Passive House Institute and the specialist planners involved, components and details were developed that meet the building physics requirements that exist in a swimming pool atmosphere. Figure 4 shows an organizational chart of the interaction of the project participants.

As part of the further implementation planning, materials were selected in part, the use of which is new in German swimming pools, but which promise significant advantages in terms of function and appearance. For example, plastic floor coverings are used in the area around the pool, which both provide the required slip resistance, but can also be laid without any joints. The high pool head is covered with a bench made of solid surface material. A little

Joint share should also help to avoid weak points and at the same time ensure favorable hygiene conditions.

Based on the implementation plans and the selected materials, the tenders are carried out across Europe in an open procedure. After the offers have been checked and a proposal for a contract drawn up, the order is placed by the Lünen spa company. Figure 5 visualizes the formal procedure for tendering and awarding.

In the course of construction, budget and costs, as well as the construction times and milestones, are monitored promptly by the project management. Deviations from the planning target are reported to the client and eliminated on time. The goals set are checked by means of project meetings scheduled every two weeks. Here

the client is also closely involved. Depending on

Work program, the regular project meetings are supplemented by individual special appointments. The client is also involved in detail here.

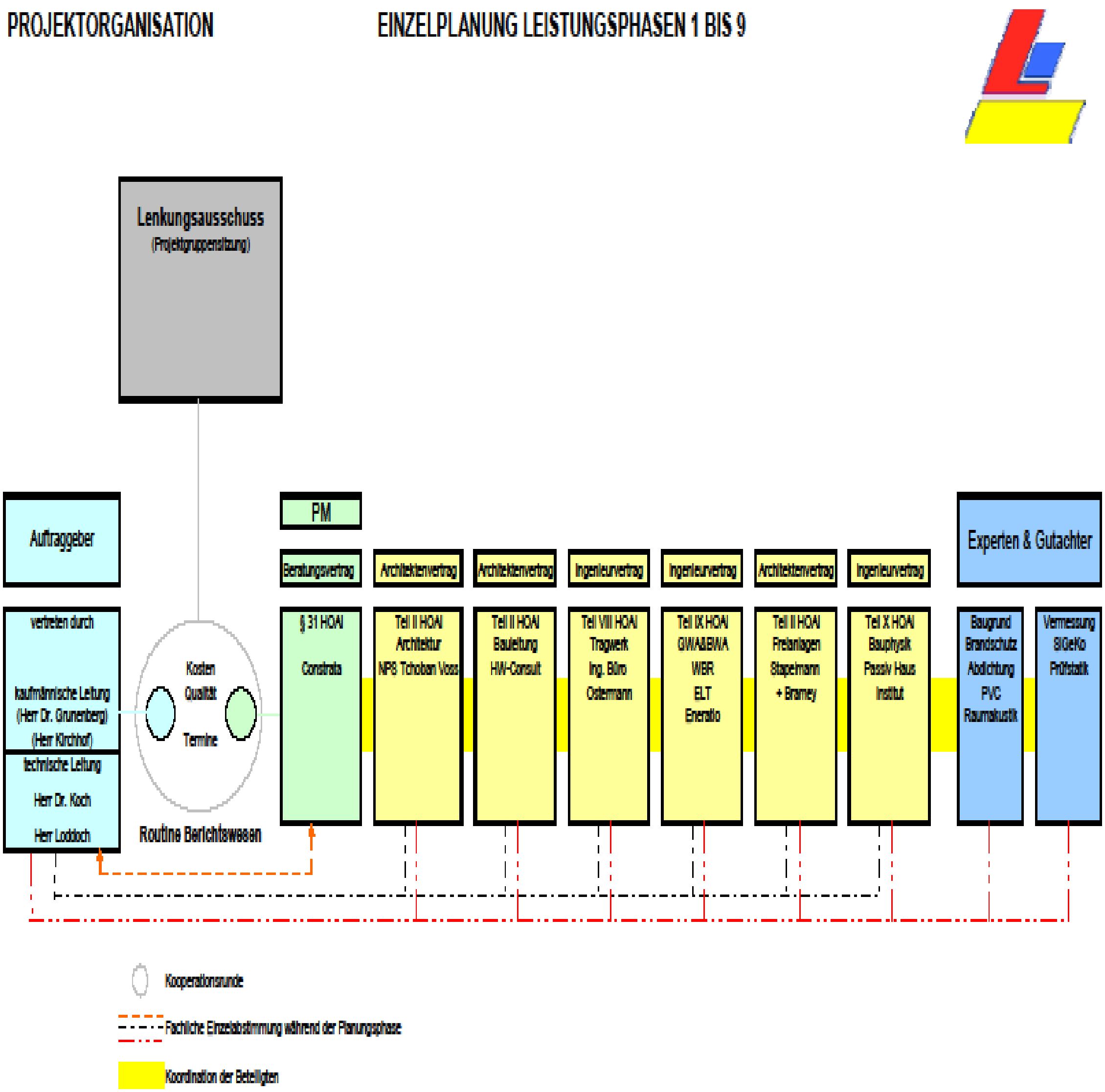


Figure 4: Project organization. Graphics: Constrata.

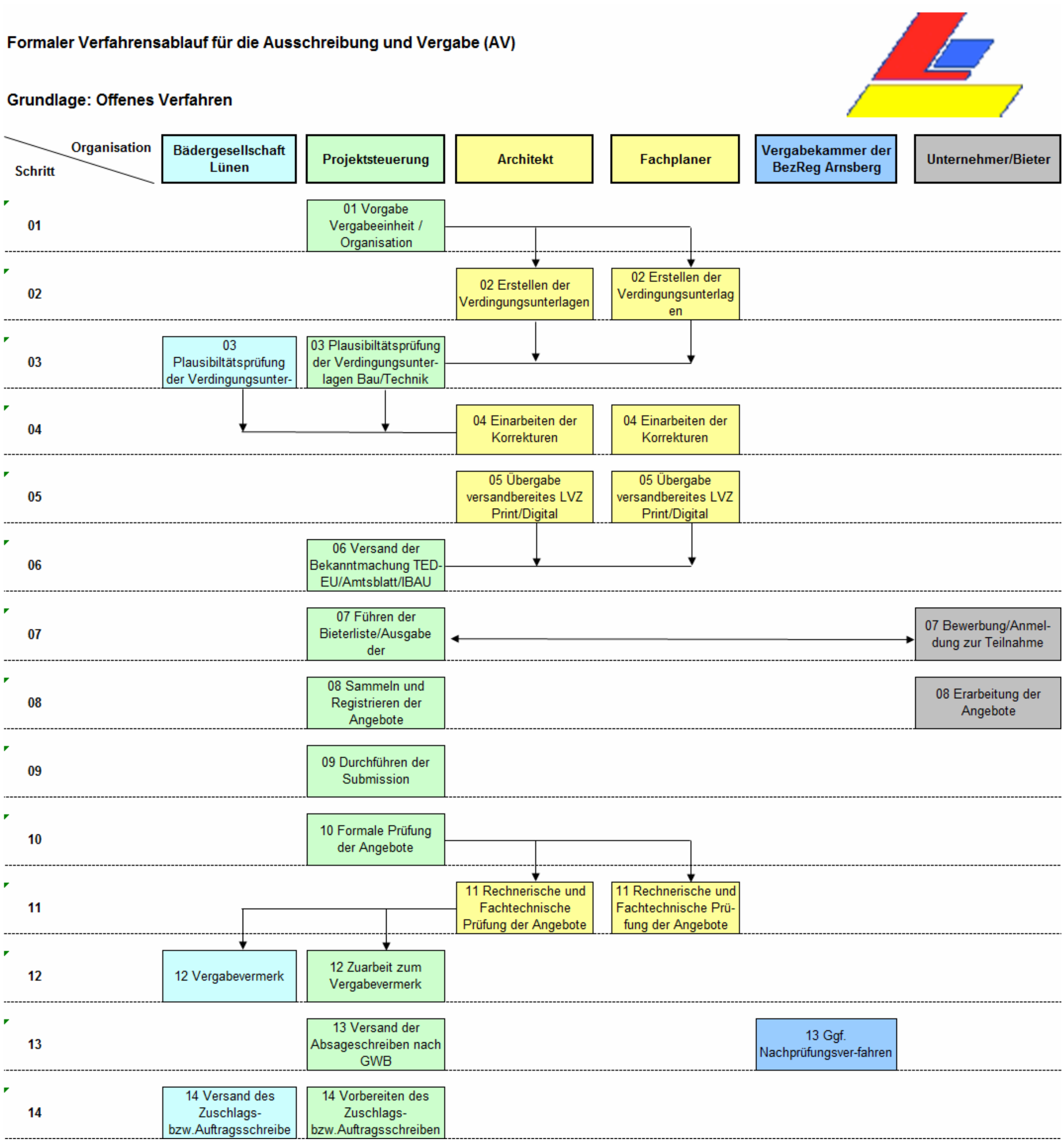


Figure 5: Procedure for tendering and awarding (graphic: Constrata)

4th building

4.1 building ground

The approximately 17,500 m² building plot is located in a central location near the city center on the Lippe and is owned by Stadtwerke Lünen GmbH. The property is built with a district heating plant (FHW) from the 1960s that is no longer used, cf. Figure 6.

A switching center for the distribution of electrical energy is integrated within the FHW. With the exception of the facade renovation and the thermal decoupling from the rest of the building, the control center remains unchanged.

The height of the future ground floor is 52.05 m above sea level. The maximum groundwater level is 46.17 m above sea level and therefore below the planned structure level. The 100-year flood level is specified as 50.13 m above sea level.

Figure 6: Building plot on the Lippe with existing buildings (Source: npstv)

The FHW's current property access via Graf-Adolf-Straße is supplemented by a new main access to the new building via Konrad-Adenauer-Straße.

For the development of traffic via Konrad-Adenauer-Straße, conversion and expansion measures are required as part of the public development. A reversing loop for school bus traffic is being built on the forecourt of the property. The drag curve also takes into account the use of articulated buses.

81 parking spaces managed by the pool company, seven short-term parking spaces and a bicycle storage facility will be built on the northern part of the property. The delivery yard for goods traffic and waste disposal is also located here.

The extinguishing water requirement is ensured by hydrants on the property and in the public area.

The media supply (electricity / water / telecommunications / district heating) takes place via supply networks of Stadtwerke Lünen. The wastewater disposal takes place via the public sewage system. Rainwater and pre-cleaned pool water are throttled into the lip via a rain retention basin.

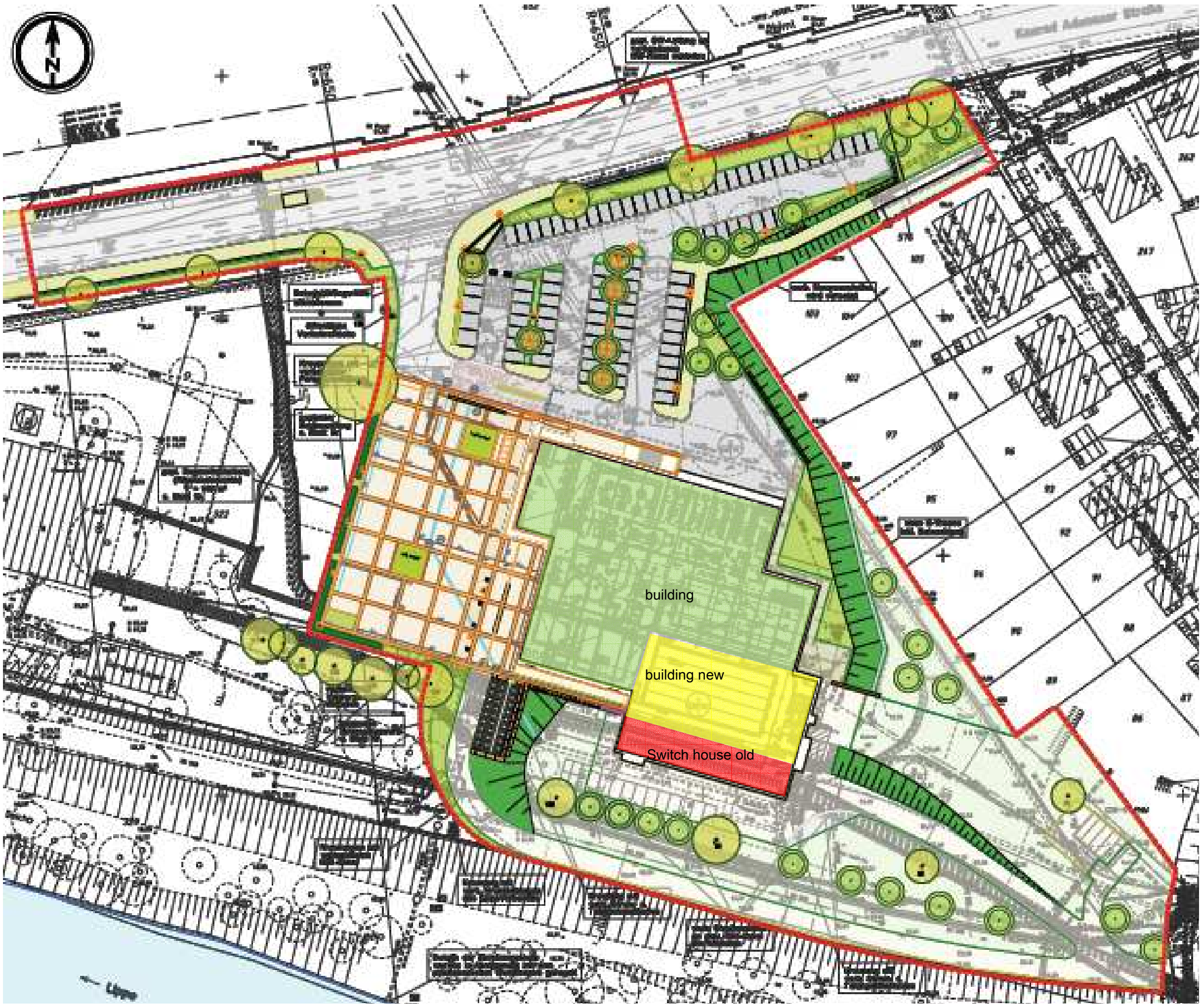


Figure 7: Plan of the outdoor facilities of the future indoor pool (source: npstv, supplemented: PHI)

4.2 Structure and area structure

The building structure is divided into three sections (see Figure 4): new building part (gross floor area approx. 5,000 m², including basement), former district heating plant of Stadtwerke Lünen (FHW, gross floor area approx. 2,100 m²), which is part of the new indoor pool through demolition and renovation measures) as well as the switching center integrated in the FHW (which is only given a new facade in the course of the renovation measures and is not the subject of this report). The upper edge of the raw concrete floor on the ground floor is + 51.85m above sea level. NN set.

All areas intended for bathers meet the structural requirements according to §55 BauO NRW and meet the requirements for barrier-free construction. DIN 18024-1 and DIN 18024-2.

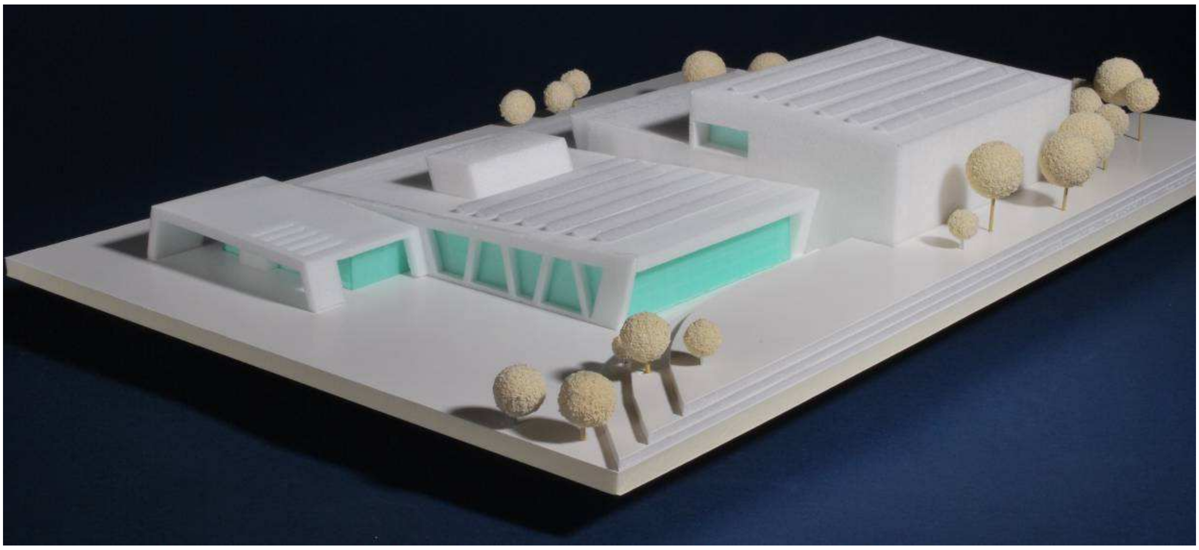


Figure 8: Working model of the bathroom, as of December 2008 (source: npstv)

The room program, based on the KOK guidelines for bathroom construction, is as follows:

ground floor

Entrance area:

A spacious canopy, a fully glazed windscreen as well as the foyer with counter for information and cashier machines supported by staff form an inviting entrance area. A seating area with a view of the bathroom is another part of the entrance area. Here it is possible to eat snacks and drinks from vending machines.

Figure 9: Perspective entrance area (Source: npstv)

Changing / sanitary area:

separation in collective changing area for school and club sports and Individual changing area For Individual bathers. By separating the Changing areas and the creation of a central entrance / exit to the pool area will be an undisturbed use of the recreation area for school / club sporting events Individual guests and families reached.
Skylights enable a good one in addition to facade window openings Daylight supply.

The pool access is via the shower facilities. The toilet rooms are entered via the shower rooms. Hairdryer spaces can be used before leaving the bath.

Pool areas:

The brine water areas totaling approx. 830 m² are structured as follows: Sports pool 1:

4-lane pool 25 x 10m, in the jumping area with 3m platform and 1m board, max. Water depth up to 3.50m

Sports pool 2 (in the FHW): 5-lane pool 25 x 12.50 m, water depth 1.80 m

Training pool: Basin with lifting floor (10 x 10 m), water depth from 0.00 to 1.60 m

Warm water pool: Recreation pool (approx. 130 m²), max. Water depth 1,35m

Parent-child pool: separated, approx. 35 m² part of the warm water basin with max. Water depth of 0.30 m

The warm pool and the parent-child pool are presented in a combined pool (water area 167 m²).

The pelvis heads are arranged around 50 cm above the pool surrounds and can be used as a seat.

An area for the installation of couches is attached to the recreation pool. The pool areas are partially separated by glass walls due to different indoor climate zones and for acoustic reasons. A very good room acoustics is made possible by large wall and ceiling acoustic panels. A seating area on the parent-child pool with a view of the foyer is another part of the pool area. Here it is possible to eat snacks and drinks from vending machines.

The swimming master is given a central, elevated supervisory position in a spatially, climatically and acoustically separated room. A stair connection provides a direct connection to the technical rooms in the basement.

A first aid room with a direct pool connection as well as connection to the rear delivery zone enables shortest escape routes outside of general visitor traffic.

Ensure large-scale facade openings (some with SHEV function) in Combination with skylights for an optimized daylight supply.

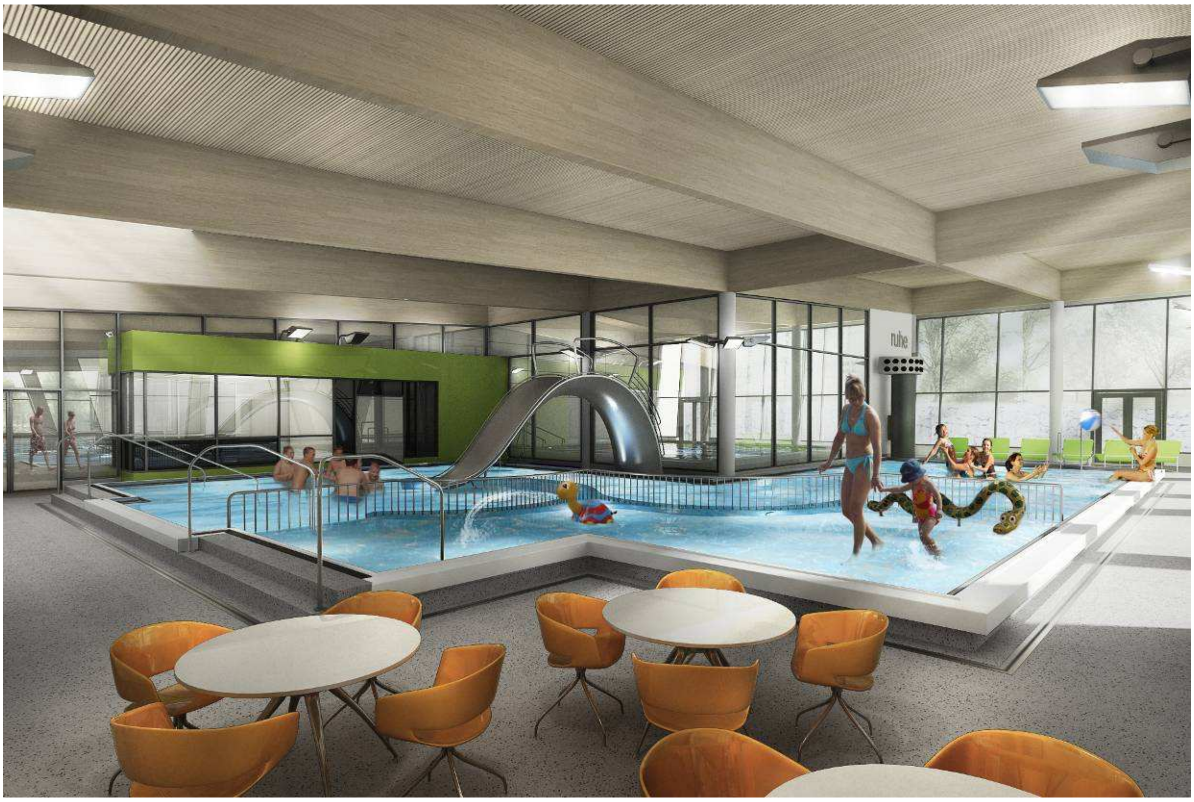


Figure 10: Perspective parent-child pool with relaxation area (source: npstv)

Basement:

For the extensive technical installations, the entire new building with the exception of the foyer area has a basement. The clear height in the basement is
3.00 m.

The personnel areas (Changing / sanitary / break room) are located in the Basement. They can be reached directly via the personnel entrance on the north facade. The break room is supplied with daylight through a basement window. The house connections (district heating / water / electrical / telecommunications) are also in the basement.

An elevator in the delivery area enables heavy loads to be transported between the ground and basement levels.

1st-3rd Upper floor FHW:

The former adjoining rooms of the former FHW become part of the renovation measures the passive house envelope (Facade insulation, new Window elements, inner partial area insulation to the resulting swimming pool (pool 2).

4.3 Static concept

4.3.1 Existing building, former district heating plant

The existing district heating plant is an industrial building in reinforced concrete skeleton construction, which was built for the power plants and systems of the district heating supply Lünen in the late 1960s. The portfolio consists of a seven-axis hall construction and a side axis field with administrative and social rooms.

Reinforced concrete roof trusses run in the north-south axes. These are loosely reinforced with upper chords rising towards the middle. They have a roof structure consisting of Siporex panels, cork insulation and masking tape. To reinforce the building, edge joists are arranged at the level of the 2nd and 3rd floors, which connect the outer supports, which in turn are rigidly integrated into the floor slab (system: cantilever support from the top of the floor or basement ceiling).

In the administration wing, the ceiling supports were partly designed as joists and partly as load-bearing masonry walls.

The complete construction is based on a base plate with connected bored piles.

All district heating systems have been removed from the former boiler room. All internals in the former coal bunker area have also been removed. The ceilings are designed as reinforced concrete ceilings. For the new use, the reinforced concrete ceiling above the basement in the area of the former boiler hall for the installation of a swimming pool was almost completely removed. Since the reinforced concrete soleplate is based on piles and was not insulated, it was decided to apply pressure-resistant insulation to the floor slab and to achieve an even pressure distribution with individual foundations. Glass foam insulation was chosen because practically no compression or settlement is to be expected.

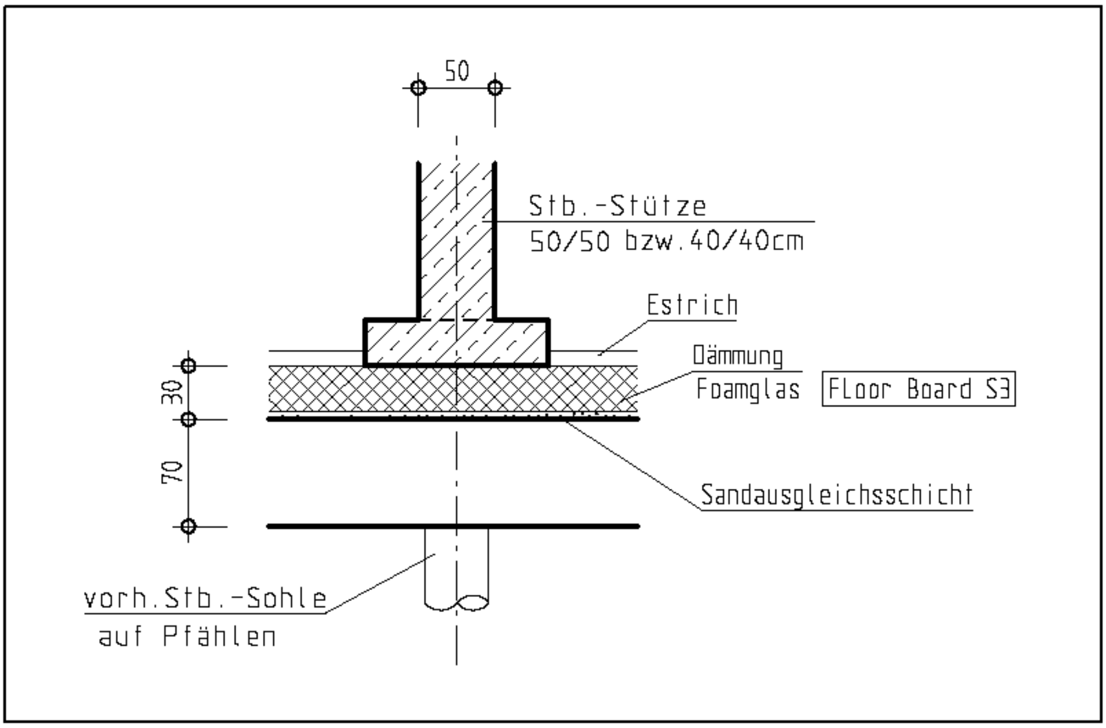


Figure 11: System detail of pool support on foam glass in the existing building (Source: Ostermann)

The entire existing concrete structure such as columns, ceilings and trusses were assessed by an expert with regard to the resilience of the swimming pool atmosphere and proposals for renovation of the surfaces were worked out.

In the roof area, the existing lightweight concrete slabs and seals were dismantled,
however with the receipt of the reinforced concrete girder, in favor of a new one
Supporting structure made of wooden elements with thermal insulation analogous to the new part. The transition from the old to the new building was carried out consistently with a structural joint from the foundation to the roof and sealed in the area of the white tub in the basement against pressurized water with sealing tapes.

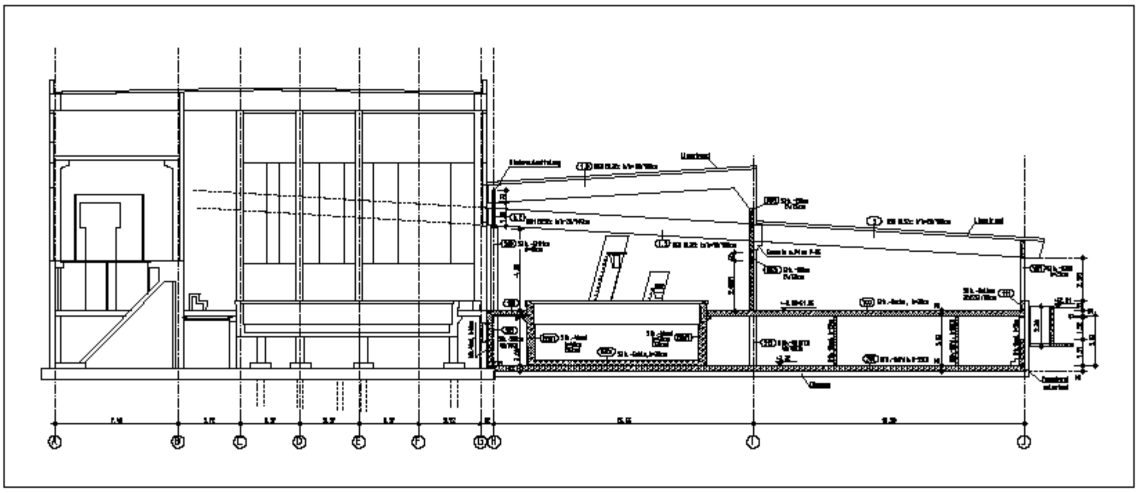


Figure 12: Cross section through old and new building (Source: Ostermann)

4.3.2 New part

For the new building, a solid construction method with a predominantly concrete construction was chosen.

The building is braced via the 24 cm thick cantilevered wall panels on the ground floor, which are clamped in the basement wall. With this variant, complex umbrella associations and their connections were avoided, since the wind load is immediately diverted to the outside surface.

Glued laminated timber trusses w / d = 20/108 cm with a grid of 5.00 m and spans of 16.0 m with lignotrend roof elements were chosen as the roof construction. This version has the advantage that the roof elements can be quickly moved over 3 fields and the tilting of the trusses is guaranteed via this roof panel.

The ground floor mainly consists of surrounding walls made of reinforced concrete and internally arranged reinforced concrete round columns that support the roof structure.

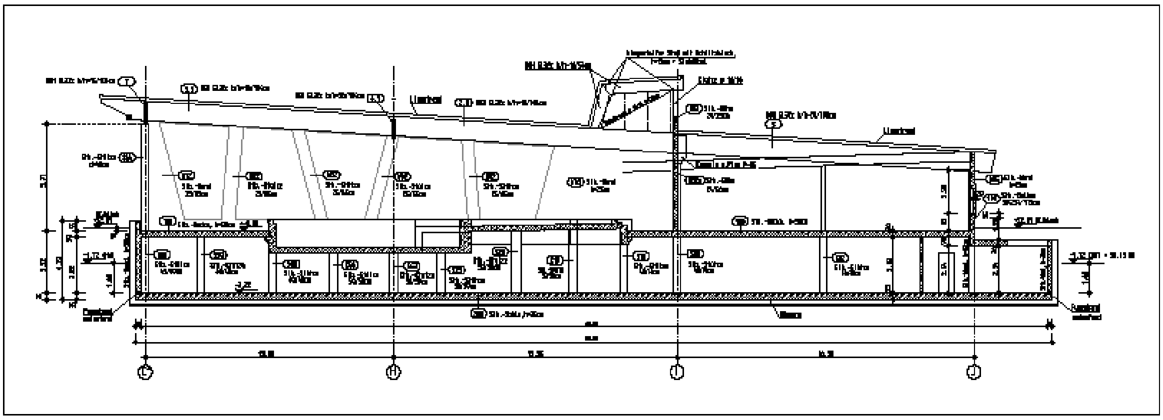


Figure 13: Cross section through the new building (Source: Ostermann)

For the basement ceiling, which forms the pool surrounds and ceiling in the area of the changing rooms, a beam-free reinforced concrete flat ceiling with d = 30 cm was chosen. The reinforced concrete pools on the inside have a circumferential bracket on the outer walls, on which the basement ceiling is supported in line.

In order to ensure easy installation of the load-bearing thermal insulation panels, a continuous, elastically embedded reinforced concrete floor panel (d = 35 cm) was calculated without cross-sectional jumps. In this context, a base plate protrusion was also dispensed with and the formwork edge of the floor slab was simultaneously created with prefabricated insulation elements.

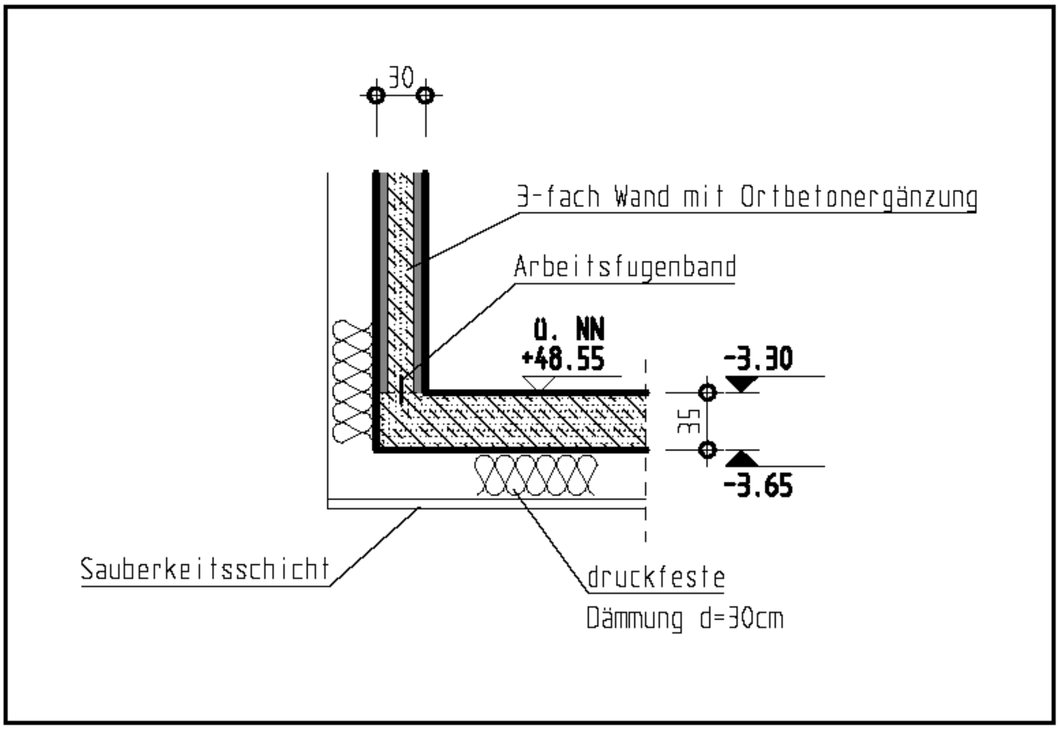


Figure 14: System detail transition from sole to wall (source: Ostermann)

Since the adjacent lip is expected to be flooded, the floor slab was designed as a white trough with increased reinforcement to limit cracks. The basement walls were designed as triple walls with in-situ concrete additions and are also watertight.

In order to leave the passive house envelope almost undisturbed and to avoid thermal bridges, the smoke extraction duct and the light ducts are placed as independent structures in front of the insulation shell of the basement outer wall in the ground. Likewise, the steel canopy in front of the entrance foyer is built as an independent steel frame structure with a joint in front of the passive house.

4.4 Color design of the exterior components

- Walls gray, some with white window elements
- Gray doors
- Canopy main entrance white
- Glass mullion-transom facade, windows: 3-pane thermal insulation, insulating glazing, cover strips / window sills / fittings silver / gray
- Light gray roof, some with raised photovoltaic modules
- Steel railings hot-dip galvanized
- Air intake and exhaust ducts, stainless steel, silver-gray

4.5 Component designs building envelope

All component designs were defined in collaboration or in accordance with the specifications of the Passive House Institute Darmstadt. The existing district heating plant becomes part of the passive envelope.

The entire building envelope is planned airtight in detail. The execution is monitored during the construction period and checked by airtightness measurements. The brine-containing pool water implies the use of corrosion-resistant mounting / fastening materials made of stainless steel (V4A) and aluminum. 64% humidity during operating hours and an increase in humidity up to 80% during the night are taken into account.

4.5.1 Soil against soil

a) elected **Structure sole New building (** from the inside to the outside):

- Waterproof concrete (300 mm)
- Separation layer PE film
- XPS perimeter insulation (WLK 041, 320 mm)
- Cleanliness layer
- Heat transfer coefficient: 0.12 W / (m²K) Decision

making: XPS insulation:

- as continuous insulation possible even with high pressure loads (basin).
- Simple and seamless installation possible thanks to the selected flat foundation
- economical solution

b) elected **Structure sole Duration (** from the inside to the outside):

- Cement screed (100 mm)
- Separation layer PE film
- seal
- Foam glass insulation (300 mm, WLK 040)
- Sand leveling layer
- Reinforced concrete base (600 mm)
- Heat transfer coefficient: 0.12 W / (m²K) Decision

making: Foam glass insulation:

- Combination of highest compressive strength and thermal insulation,
- Vapor-tight design and non-combustibility bring advantages over rigid foam insulation materials
- this avoids penetration of the passive envelope through new components

?

b) elected **Facade construction inventory (** from the inside to the outside):

- Cement plaster (inventory)
- load-bearing solid outer wall (existing)
- Thermal insulation composite system made of EPS hard foam,, WLK 035, 300 mm thick, layer structure acc. Approval manufacturer, glued
- Coordinated coating system with any additional coatings (impregnating, fungicidal etc.)

- Heat transfer coefficient: 0.11 W / (m²K) Decision

making:

- as before

4.5.4 Roofs against outside air

a) elected **Roof construction new building (** from the inside to the outside): :

- load-bearing roof trusses (5m grid) acc. Glulam statics in F30 quality

- Prefabricated wooden box elements made of glulam according to Statics with integrated wooden acoustic absorber in F30 quality
- Emergency sealing (bituminous membrane)
- Vapor barrier
- Thermal insulation (EPS rigid foam), WLK 035, 300 mm thick. 2-layer version glued with staggered joints
- Plastic roof sealing membrane, gluing
- Heat transfer coefficient: 0.11 W / (m²K)
- Drainage through drains and downpipes Decision making:

- Support structure made of wooden components (renewable raw material) that meets the combination of fire protection requirements and high corrosion resistance

- 6% roof pitch for permanently safe drainage and avoidance of long-term damage from standing water

- Warm roof design as a glued system to avoid thermal bridges through mechanical fastenings; Mechanical additional fastenings are only required in certain areas

- Use of EPS (alternatively PUR) insulation materials with very good insulation properties and low weight
- Roof statics enable the installation of rooftop photovoltaic systems
- Avoidance of roof penetrations in technical building equipment (avoidance of additional thermal bridges)

b) elected **Roof structure inventory (** from the inside to the outside):

- as before, but on existing reinforced concrete roof trusses
- Heat transfer coefficient: 0.11 W / (m²K) Decision

making:

- Replacement of the low-insulated existing structure with a passive house-compliant roof structure

- Static consideration of the mounting option of photovoltaic modules mounted on a thermal bridge

- otherwise as before

4.5.5 Windows and glass facades

Windows are particularly important in passive houses. On the one hand, they form the thermal weak point of the building envelope (at approx. 0.8 W / (m²K), the windows have the highest heat transfer coefficient and the lowest inside surface temperatures occur in the area of the edge bond), and on the other hand, transparent components are required to provide a line of sight to the outside to realize the daylight and the use of solar profits.

Thermal transmittance and thermal bridge loss coefficients of the frames

In consultation with the project participants, the following qualities for windows and mullion-transom facades were determined.

- Wooden post and transom facade made of larch, glazed, aluminum cover strips on the outside

- Edge bond made of plastic strips
- Triple thermal insulation glazing with inert gas filling
- Safety glazing
- with integrated seat training of the lower window sill
- Exterior doors as wooden frame doors in the passive house standard
- necessary RWA openings as high quality insulated window elements with approval in individual cases Decision making:

- System determined in coordination with the Passive House Institute
- U values around 0.7-0.8 possible
- Advantages compared to an aluminum construction. Insulation properties
- additional Metal heat conducting plate acc. Specification PHI on the edge network
- Use of renewable raw materials

The post and frame facade Therm + 50 hv from Raico, certified by the Passive House Institute, will be used. The facade is thermally upgraded by the higher thicknesses of glass and the Super Spacer Tri-Seal from Edgetec compared to the certified variant. Table 1 shows the thermal qualities of the windows and mullion-transom facades according to the planning status. The values were determined by the PHI based on DIN EN ISO 10077-2. This standard provides boundary conditions of -10 ° C outside and 20 ° C inside. These boundary conditions have been adopted, deviating from the actual temperatures in the bathroom. Figure 15 and Figure 16 show the calculation models and isothermal graphics of the calculated constructions.

Table 1: Thermal qualities of the windows and mullion-transom facades used

No	frame	Heat transfer coefficient U [W / (m²K)]	Frame view width b [m]	Thermal bridging loss coefficient (glass edge) [W / (mK)]
1	Posts in the hall	0.95	0.05	0.037
2nd	Bars in the hall *	0.93	0.05	0.035
3rd	Post (remaining area)	0.91	0.05	0.034
4th	Latch (remaining area) *	0.89	0.05	0.032
5	Opening wing (all Cuts, all areas)	0.97	0.13	0.031
6	Skylights **	1.10	0.13	0.040

* Values estimated based on the posts and the certified variant

** Assumptions, no concrete product information available yet

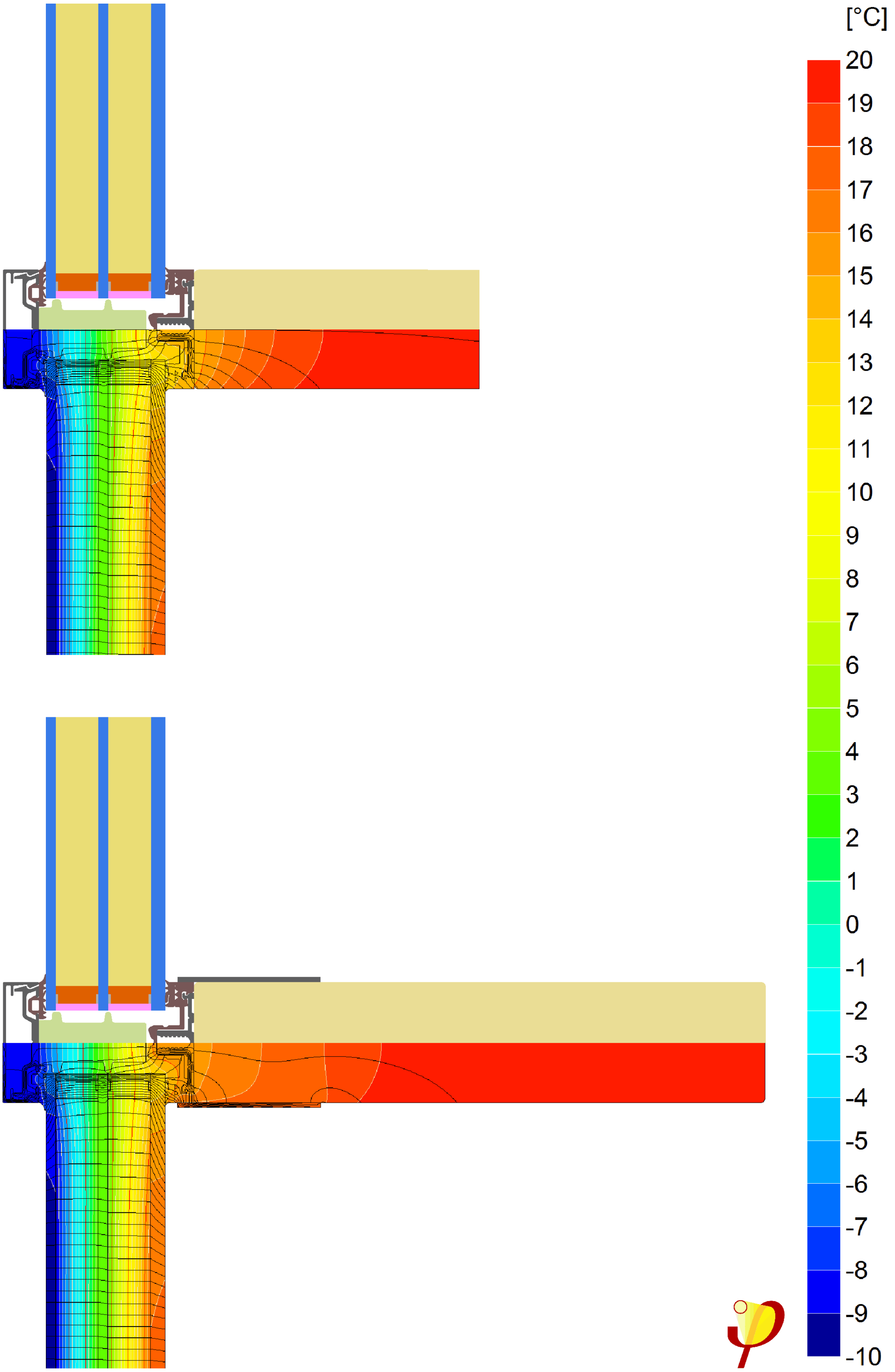


Figure 15: Mullion-transom facade Raico Therm + 50 hv in those used in the lip bath

Versions (top: calculation model, bottom: isothermal graphics with temperature and heat flow lines). In the hall, a variant with heat-conducting sheets to increase the glass edge temperature will be used (bottom illustration) (source: PHI)

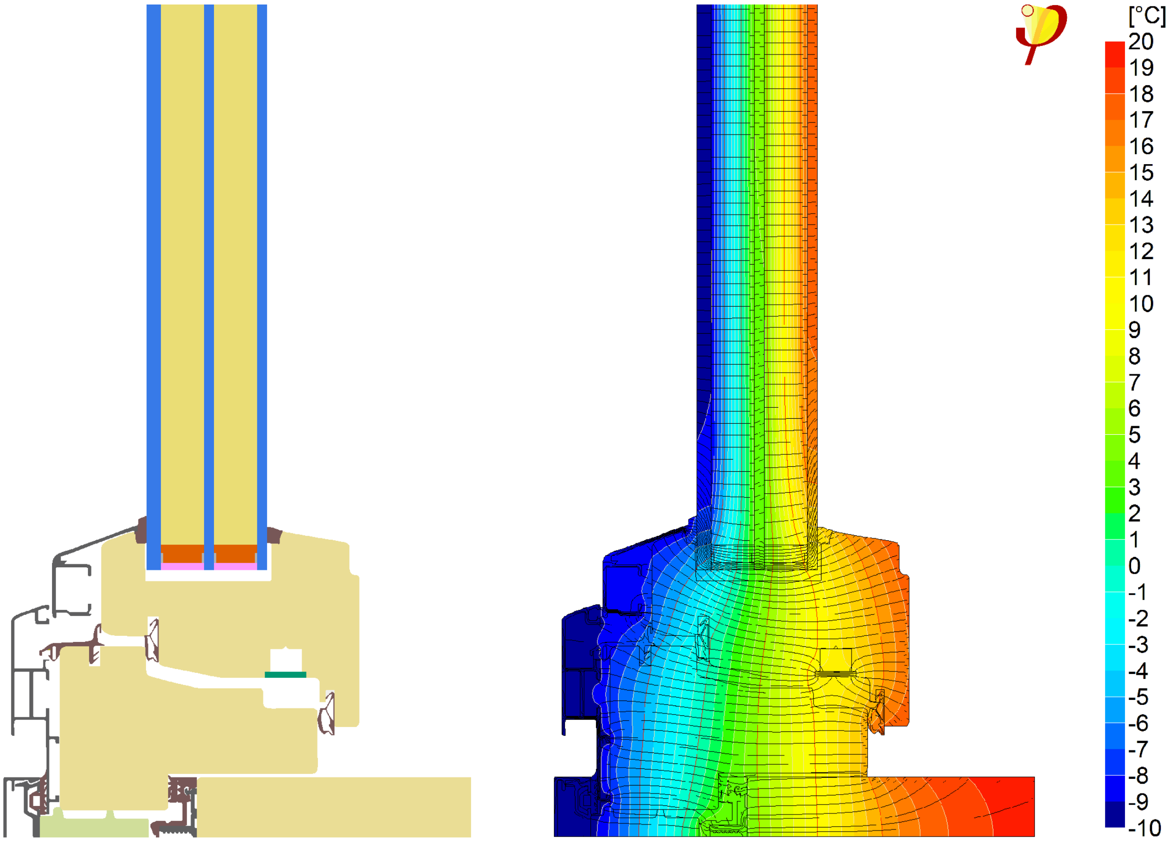


Figure 16: Opening sash in the Raico facade version being used

Therm + 50 hv. Left: calculation model, right: Isothermal graphics with

Temperature and heat flow lines (source: PHI)

Installation situation

In Figure 17 the installation situation is shown as an example. The

The built-in thermal bridge loss coefficient is 0.070 W / (mK), which is the usual range for mullion-transom facades.

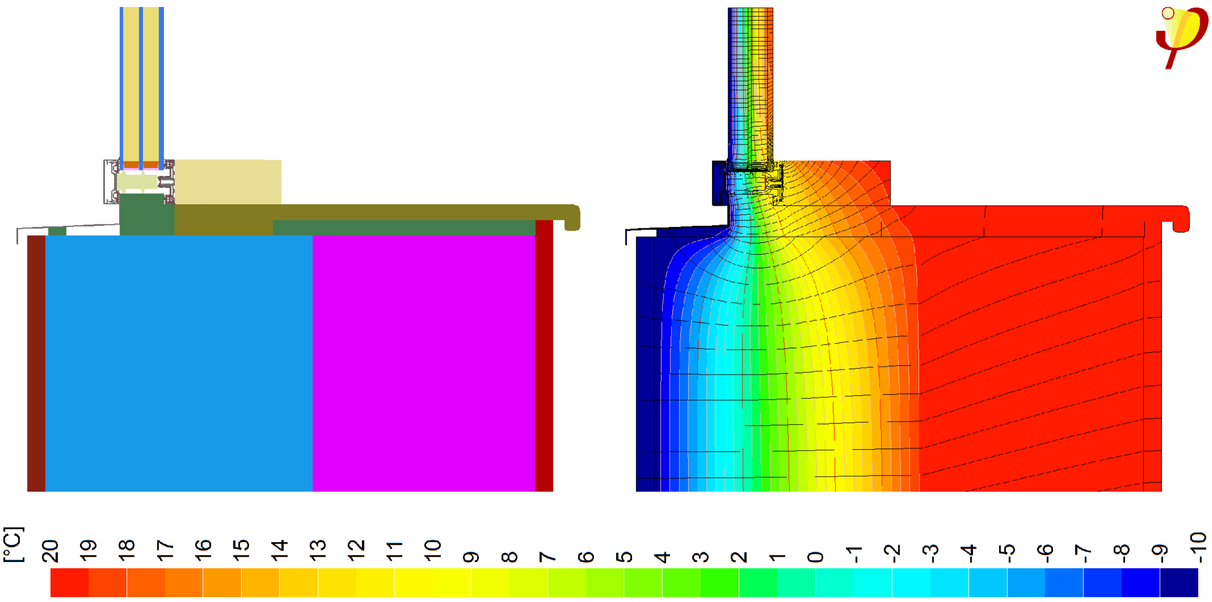


Figure 17: Installation situation "below" of the mullion-transom facade in

the planned concrete wall with thermal insulation composite system (source: PHI)

?

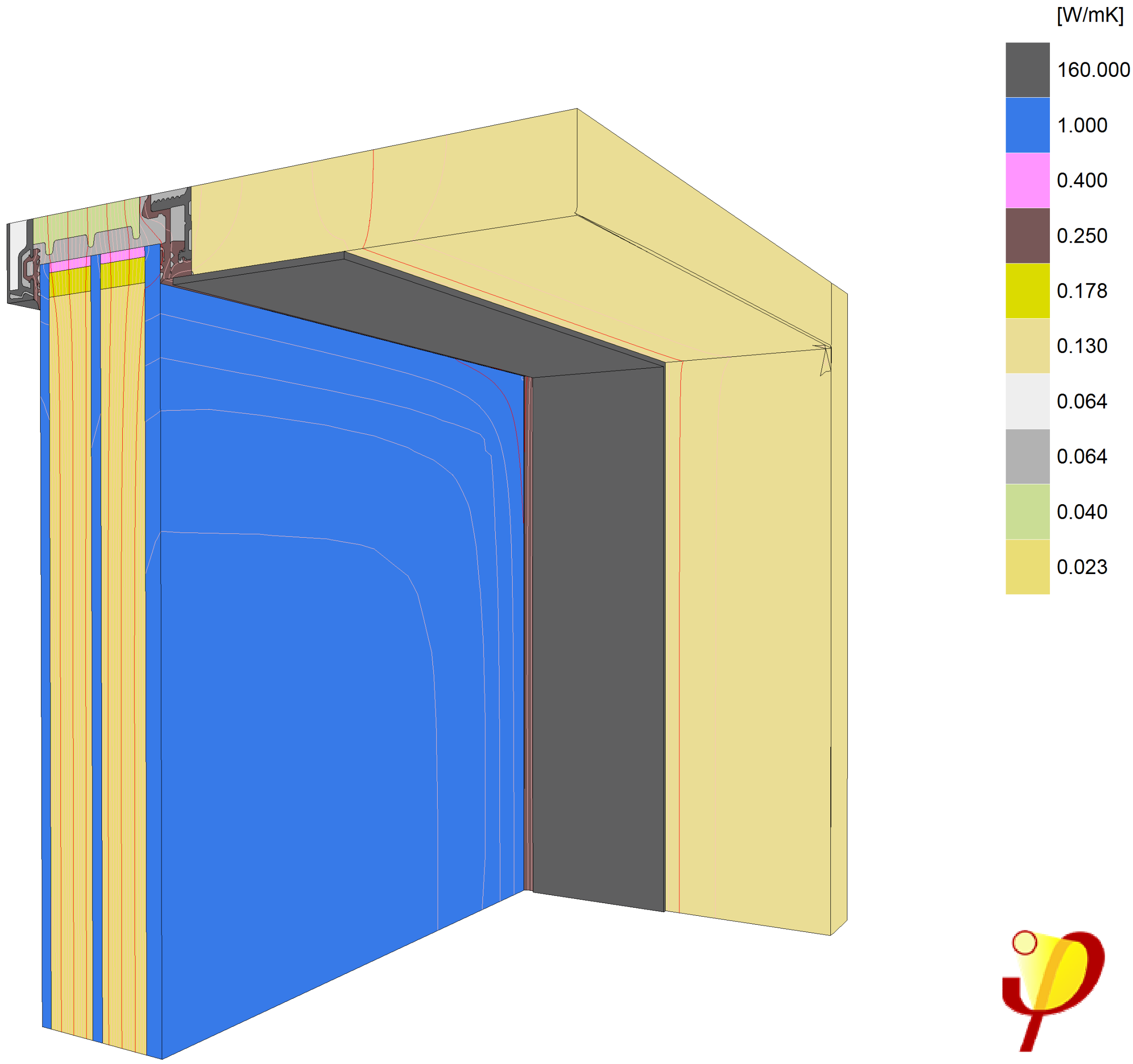


Figure 18: Simulation model for determining the minimum surface temperature of the planned facade (source: PHI)

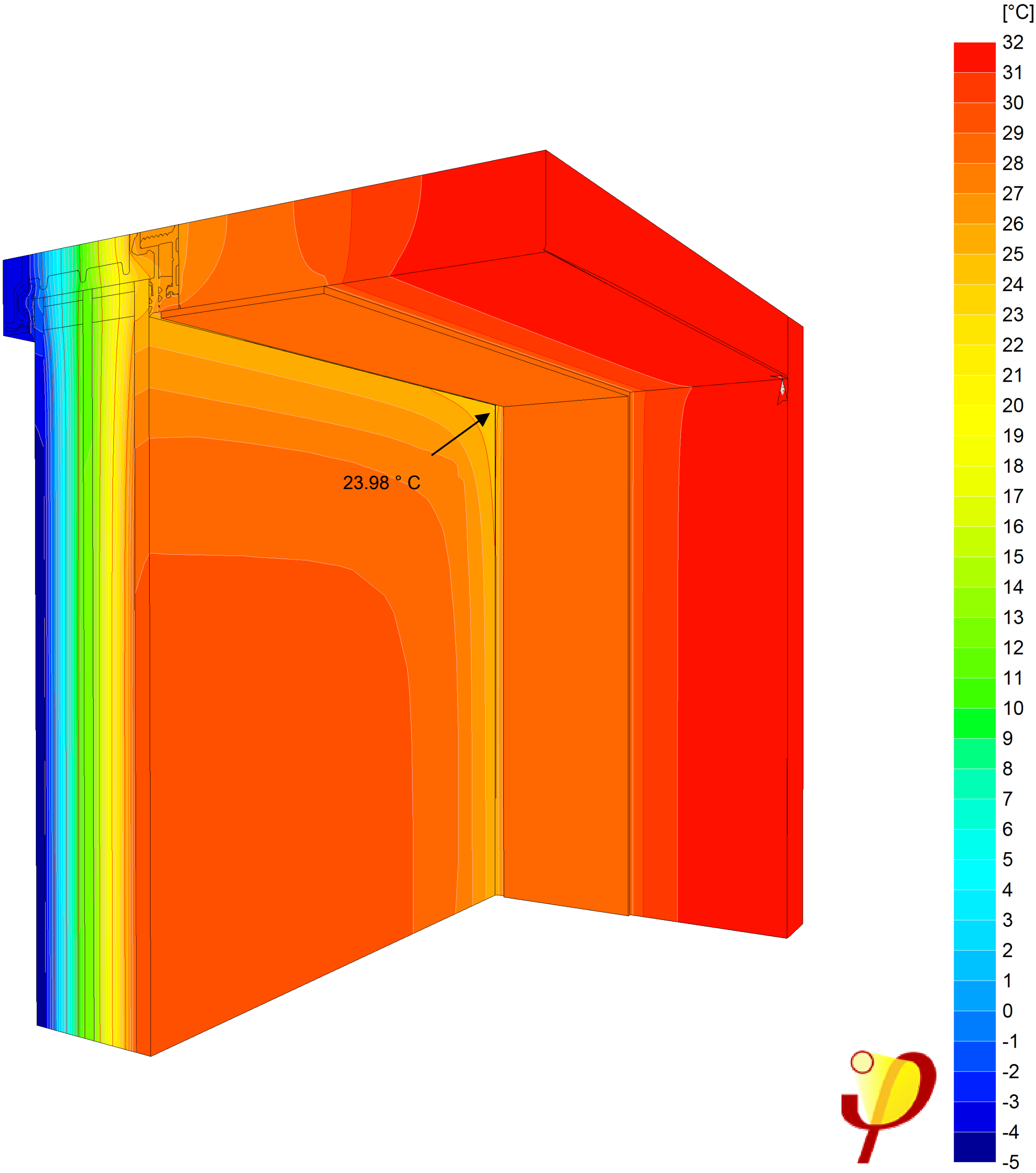


Figure 19: Isothermal representation for the simulation model to determine the minimum Surface temperature of the planned facade at an outside temperature of -5 ° C and an inside temperature of 32 ° C (source: PHI)

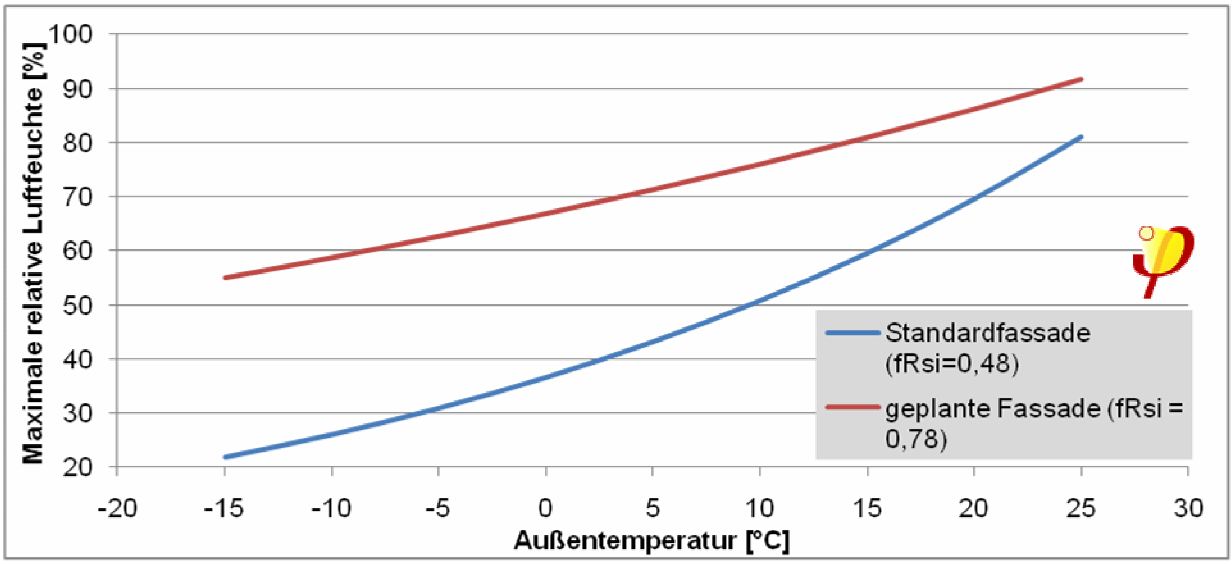


Figure 20: Maximum condensation-free room air humidity of a standard facade (aluminum Transformer system, double glazing, aluminum edge bond) and the planned facade depending on the outside temperature (source: PHI).

Glass qualities

In the Lippe Bad Lünen, all vertical glazing where this is statically possible has a gap of 18 mm between the panes. This enables glass U values from 0.56 W / (m²K) also with Argon filling. The Total energy transmittance g is assumed to be 0.46.

A glass U-value of 0.7 W / (m²K) with a total energy transmittance g of 0.3 was assumed for the skylights in the area of the changing rooms.

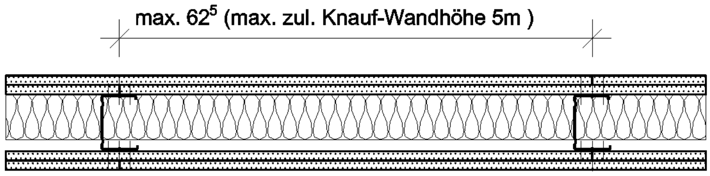
4.5.6 Internal components between temperature zones

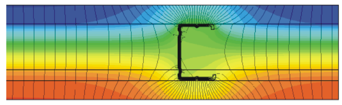
To reduce the heat flow between the temperature zones, the inner walls are also provided with insulation. In some cases, lightweight walls with a steel profile support structure are used. These steel profiles represent thermal bridges that were determined by the PHI and taken into account in the energy balance:

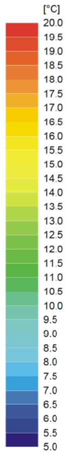
LW 1

Trennwand mit Metall-Einfachständerwerk, doppelt beplankt
z.B. KNAUF AQUAPANEL Cement Board Indoor
Einbaubereich 2

max. 62[5] (max. zul. Knauf-Wandhöhe 5m)







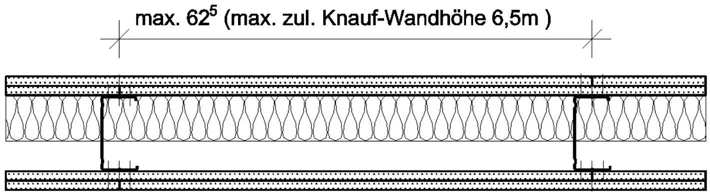
AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)
Metallständerwerk CW 75/0,6-Profil	7,5cm	λ = 50,00 W/(mK)
Mineralfasereinlage A_F>= 5kPa/m² optional	6 cm	λ = 0,04 W/(mK)
AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)

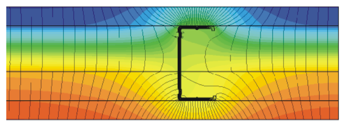
Ψ_{WB} = 0,158 W/(mK)
ΔU_{WB} = 0,253 W/(m²K)
U = 0,733 W/(m²K)

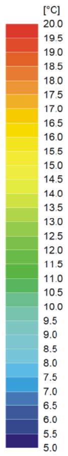
LW 2

Trennwand mit Metall-Einfachständerwerk, doppelt beplankt
z.B. KNAUF AQUAPANEL Cement Board Indoor
Einbaubereich 2

max. 62[5] (max. zul. Knauf-Wandhöhe 6,5m)





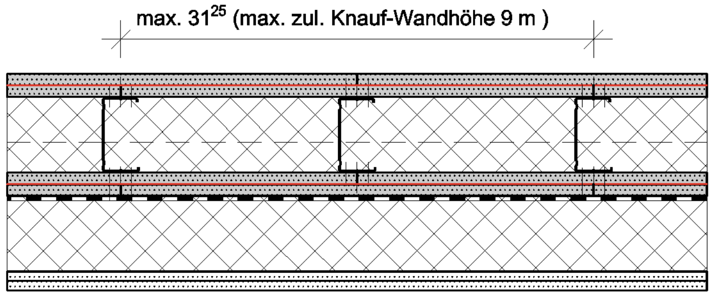


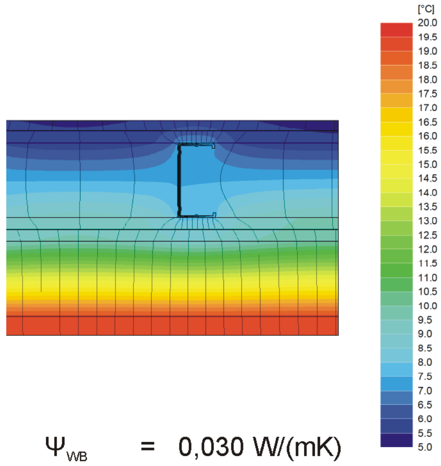
AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)
Metallständerwerk CW 100/0,6-Profil	10cm	λ = 50,00 W/(mK)
Mineralfasereinlage A_F>= 5kPa/m² optional	6 cm	λ = 0,04 W/(mK)
AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)

Ψ_{WB} = 0,162 W/(mK)
ΔU_{WB} = 0,259 W/(m²K)
U = 0,757 W/(m²K)

LW 3

Brandwand A1, nichttragend als Montagewand
mit Metall-Einfachständerwerk, doppelt beplankt
z.B. KNAUF W132
Treppenhaus E.09 Altbau





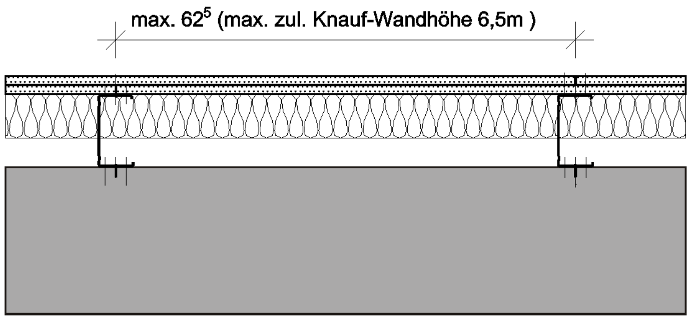
Brandwand F90 nach DIN 4102-3, nichttragend D= 61,1cm

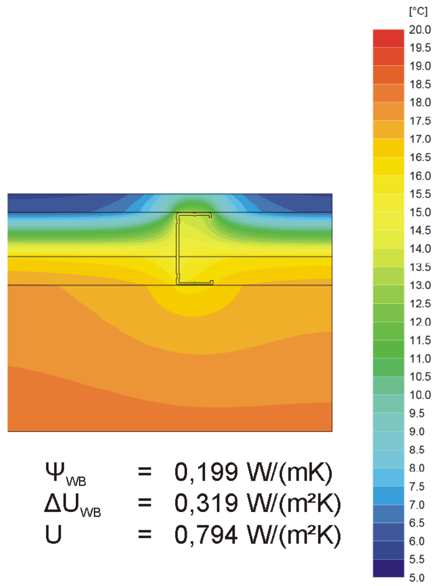
Knauf Fireboard, 2x15mm Stahleinl 0,5mm	3,05cm	λ = 0,25 W/(mK)
Metallständerwerk CW 100/50/0,6-Profil	10cm	λ = 50,00 W/(mK)
Dämmschicht Bauklasse A	10,cm	λ = 0,04 W/(mK)
Knauf Fireboard, 2x15mm Stahleinl 0,5mm	3,05cm	λ = 0,25 W/(mK)
Schaumglas, dampfdicht geklebt, z. B. FOAMGLAS Platten T4+ o.glw.	10cm	λ = 0,042 W/(mK)
AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)

Ψ_{WB} = 0,030 W/(mK)
ΔU_{WB} = 0,094 W/(m²K)
U = 0,280 W/(m²K)

LW 7

Trennwand mit Metall-Einfachständerwerk, doppelt beplankt
z.B. KNAUF AQUAPANEL Cement Board Indoor
Auf Stahlbetonwand





AQUAPANEL Cement Board, 2x12,5mm	2,5cm	λ = 0,36 W/(mK)
Metallständerwerk CW 100/0,6-Profil	10cm	λ = 50,00 W/(mK)
Mineralfasereinlage A_F>= 5kPa/m² optional	6 cm	λ = 0,04 W/(mK)
Stahlbeton	20 cm	λ = 2,3 W/(mK)

Ψ_{WB} = 0,199 W/(mK)
ΔU_{WB} = 0,319 W/(m²K)
U = 0,794 W/(m²K)

4.6 Thermal bridges

An essential pillar of the passive house concept is the avoidance of thermal bridges. For this reason, thermal bridge-free constructions and connections are generally required for passive houses (cf. e.g. Feist 2001). In the case of complex buildings, however, there can be unavoidable thermal bridges for structural and structural reasons (see e.g. AkkP 35). This is especially true in the energetic upgrading of existing buildings (see eg AkkP 24, AkkP 32, AkkP 39). Table 2 lists the identified thermal bridges with their thermal bridge loss coefficients and lengths. Figure 21 to Figure 23 show the simulation models and temperature profiles.

Table e 2: Balanced thermal bridges

No	**thermal bridge**	[W / (mK)] or [W / K]	**length** [m]	**source**
1	Insulation apron, new building	0.167	35.2	Figure 21
2nd	Connection of smoke or ventilation shaft, new building	0.227	28.9	Figure 21
3rd	Cantilevered wall corner, new building	0.040	22.0	Figure 21
4th	Integration of concrete ceiling in old building	0.694	35.3	Figure 22
5	Attic connection old building	0.097	63.6	Figure 22
6	connection Indoor swimming pool Control center old building	0.658	37.9	Figure 22
7	Base of the old building	0.668	27.0	Figure 23
8th	Connection base plate old and new building	1,128	49.5	Figure 23
9	(Line) ventilation pipes	0.1	27.5	PHI
10	attachment points For Aluminum Fixed ladder (punctiform, number)	0.01	4th	AkkP 35
11	glass supports (punctiform, number)	0.04	294	Krick 2010

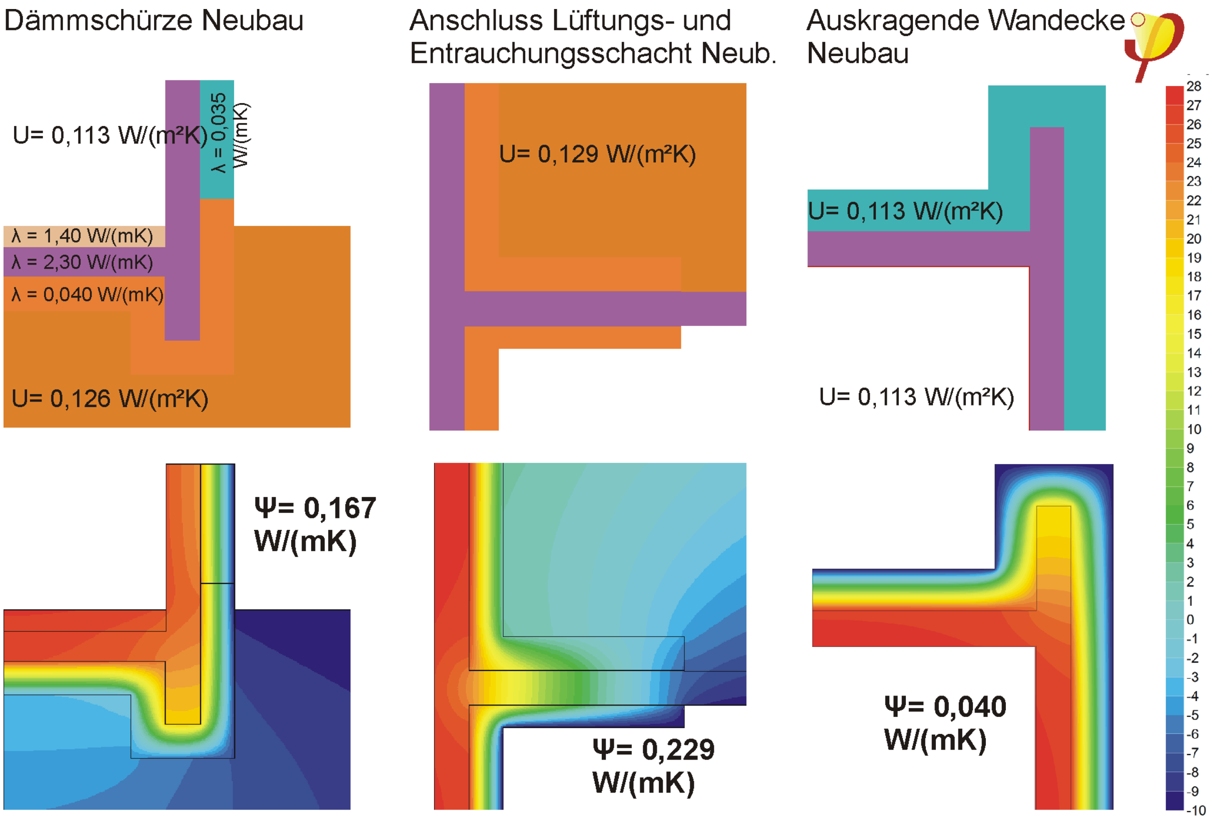
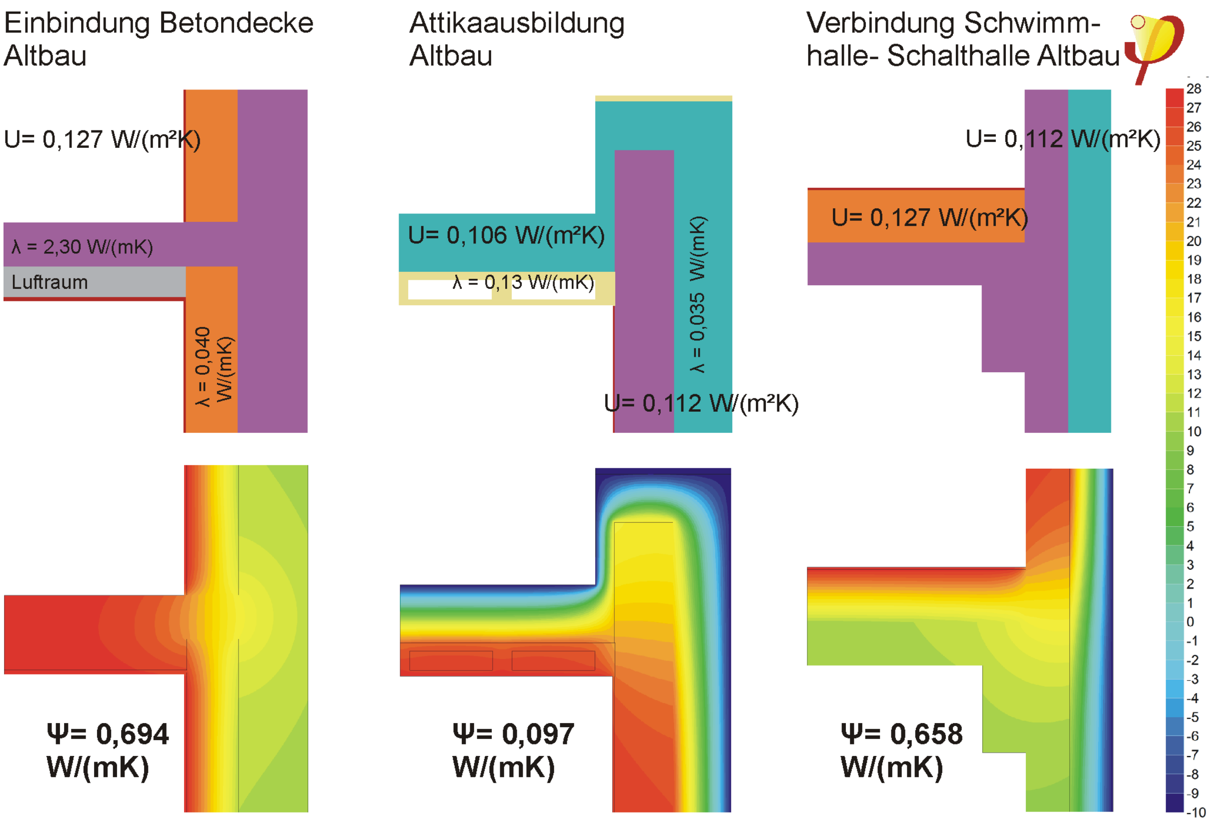
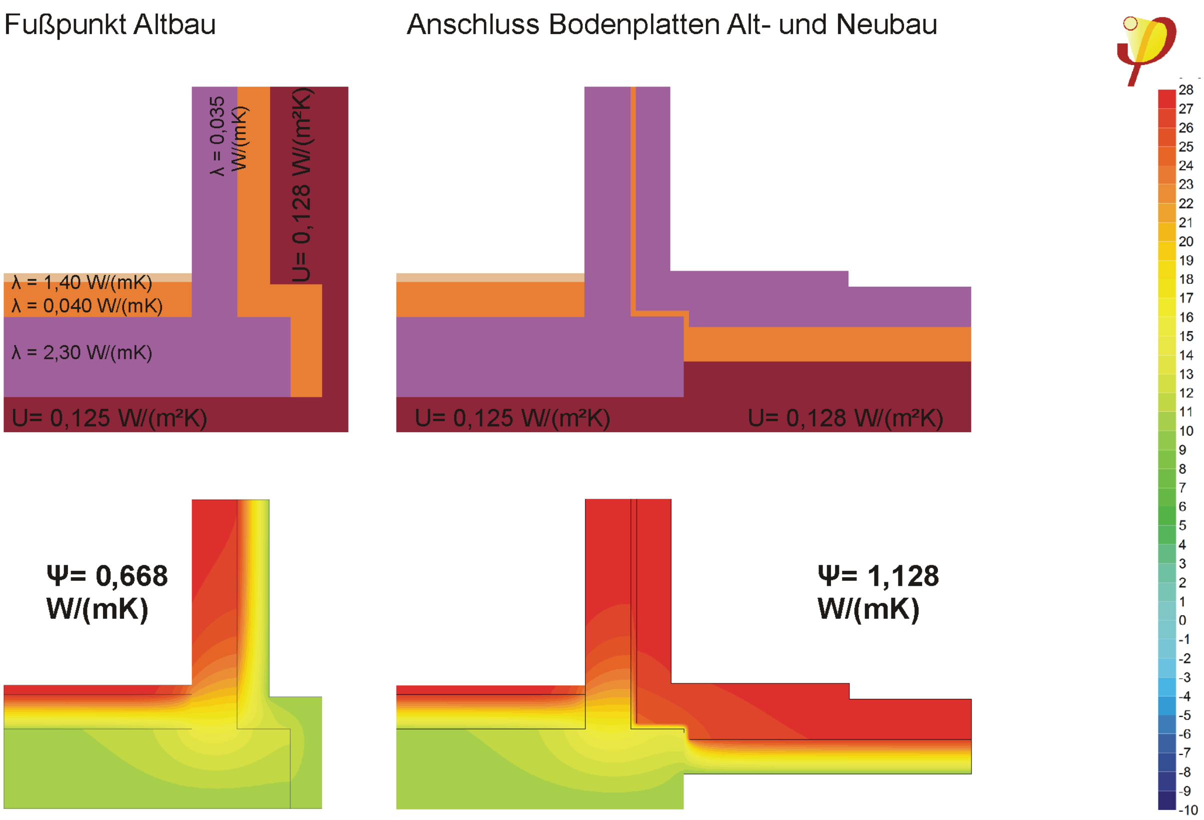


Figure 21: Calculated thermal bridges in the area of the new building (PHI)




Fußpunkt Altbau
Anschluss Bodenplatten Alt- und Neubau
λ = 0,035 W/(mK)
U= 0,128 W/(m²K)
λ = 1,40 W/(mK)
λ = 0,040 W/(mK)
λ = 2,30 W/(mK)
U= 0,125 W/(m²K)
U= 0,125 W/(m²K)
U= 0,128 W/(m²K)
Ψ= 0,668 W/(mK)
Ψ= 1,128 W/(mK)
28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10

≤≤

In the floor and wall area airtight level through the Reinforced concrete construction, partly made in connection with the interior plaster. In the roof area, the vapor barrier between the insulation and the wooden structure forms the airtight level. The transitions of the levels and the connections to window and mullion-transom facades have been carefully detailed.

4.8 Summer fall

The investigations of the basic report on the passive house indoor pool [PHI 2009] show that, due to the high temperatures in the indoor pool, there is hardly any overheating in summer even without sun protection. For this reason, apart from the roof overhangs, shading devices have been dispensed with. Cooling takes place by increasing the outside air change.

4.9 Daylight optimization

The use of primary energy to ensure adequate lighting reaches significant dimensions for non-residential buildings. In terms of a sustainable energy efficiency strategy, wherever this is economically justifiable, all structural options that contribute to reducing the use of artificial light should be exhausted. In addition to the choice of the reflectance of the surrounding space, this primarily includes the optimization of the transparent surfaces. For this purpose a daylight simulation of the individual hall sections was carried out by the PHI. Based on the results, improvements in artificial light autonomy could then be achieved.

4.9.1 Daylight quotient

The daylight quotient (D) gives the ratio of in the building actually existing illuminance (E_P) the illuminance available outside the building, measured on a horizontal surface (E_{HZ}), at:

$$D = E_P / E_{HZ} \ [\%]$$

The average illuminance outdoors is overcast
10,000 lux. With a desired illuminance in the hall area of 300 lux, the daylight quotient must reach at least 3%.

The uniformity of the illumination is another important criterion for assessing the quality of the daylight supply. High quotients in the

The area close to the window and the low area in the middle of the hall lead to strong contrasts, which prevents optimal user-friendliness.

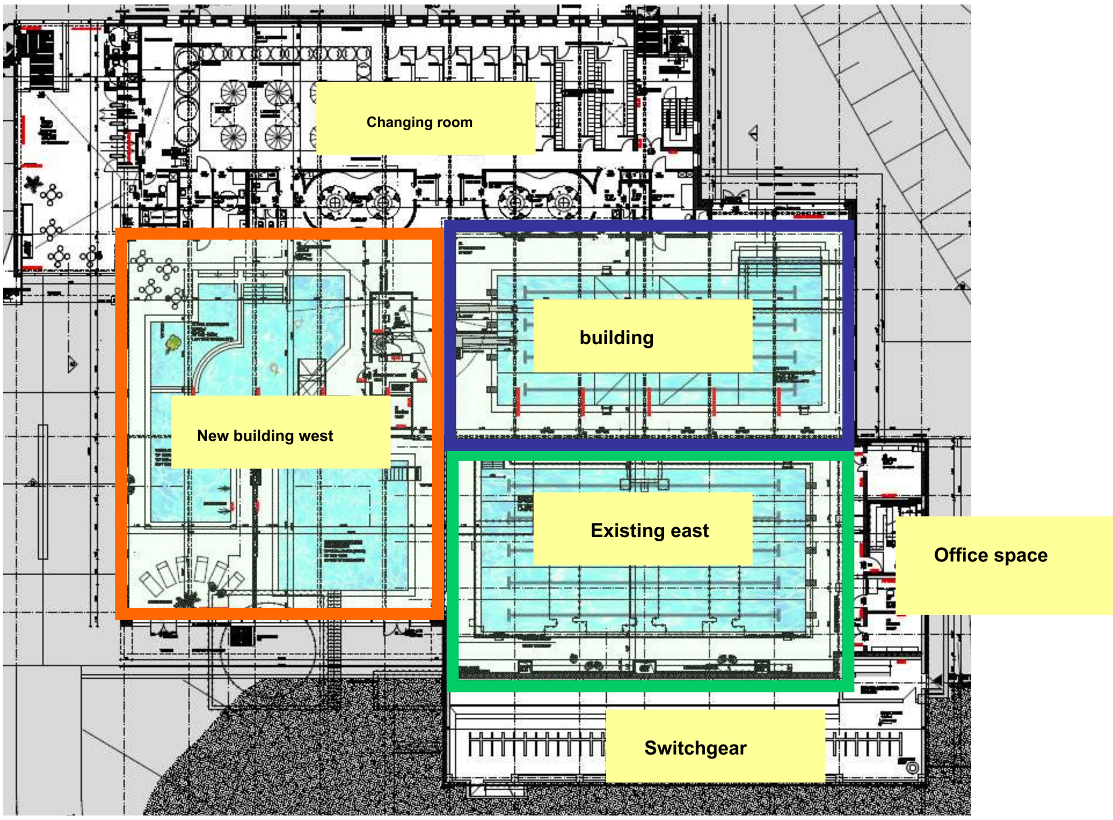


Figure 24: Floor plan of the indoor pool - viewed areas of the daylight simulation

4.9.2 Optimizing the use of daylight in existing buildings

The district heating plant consists of a solid reinforced concrete construction with a clear hall height of 12.8 m. The south side of the hall area is delimited by the switch building, office space is in the east area, the new building is on the north and west side with a hall height of about 6 m. Therefore, only the upper hall areas on the west and north sides and the roof areas are available for daylight supply. For the simulation, lines of reflection of the wall and ceiling of 70% and the floor areas 60% (very bright) were assumed. For comparison: a white coat has reflectivities of 75 to 85%.

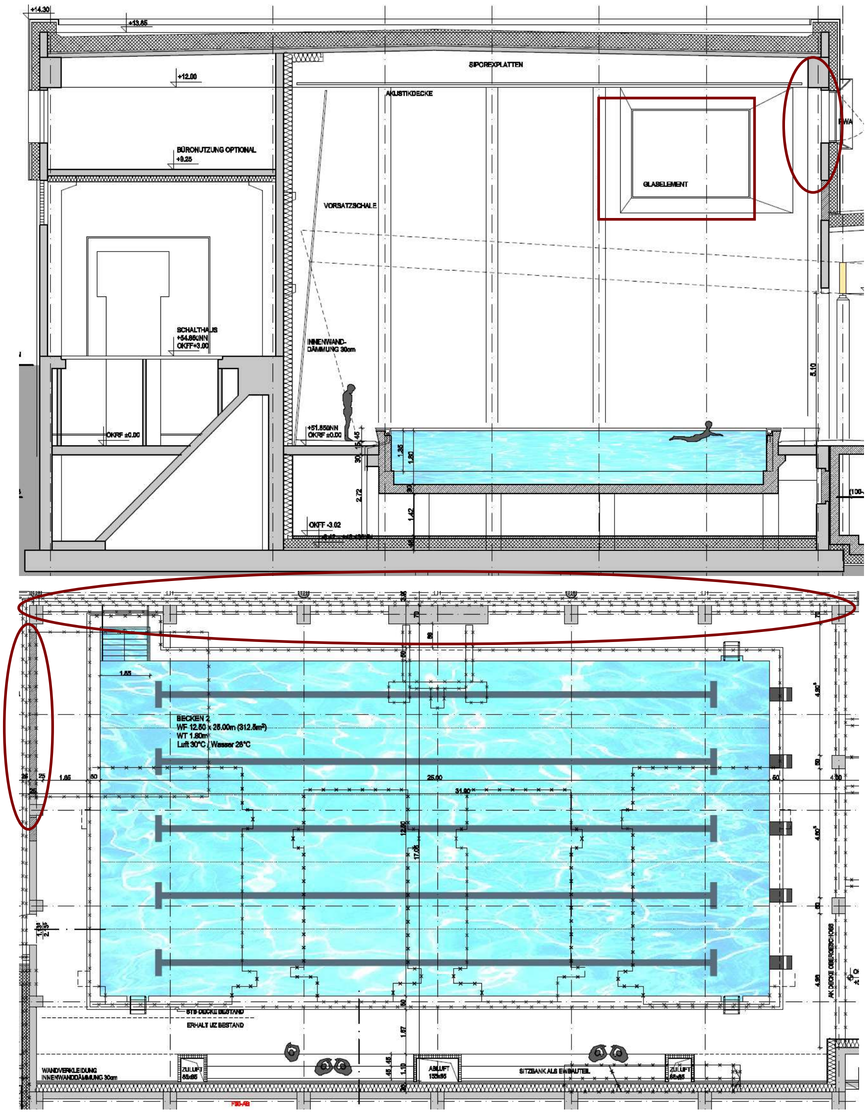


Figure 25: Section and floor plan of the district heating plant with planned window elements on the west and north side

The daylight simulation clearly fell below the desired daylight coefficient. Self in the direct area of the window is Luminous efficiency only 2.3% (Figure 26).

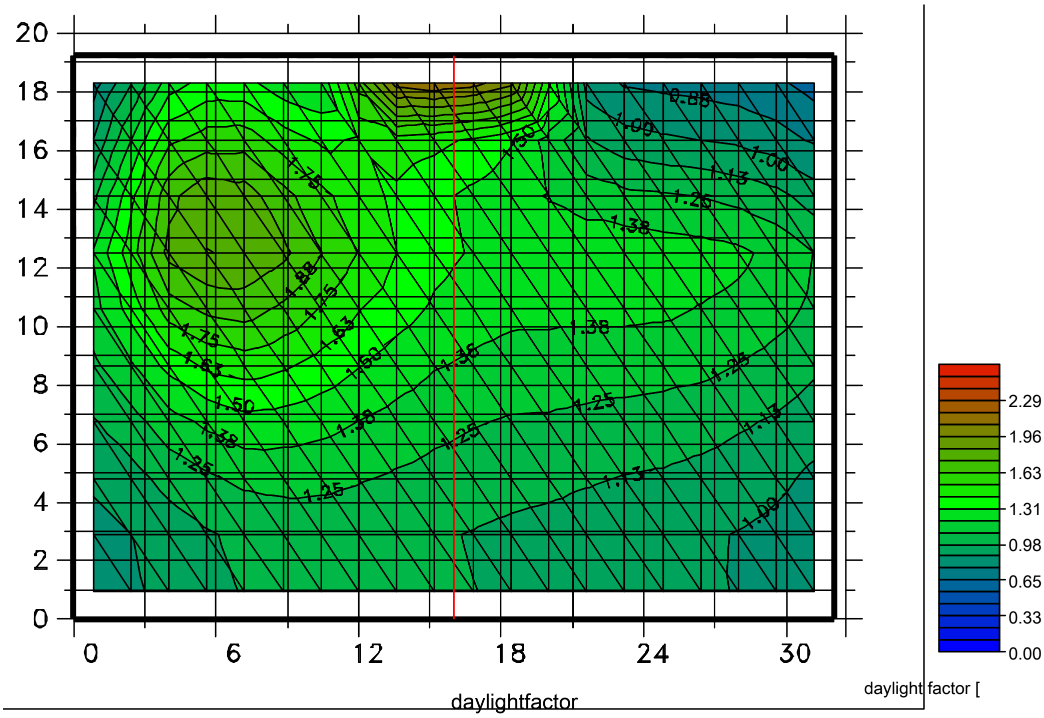


Figure 26: Daylight coefficient for the hall section in the existing building

In order to optimize the daylight quotient, an increase in the window height in the north to 1.5 m and an increase in the window area in the west were proposed. These measures resulted in a significantly better use of daylight and good uniformity of lighting (Figure 27 and Figure 28).

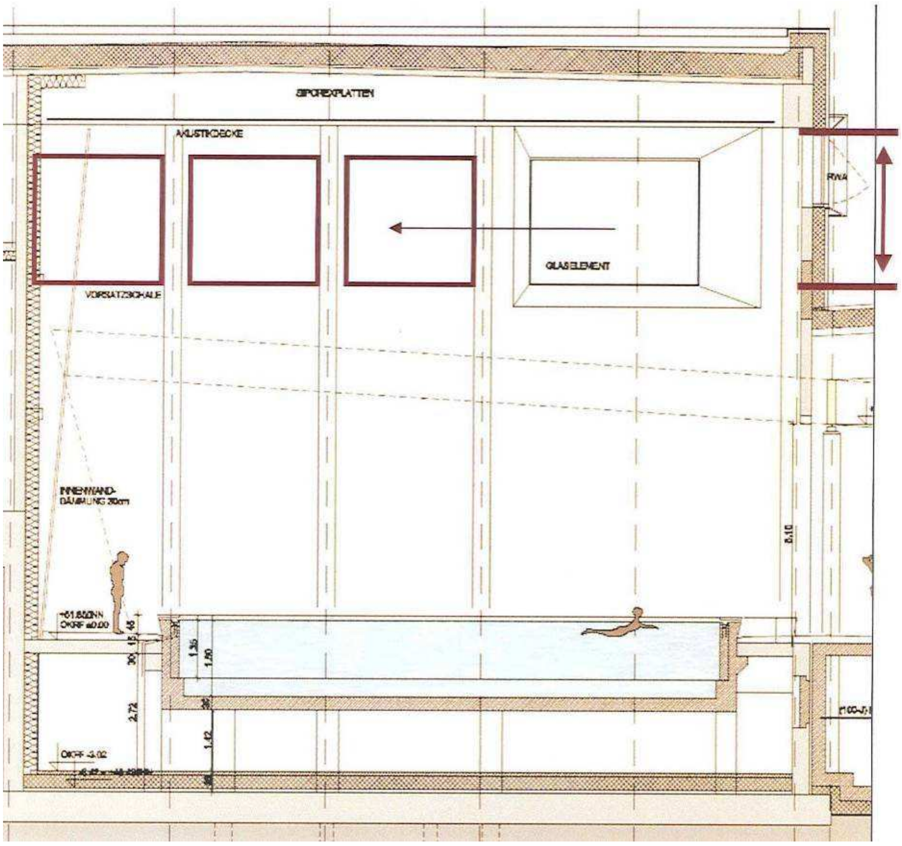


Figure 27: Proposed improvement to optimize the daylight yield in the existing building

Skylights in the roof area are still difficult for indoor swimming pools in the passive house standard, since all available constructions are subject to thermal bridges. This could lead to condensate problems when the indoor air humidity is planned to be raised. Further reasons for the decision against skylight domes were considerable additional costs, problems with overheating in summer, glare for the swimmers, reduction of the roof area that can be used for photovoltaics as well as high maintenance and cleaning costs.

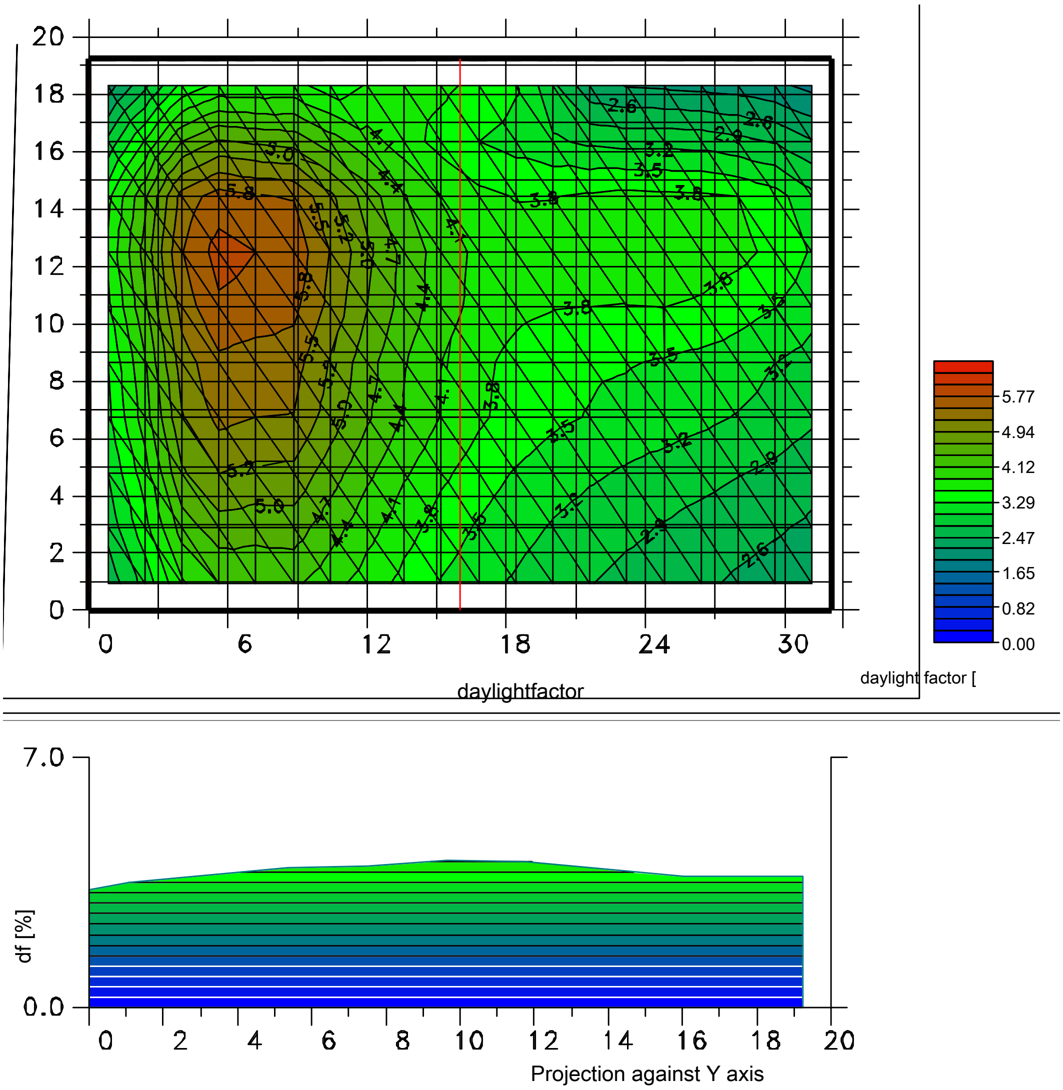


Figure 28: Daylight coefficient for the hall section in the existing building with optimized window areas

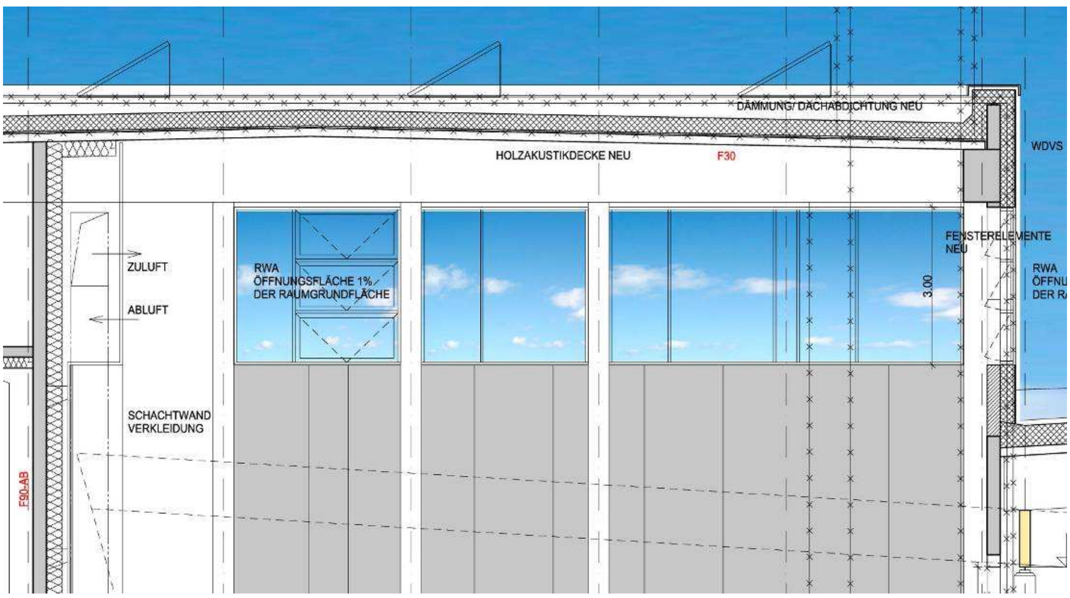


Figure 29: Improved window situation in the existing building

The recommendations from the daylight simulation for this area were implemented in the planning as follows:

- Enlargement of the north facade window band from h = 1.50m to h = 3.00m.
- h = 3.50m not possible due to the roof connection.
- Enlargement (h = 3.00m) and extension of the window facade west facade in the south direction.

- Extension to the control room wall of the room is not possible due to the TGA installation wall.
- Reflectance: wall: approx. 80% (essentially white paint)
  Blanket: approx. 70% (silver fir natural)
  Ground: not yet determined (depending on the product)

4.9.3 Optimizing the use of daylight in the east hall area

Figure 30 and Figure 31 show the planned situation in the eastern area of the new building. There, the window areas are planned to be room-high both in the north and in the east. Only skylights are possible in the changing room area.

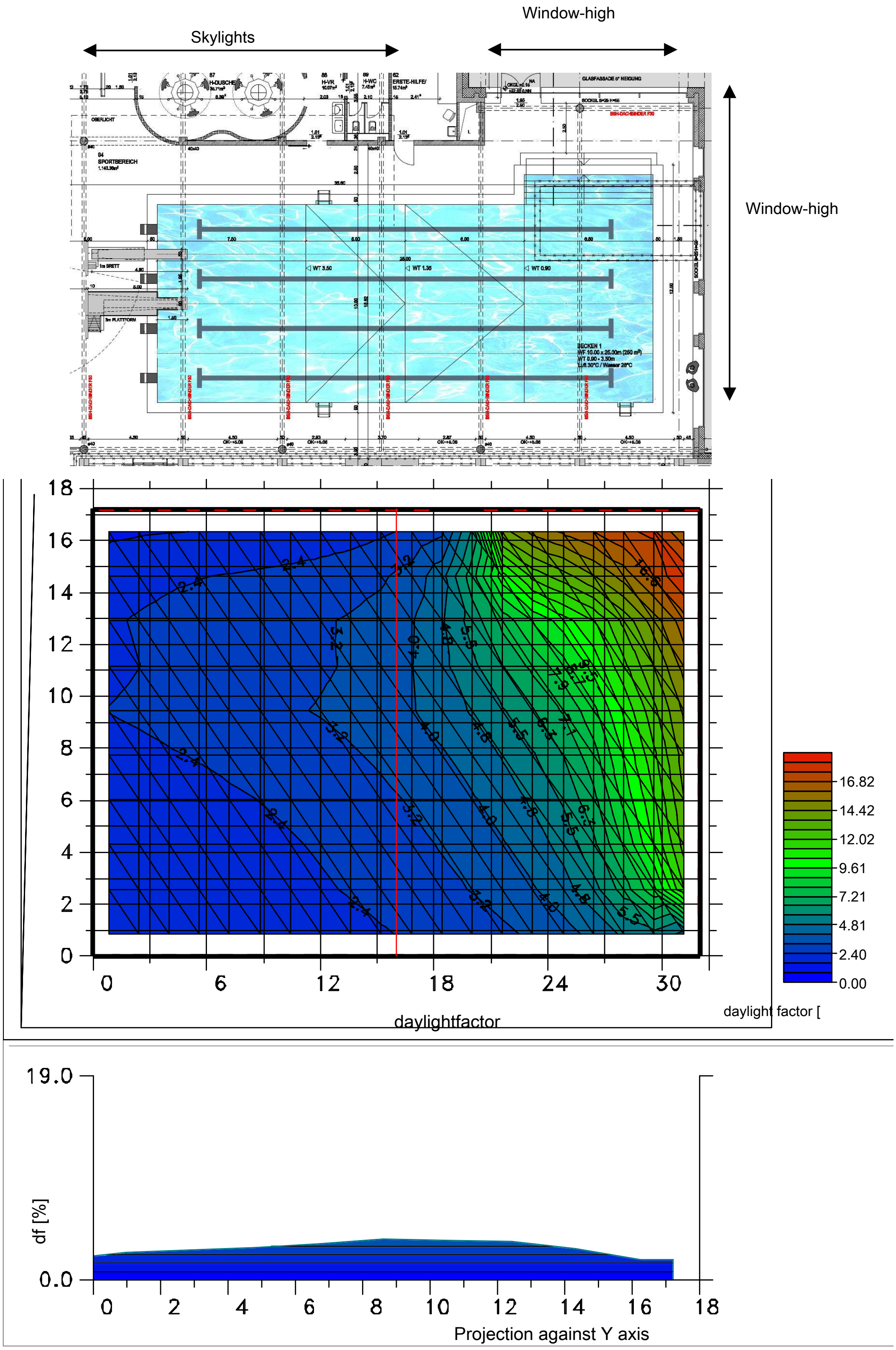


Figure 30: Daylight coefficient for the east hall section

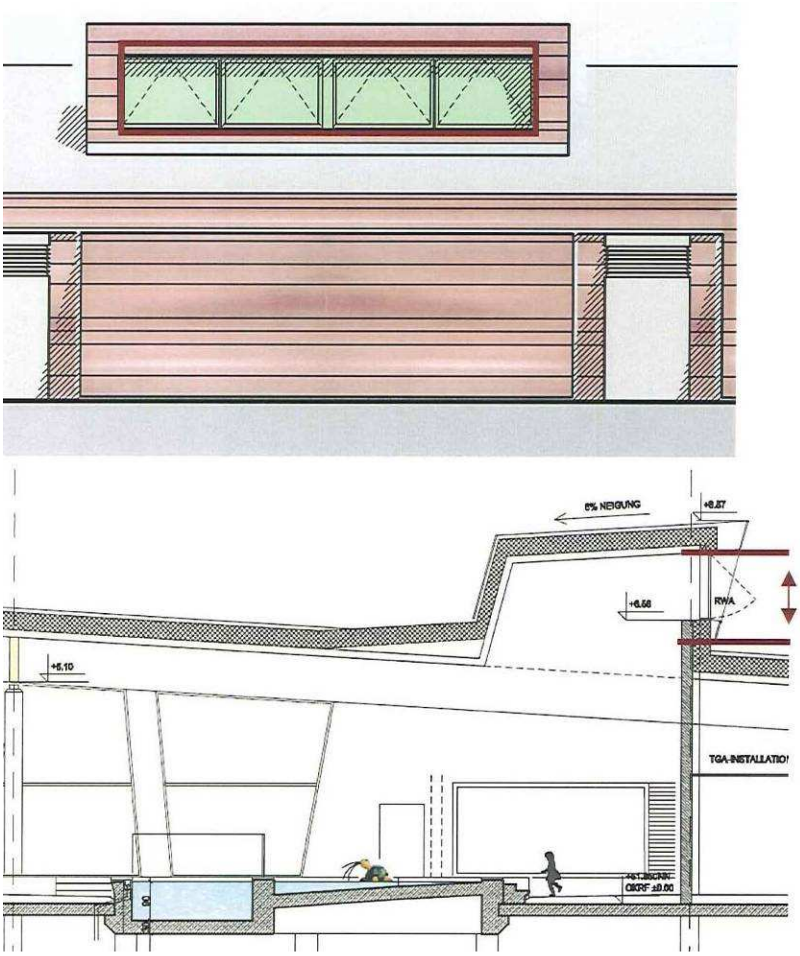
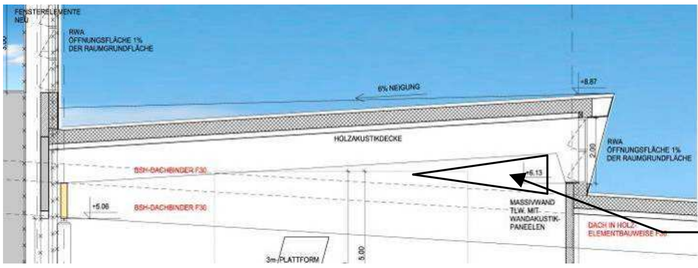


Figure 31: Suggestion for improvement to optimize the daylight yield of the eastern new building through higher skylights

The simulation brought the following results: The daylight coefficient decreases significantly from northeast to southwest. In the middle of the hall (diving tower area), very low values of less than 3% are achieved.

The northeast corner is oversupplied due to the room-high glazing so that the daylight supply is uneven. To improve the daylight supply in the middle of the hall, the skylights could be enlarged or expanded. If the floor-to-ceiling glazing is provided with parapets, the uniformity of the lighting improves.

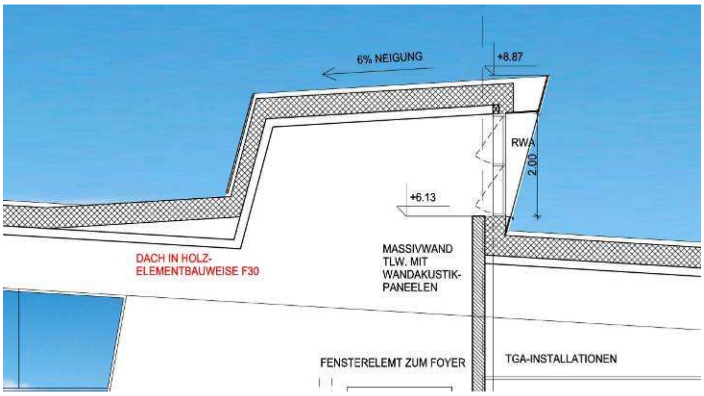
The recommendations from the daylight simulation for this area were implemented in the planning as follows:



Skylight strip for

sports pool 1

No window possible!



Skylight strip hot water / recreation pool

- Enlargement of the skylight strips north facade from H = 1.50m to H = 2.00m.
- Roof dormer sports pool 1: additional, side Window element West / east facade due to lateral Roof connection not possible.

Despite the enlargement of the northern skylights, the supply in the middle of the hall is not yet optimal. The daylight supply above the pool is sufficient, cf. Figure 32.

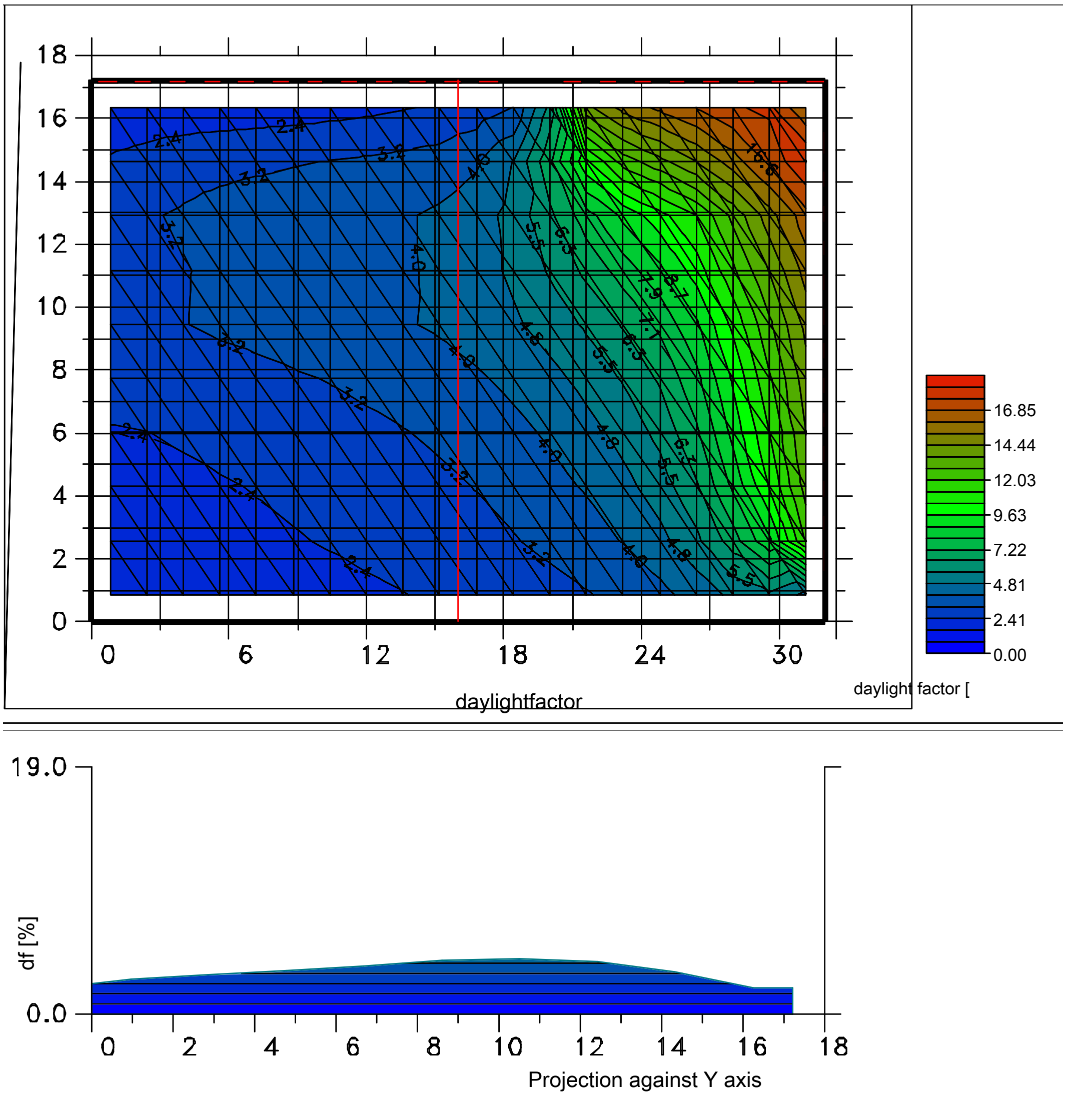


Figure 32: Daylight coefficient for the east hall section with optimized window areas

4.9.4 Optimizing the use of daylight in the new western building

The west and south facades in the western part of the new building are generously glazed, in the north this part is delimited by the foyer, in the east are the hall areas of the bathroom described above.

Figure 33 shows the planned situation and the results from the daylight simulation.

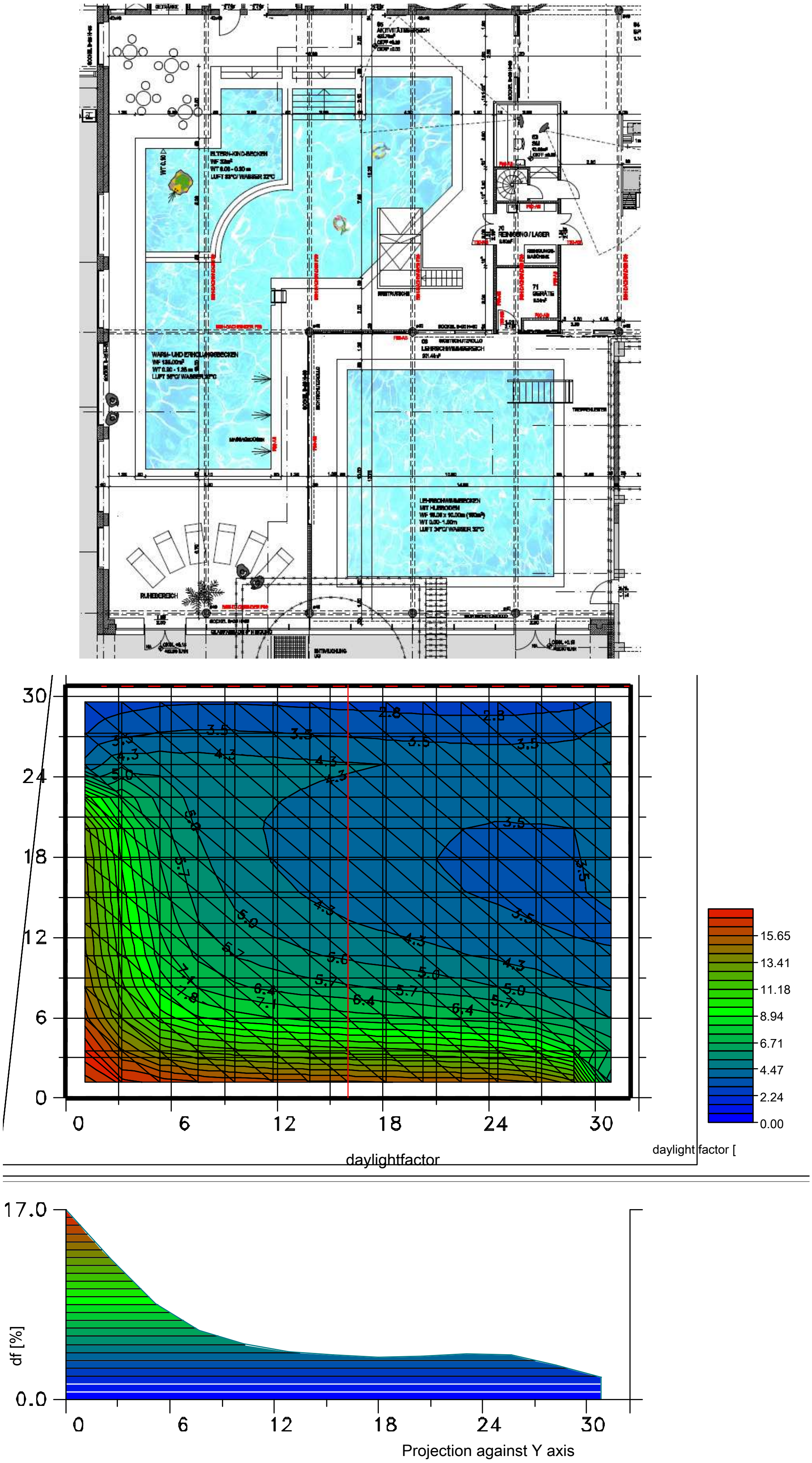


Figure 33: Daylight coefficient for the south-west section of the hall

Results from the simulation: While the north wall is undersupplied, the south-west facade has very high daylight ratios. By closing the facades in the lower area, a more uniform illumination can be achieved.

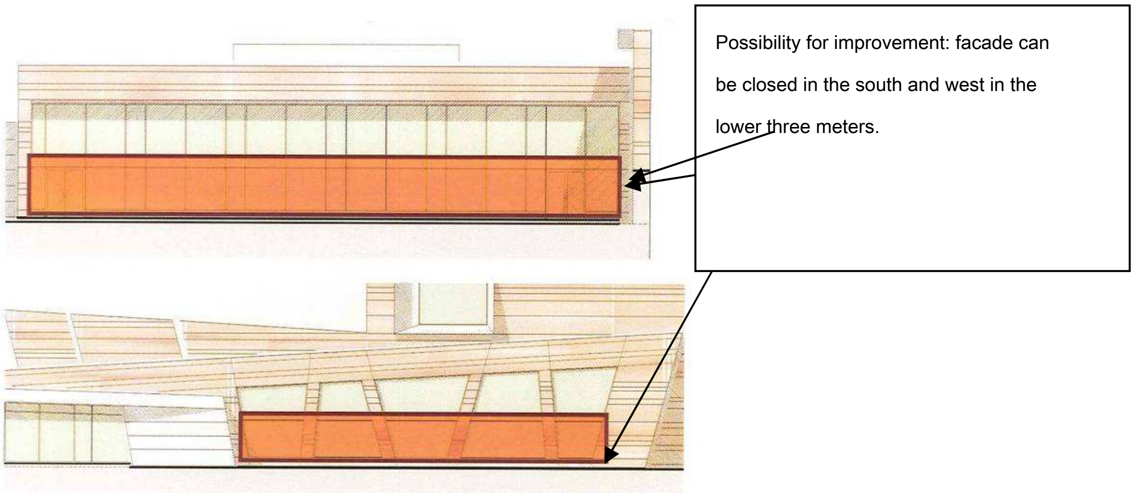


Figure 34: Possibilities for improvement in the area of the west part of the hall

Glazing area in the southwestern part of the bath (see Figure 35) was not reduced for the following reasons:

- The positive, bright impression of the room and the very good external reference (especially in the lying / relaxation area) should be retained.
- The solar gains resulting from the large areas help to reduce the annual heating requirement.
- Increased floor reflection allows more indirect light to penetrate into the depth of the room

Figure 35: View of the swimming pool from the southwest (source: ntspv)

5 building technology

5.1 General

The interlocking of the various technical trades in no other public building is as complex as in an indoor pool. Even the smallest changes in parts, such as the number of sanitary objects, changing the overflow channel on the pool, installing additional water attractions, etc. have an impact on almost all other technical trades.

For example, the installation of an additional children's slide brings about a significant change in the amount of evaporation, which in turn has an impact on the proportion of outside air and the amount of supply air, which in turn affects heat recovery and space requirements in the technical area up to the dimensioning of the outside air intake, which in turn influences the architecture . Against this background, various planning meetings repeatedly tried to optimize the building, including the system technology, with all the specialist planners involved.

In the basic selection of the individual concepts, neither the investment costs with the cheapest price nor the best energy variant were considered. The focus was on the cost-effectiveness of the individual systems within the overall complex.

5.2 Energy supply, primary energy factors

There are two combined heat and power plants in the swimming pool building, one of which is operated with biogas and one with natural gas. The CHPs are part of the district heating network of the city of Lünen, for which a very low primary energy factor of 0.17 was determined due to the high proportion of renewable energies (cf. [Wibera 2010]). The bathroom draws part of the heat it needs from the district heating network.

Since there is a high demand for low-temperature heat in the bathroom, both condensation heat from the CHP plants (condensing boiler use) and waste heat from the installation room of the CHP plants can be used. The use of this waste heat is exclusive
possible in connection with the bathroom. Hence the
The primary energy factor for this waste heat is set to zero.

The primary energy factor for electricity is assumed to be 2.6 according to the regulations of the current Energy Saving Ordinance (EnEV).

5.3 Ventilation technology and heat recovery

5.3.1 Interpretation

The number of ventilation systems was selected according to the different zones within the swimming pool, divided according to temperature and air quality. In total there were 6 different zones for the planned Lippe bath. These are in detail (see Figure 36):

- Children's / warm pool
- Instructional pool
- Sports pool (4 lanes, new building)
- Sports pool (5 lanes, old building)
- Changing room and shower area
- Entrance area, swimming master's room, medical room, staff and ancillary rooms

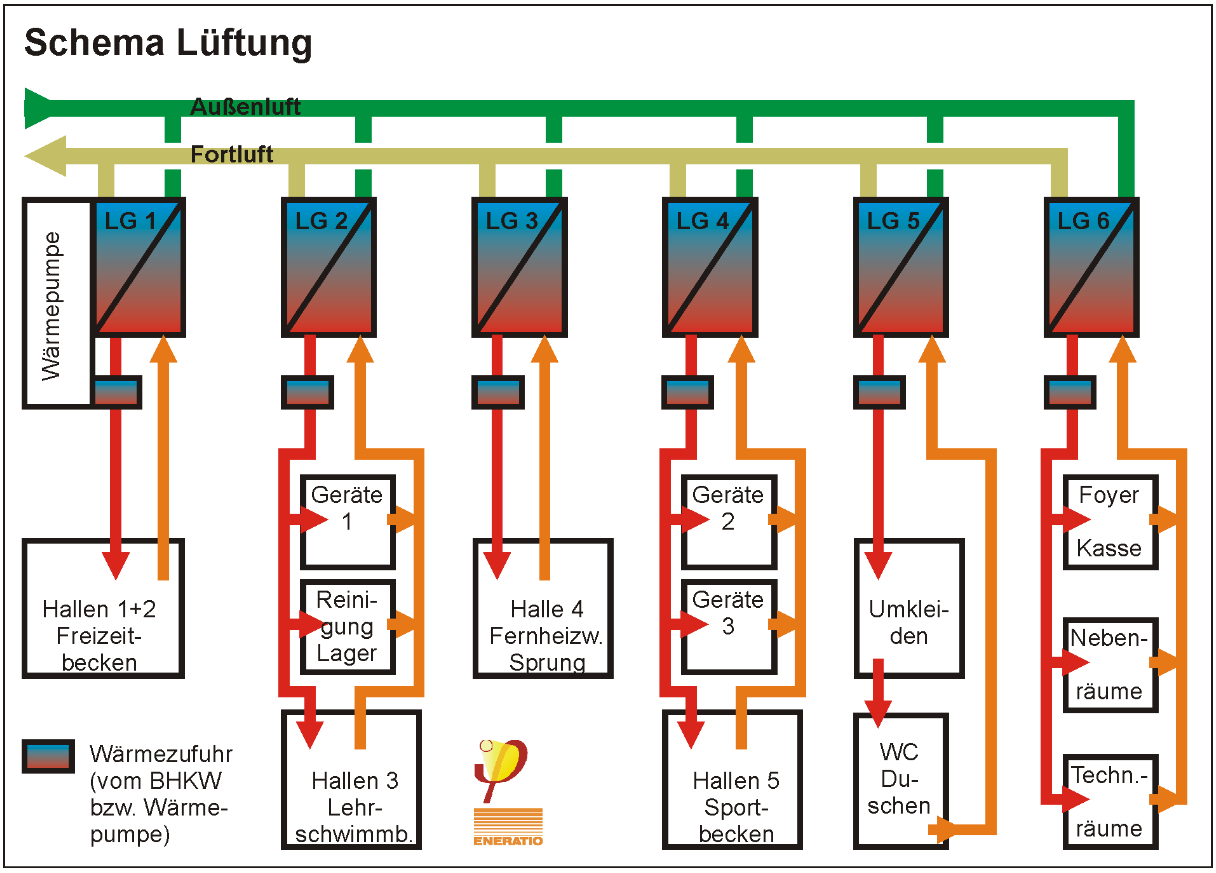


Figure 36: Schematic representation of the ventilation in the lip bath (graphic: PHI)

To the thermal bridges in the area of fresh air intake and
To reduce the exhaust air outlet and the cold ventilation pipes as much as possible, a central outside air intake / exhaust air by means of ventilation towers was planned. The outside air is then led directly to the respective ventilation units through the GRP pipes laid under the insulated basement floor. Likewise, the exhaust air cooled in the heat recovery (partly with evaporators) is led out of the passive house envelope and to the exhaust air tower in a short way. This avoids large areas of cold outside air ducts inside the building, which would otherwise take up a lot of space due to the considerable insulation thickness

in the basement and high
Investment costs for the diffusion-tight insulation would result. Each ventilation unit has recuperative heat recovery consisting of a propylene heat exchanger. Ventilation unit 1 in Figure 36 is also equipped with a heat pump. This cools the exhaust air well below the dew point and condenses it. A speed-controlled compressor brings the latent heat of condensation thus obtained to a temperature level of 40 ° with a performance factor of at least 5. Due to the very low primary energy factor of the entire heat supply due to the use of biogas in a combined heat and power plant and the high investment costs for the heat pumps, the heat pump equipment was only intended for the ventilation unit 1, as attractions (slide, massage jets, Animals) and user behavior (leisure pool, fun, children) the highest evaporation is to be expected. In addition, this area of the hall can be easily separated from the rest of the bathroom, so that measurements of the heat pump system can be easily performed, cf. Figure 37.

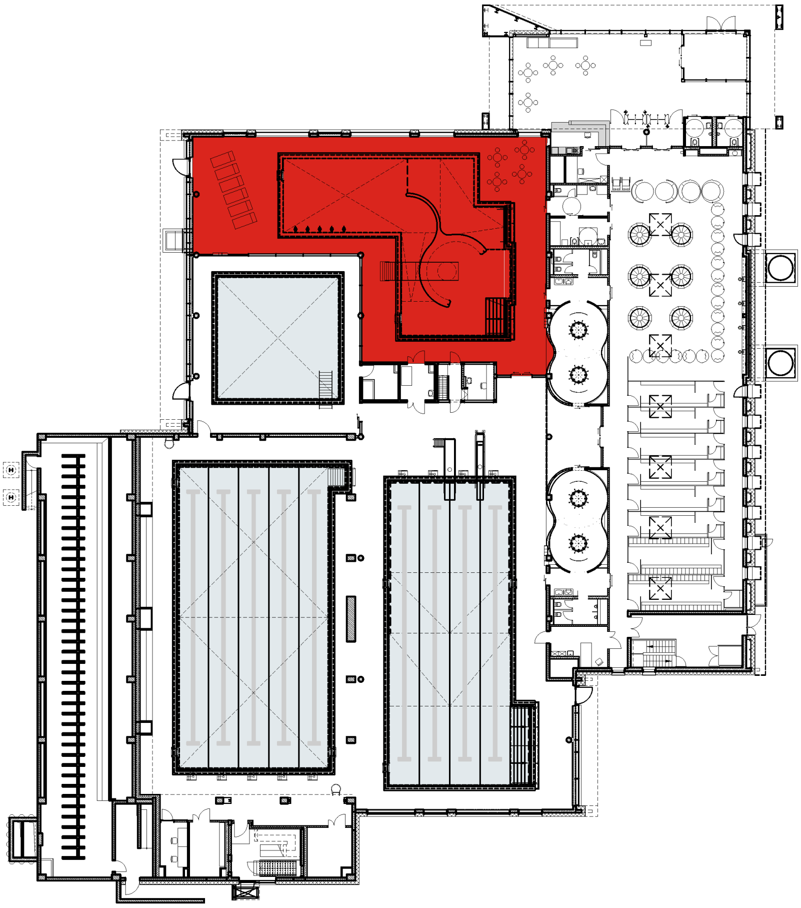


Figure 37: Area that is supplied by the heat pump (marked in red) (graphic: PHI, ntspv)

The heat recovery is dimensioned for the total amount of outside air required according to the KOK / VDI guidelines (approx. 60,000 m³ / h). For this purpose, the amount of evaporation was determined for the hall ventilation devices depending on the use and the pool water temperature. The maximum amount of outside air required for this is obtained in summer with an absolute moisture content of 14.3 g / kg inside the swimming pool. However, the plant is to be operated with significantly lower average air changes. This results in significantly improved degrees of heat recovery over much of the year.

In general, the hall humidity is regulated via the proportion of outside air. In order to keep the supply air volume in the hall area constant, more or less hall air is added. This ensures sufficient air flow through the hall. The minimum surface temperature of the external components is decisive for the permissible air humidity and thus for the required outside air change. The higher this temperature, the higher the dew point and thus allows a higher building moisture-free humidity. The higher the air humidity, the less water evaporates, the less heating energy has to be added to the pool water. Due to the lower dehumidification performance, the one to be reheated can

Outside air content can be significantly reduced. It is therefore energy efficient to allow higher levels of humidity.

In operation, it should be determined to what extent the absolute humidity is raised can, without that this to one impairment of Comfort of the bathers and the operating personnel leads. This operating point is probed via the existing hall humidity and temperature sensors by reducing the proportion of outside air.

5.3.2 Regulation

The air is distributed within the individual ventilation areas by means of adjustable long throw nozzles, which can be adjusted in the throwing direction on the one hand, and in groups on the other using control flaps. This is intended to reduce the amount of supply air, especially in the bathroom area, in order to then be able to carry out a more detailed investigation, on the one hand, of the pollution in the air and, on the other hand, of the air distribution within the hall. For this purpose, individual supply air nozzle boxes with shutter flaps can be controlled, the air volume per hall is

can be reduced in 20-25% increments. Due to the individual adjustability of the air outlets, large throwing distances can be achieved within the hall without drafts, and on the other hand condensate-critical points on the outer facade (e.g. doors, SHEV openings) can be blown directly.

The control concept provides for the ventilation system to be completely switched off outside of operating hours and for the moisture to rise to be monitored on the components at risk. The ventilation system only has to be started up when a limit value with a high proportion of outside air is exceeded in order to remove the moisture. If an uncritical humidity is reached, the system is switched off again. The control of the temperature is similar, with the ventilation only introducing heat when the setpoint falls below a set value in full recirculation mode, ie without outside air, in order to reset the temperature. The ventilation of the entrance area as well as the changing rooms / showers takes place without recirculating air due to the connection of the toilet area. Here

is planned on the one hand the warm, dry, unpolluted exhaust air from the Reheat the changing area and then put it in the showers for dehumidification. This saves a significant amount of energy that would be required to heat the shower supply air. At the same time, the required room conditions are set securely.

?

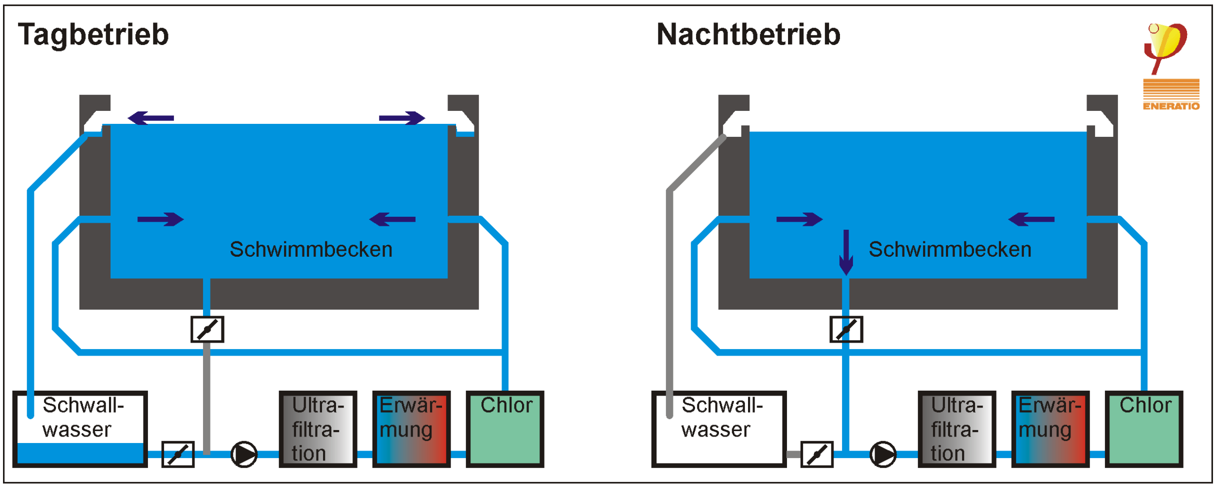


Figure 38: Diagram of the pool hydraulics in day and night operation (graphic: PHI)

5.5 Pool water and swimming pool technology

5.5.1 Optimizing the hydraulics

To reduce pipe friction losses, flow-efficient pipes made of HDPE are used and flow-unfavorable molded parts such as 90 ° angles and T-pieces are largely avoided and replaced by bends with large radii and Y-pieces. Horizontal flow (jet turbulence) is provided for the pool hydraulics. With this technology, even with the planned low water exchange rates (reduction by ultrafiltration and by adjusting the volume flow

to the actual occupancy of the Pool)
Experience has shown that thorough mixing is achieved.

The inflow system is installed on the two long sides of the basin in the lower third, the inflow nozzles are dimensioned for the nominal volume flow, but can be controlled individually during operation.

In order to further minimize the use of electricity, we planned to set up the surge water tank as high as possible in order to reduce the delivery head to be performed by the pumps.

All pools receive a high water level, since the pool edge can also be used as a seat for bathers and so there is no need for other facilities such as heated benches etc. The overflow gutter is designed as a Wiesbaden gutter with a width of 10 cm, in which gutter drains DN 80 are planned. After consultation with the municipal accident insurer, these gutter stones themselves do not require any additional rust cover, which prevents turbulence and evaporation. Only the channel drains themselves get one domed and perforated cover. Due to the relatively small gutter, the head is kept low and the overflowing water is quickly led into the gutter line below. Both measures are intended to reduce the evaporation of the pool water.

5.5.2 Pool water heating: use of waste heat

On the one hand, district heating from the Lünen municipal utility is available for pool water heating, which is generated by combined heat and power. On the other hand, a low-temperature heat exchanger is used in each pool water circuit, which will use the waste heat from the room exhaust air from the CHP plants.

5.5.3 Filtration: Ultrafiltration has advantages

In the course of the design planning, various filter systems were planned and compared in a total cost / benefit comparison, cf. Figure 39. Three filter systems were considered:

- Pressure filtration via gravel filter (steel filter)
- Low pressure filtration through gravel filters
- Ultrafiltration (UF)

In the evaluation, the respective resilience factors of the currently valid DIN standard as well as the draft of DIN 19346, part 6, ultrafiltration systems currently under discussion were taken into account. With ultrafiltration, due to the significantly improved filtration result, only half the circulating volume per basin is required compared to the other processes specified in the DIN. This has an impact on the surge tank size, the dimensioning of the pipeline, the number of pure water and gutter nozzles and on the electrical output and energy consumption of the circulation pumps. The aforementioned points, expanded by an assessment of the space required, which is significantly less for ultrafiltration than for pressure

or low filtration, were rated. As the basis of the
Total cost comparison is used for this purpose, information from the client regarding the energy costs for electricity, heat, fresh water, sewage / rainwater. An ultrafiltration system was found to be the cheapest filtration process for all variants for the Lippe Bad in Lünen. Here, the filter system itself is more expensive than the other variants. But the savings in the auxiliary units, built-in parts and especially in the converted space result in the best overall result.

Ultrafiltration does not correspond to today's generally recognized rules of technology for bath water treatment, but work is currently being carried out on another part of the water treatment standard DIN 19643, in which this Filtration process should be described.

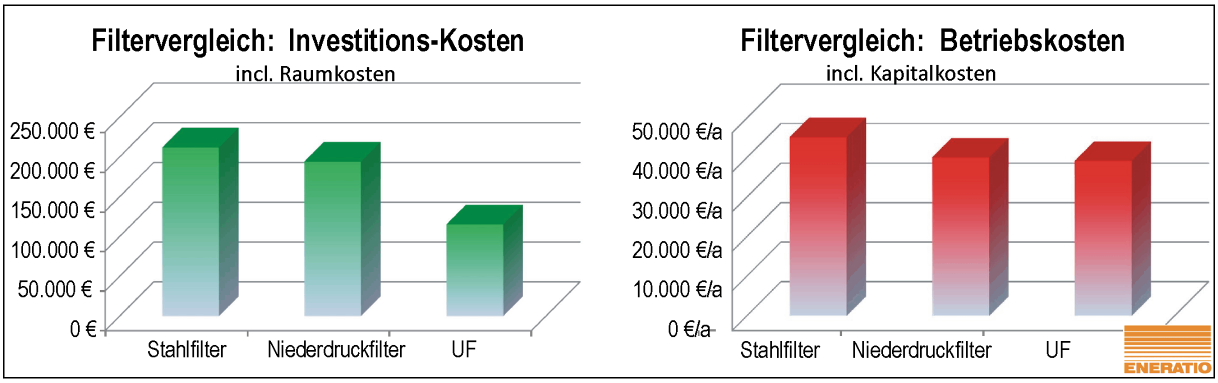


Figure 39: Comparison of the examined filter variants with regard to their specific investment and operating costs (source: ENERATIO)

The advantage of filtration technology is on the one hand the small space requirement, and on the other hand a significantly improved filter effect, which makes it possible to reduce the circulation volume overall. This reduction goes hand in hand with less chlorine addition and also less need for flocculants and pH correction agents.

Basement heights of 2.50 m are sufficient for ultrafiltration, which leads to considerable reductions in construction costs.

The lower chlorine addition reduces the THM formation potential. If a specified limit value is nevertheless not met in a future bathing water ordinance, an activated carbon filter can be installed in a partial flow. To reduce the chloramines, a medium-pressure UV burner is installed after the ultrafiltration. This technology has already had good experiences in other indoor swimming pools.

5.5.4 Chlorination: The safest and most comfortable solution selected

The following options for chlorination were examined and compared as different disinfection methods.

1. Chlorine gas - full vacuum system
2. Membrane cell electrolysis
3. Inline electrolysis

For all variants, an average pelvic load was set up over the entire year and the disinfectant requirement was determined. At the *Chlorine gas process* the chlorine gas is stored in pressure vessels in a chlorine gas room provided for this purpose and fed to the respective pool water circuit via propellant water injectors. The chlorine gas process variant is by far the cheapest in terms of investment and operating costs, but due to the pressure vessels in the event of an accident there is a risk that cannot be calculated. In the *Membrane cell electrolysis* Sodium chloride is stored in tablet form on site and an aqueous chlorine solution is made from it in the membrane cell electrolysis process.

which then by means of dosing pumps

Pool water circuit is supplied. The investment costs and operating costs are in the medium range. Due to the relatively low concentration of the aqueous solution, large motor metering pumps are required, which have a power requirement to be observed. Leaky metering lines can cause considerable damage to the entire technical system. In the third variant that was *Inline electrolysis process* examined, in which the entire pool water is driven with a slight salt content of 0.4%. The electrolysis takes place directly

within the pure water pipe on the way to

Swimming pools take place depending on the respective personal load. With this variant there is practically no danger from the chlorination system. The hydrogen generated during electrolysis is removed via the hall ventilation. This is proven by an independent expert opinion. Disadvantages of this variant are the high investment and operating costs, which are also due to the fact that all technical units and parts in contact with the pool water must be made seawater-resistant, since the salt content leads to significantly higher chloride concentrations on the respective components.

The client has already successfully used this chlorination process in several of his bathrooms and has also received an innovation award for avoiding the

Obtain handling of chlorine gas. Furthermore, the Lüner bathers appreciate the light salt content as very pleasant.

For the reasons mentioned above, the decision was not made according to the most economical, but rather the chlorination process that was most pleasant for bathers and also for safety reasons.

5.6 Heating technology

5.6.1 Heat requirement: Significantly reduced

Due to the planned highly efficient heat recovery and the passive house envelope, the ventilation heat requirement, which must be covered by district heating, is becoming less important than a conventional bathroom. The regular supply of energy for the heat of evaporation of the pools is now essential

such as of Substitute of Filter rinse water and the Domestic hot water heating.

Based on the KOK guidelines, a total connected load of 675 kW must be made available for shower water, pool water and ventilation. This power is required on a cold winter day (-15 ° C). At the same time, this performance is sufficient to bring the swimming pools to the required temperature (28 or 32 ° C) within 24 hours. In the event, however, should not take place simultaneously.

5.6.2 Heat supply: condensing boiler use

The indoor pool is heated essentially from the District heating connection of Stadtwerke Lünen (see Figure 40). The existing district heating system is indirectly connected to the house network by means of a transfer station. The largest consumers are the heating registers for heating the indoor air (which also covers the transmission heat requirement) and the heat requirement of the pools.

The total return of the bath should not be higher than 40 ° C, so that the two nearby combined heat and power plants can work in stable condensing mode (exhaust gas condensation temperature below). As the feed temperature for district heating is significantly higher, combined heat and power plants cannot work in condensing mode for this purpose. It should be emphasized that only the immediate proximity of the CHPs to the swimming pool in connection with the low return temperature opens up the possibility of condensing operation. This means that a large part of the bath's heat requirements can be met from a source that would normally be released into the environment.

In a further expansion step, the idea was to install a solar thermal system for preheating the hot water. It should be noted that high solar coverage rates (e.g. 40%, as is customary in residential construction) are neither sensible nor economical for an indoor swimming pool, since large amounts of shower water are required here in short times. In this respect, a solar thermal system can only provide economic support. The majority of the domestic hot water is obtained from the district heating network. A detailed examination of the entire heating concept has shown that in the Lippe bathroom, for reasons of effectiveness, there is no need for heat collectors in favor of an enlarged photovoltaic system.

5.6.3 Heat distribution: No static heating surfaces

The heat is supplied exclusively via the ventilation and the pool water. Static heating surfaces are not provided.

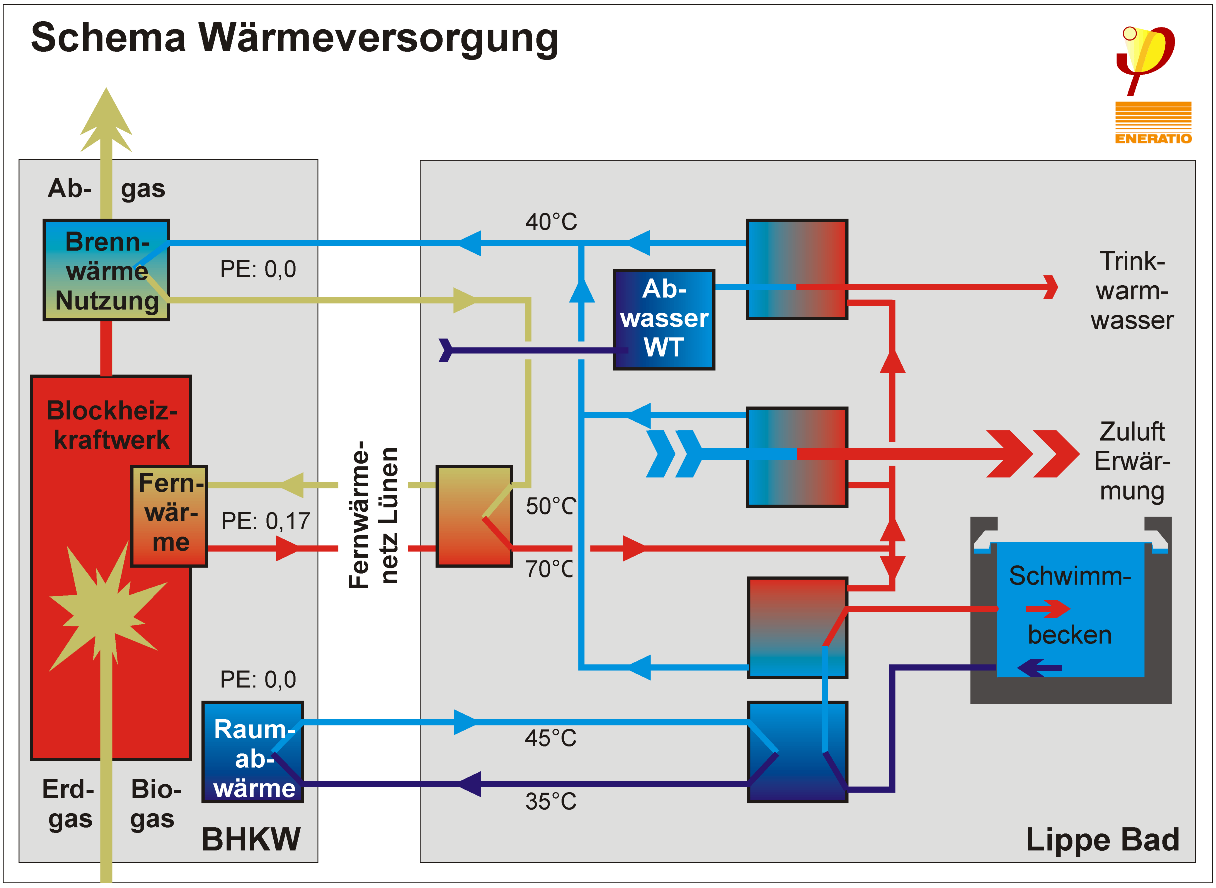


Figure 40: Scheme of heat supply via the combined heat and power plant (graphic: PHI)

5.7 Drinking / industrial water, waste water, rain water

5.7.1 Flushing wastewater: Continuous accumulation enables recycling

The amount of flushing waste water from an ultrafiltration system for pool water treatment is comparable to that of normal pressure filtration. Ultrafiltration does not initially reduce the amount of wastewater. Pressure filters are usually rinsed twice a week. In these phases, wastewater is concentrated in large quantities. The ultrafiltration is rinsed up to 8 times a day with considerably smaller amounts of water. The wastewater accumulates more evenly and can be treated quasi continuously for further use.

The filter rinsing wastewater from the pool water treatment system is collected in an intermediate tank and processed from there via a further prefiltration with downstream ultrafiltration and added to the splash water tank as a fresh water replacement. This filtration water replaces approx. 70% (9,000 m³ / a)

the normally necessary fresh water requirement of the
Swimming pool.

In addition to the fresh water additive, rinsing wastewater treatment also saves considerable amounts of thermal energy, since the treated water only cools slightly during the filtering.

The remaining filter rinse water and the filter rinse water from the downstream treatment plants are fed to the settling tank. The rinsing waste water can settle (settle) in this container within a period of 2 to 4 hours. The clear water in the upper area of the sedimentation tank is drawn off and passed through a further treatment plant. This essentially consists of a gravel filter and a downstream activated carbon filter. With this treatment, the filter rinse water is treated to such an extent that it can be discharged directly into the nearby lip. Part of the filter rinsing water (approx. 1,200 m³ / a) is passed through another UV treatment system and used in-house for toilet and urinal flushing. Through recycling, further recycling and direct discharge avoid considerable amounts of dirty water and significantly reduce the burden on the municipal sewage treatment plant. The requested initiation permits of

competent authorities
(Lippeverband, district, city) are already available.

In the Lippe bath, the entire pool water is mixed with 0.4% brine due to the selected chlorination process. Since the salt is not removed by ultrafiltration, it is also contained in the waste water. After clarification with

Various manufacturers can apply pressure flush valves to the toilet / urinal system with the brine-containing wastewater. In order to minimize the signs of corrosion as far as possible, the use of plastic pipes is intended for these pressure lines. In addition, measures must be observed, such as laying the pipes in a circuit completely separate from the drinking water system, and with a clear visual distinction in order to reliably avoid cross connections. In addition, all taps are labeled with the warning "No drinking water".

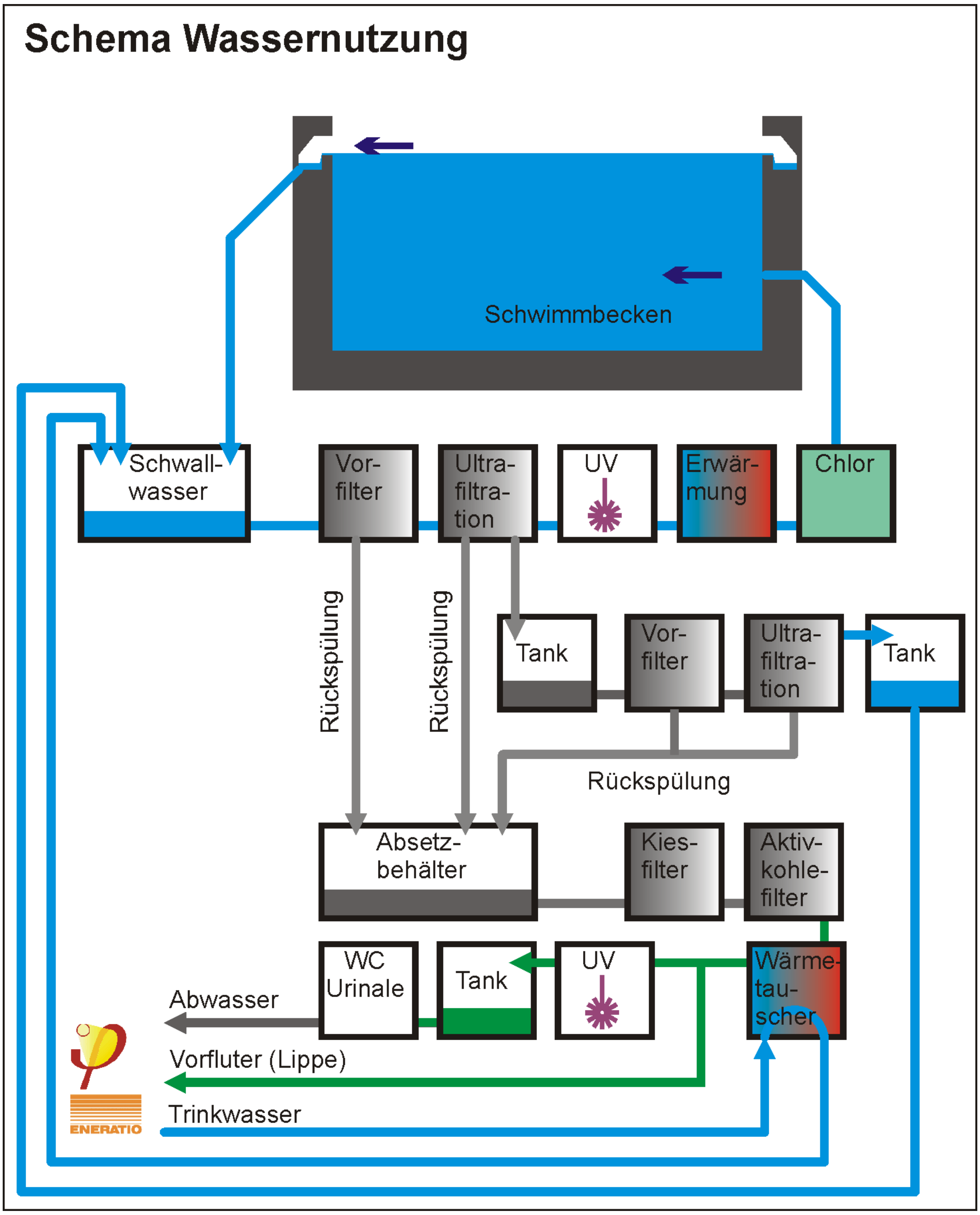


Figure 41: Scheme for filtration and water recycling (graphic: PHI)

5.7.2 Use of rainwater: Not useful due to the recycling concept

For use within the toilet / urinal flushes there was also a
A rainwater harvesting system is planned, which captures all the rainwater in the roof of an outside cistern and from there provides the fittings in question via a pressure booster system. As already described in the previous paragraph, dual use of the mandatory rinsing waste water is possible.

In this context, the
Rainwater harvesting system discarded as not economically viable.

5.7.3 Process water: Consistent use of water-saving technology

At all drinking water taps, water-saving fittings are important. Electronic, demand-controlled trigger units are provided on the hand wash basin, as well as on the shower fittings and urinals. These must be kept hygienically perfect, especially in public areas. In the area of the showers, which are generally the largest hot water consumer in the indoor pool, fittings with sensor technology were planned that automatically switch off the shower water supply after an adjustable run-on time when leaving an area of influence. Shower heads with a flow of 6 l / min are used. This is a 50% reduction compared to shower heads normally used. The lower amount of water is compensated for by a special swirling system with air intake, so that there are no restrictions in shower comfort. In the area of the toilet facilities, flush valves with automatic 2-flow control are used, which can be triggered by means of electronic buttons.

Because of a clear labeling
("SMALL" / "LARGE") the necessary flushing should be selected by the user. Through the consistent use of water saving technology, the entire installation

including the domestic and hot water heating system smaller
be dimensioned.

5.7.4 Drinking water hygiene: ultrafiltration and chlorine dioxide addition

To reduce the chloramines in the pool water area, the addition of chlorine dioxide to the pool filling water in connection with UV technology has proven itself in recent years. The agent chlorine dioxide is an approved disinfectant in the area of drinking water networks.

In order to ensure permanent drinking water hygiene in addition to pool water hygiene,
is the use of an ultrafiltration system in the area of
Main drinking water connection planned. All bacteria are caught at the entrance to the house. The pipeline network cannot be populated. To further ensure hygienically perfect drinking water, the chlorine dioxide system that is actually only required for the swimming pool is also used for the drinking water network of the showers and water dispensing systems. Due to these two successive systems (ultrafiltration + chlorine dioxide system), the domestic hot water temperature can be set at 40 ° C in the entire bathroom. This significantly reduces storage, pipeline and circulation losses. Of course, if there is any contamination, the entire pipeline network can be run and disinfected in accordance with the DVWG worksheet.

5.7.5 Domestic hot water: Circulation pipe avoided

A circulation is not planned. Instead, the temperature at the end of the pipeline network of the cold and hot water pipes is monitored. If the desired temperature is exceeded or fallen below, the amount of water is fed into the surge tank 4/5 until the desired temperature is reached again.

For DHW heating, a storage tank charging system with an external plate heat exchanger is planned in order to maintain low return temperatures. The drinking water is used for preheating
in counterflow to the directly introduced
Pre-heated rinse water via a plate heat exchanger. This removes the residual heat from the waste water from 25 ° C to approx. 15 ° C.

5.8 Electrical use and efficiency conditions

5.8.1 Electricity requirements: reduction and self-generation

Particular attention was paid to the reduction of electricity requirements for lighting, drives, etc. A large part of the demand is generated with the two combined heat and power plants located in the technology cellar of the old district heating plant (2 motors, each 260 kW_{el}, 1 * biogas, 1 * natural gas).

In order to keep the overall electricity requirement low, various concepts have been developed and implemented in the planning.

5.8.2 Lighting: Reduction of energy requirements through efficient luminaires, intelligent control and light simulations

In the field of lighting technology, only luminaires with high efficiencies are used.

Lighting strips with fluorescent tubes are provided in the changing areas. These are controlled depending on daylight, because on the one hand a lot of natural light falls into the area via the window facade and on the other hand via the skylights. In addition, presence detectors monitor the individual areas and switch off the lighting if they are not used for a long time. Fluorescent lamps are also provided within the shower rooms, which are switched via presence detectors.

The indoor pool lighting is also controlled via daylight measurement. Here, individual lighting circuits are switched on or off in order to achieve a uniform illuminance. Some of the double-flame metal vapor lamps are always switched with an efficiency of approx. 100 lm / W. The desired illuminance (different scenarios) can be preselected on the programmable logic controller (PLC), after which the control runs automatically.

The optimal locations of the lights were determined by light simulations. In this way, the illuminance levels required on and next to the water surface are achieved with very little energy. Switching on and off manually, e.g. by the operations manager or swimming supervisor, should only take place in exceptional cases and at special events.

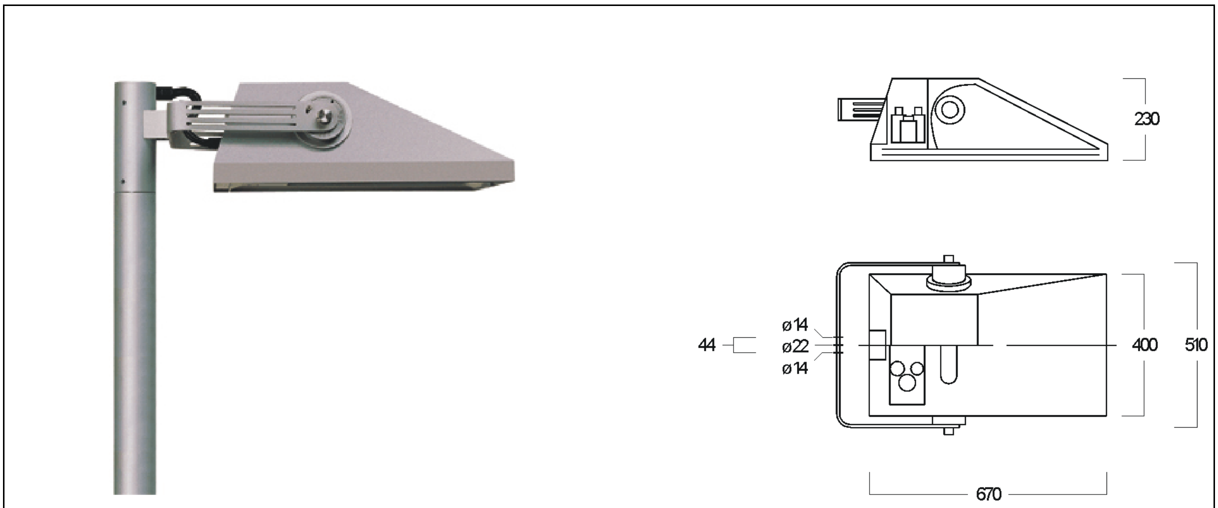


Figure 42: Selected luminaire: we-ef model FLA760. (Source: www.weef.de)

The entire lighting can be switched off at a central point (staff entrance), so that when leaving the bathroom it is ensured that lighting is not unnecessarily operated permanently. At the same time, a key switch ensures that the cleaning staff who come into the hall before starting the bath can only switch on the lighting required for cleaning.

All lighting fixtures are planned so that the maintenance / servicing / replacement of the illuminants can be carried out from one ladder. This measure is expected to significantly reduce operating costs. The requirement for maintenance options by means of instructions is accompanied by a limitation of the installation heights in individual areas. Using light calculations, however, it was demonstrated that the required illuminance levels can still be maintained in normal and competitive operation.

In the area of underwater lighting, modern LED underwater spotlights are used, which in turn are able to generate lighting images within the pool similar to metal halide lamps thanks to an upstream lens technology. The significantly longer lifespan and the possibility of coloring were the basis for the decision. The underwater spotlights can be operated from the basement-side aisle and serve only for the visual impression. Underwater lighting designed for competitions was not requested by the client.

5.8.3 Plant technology: efficient pumps, motors, fans and compressors

All drive motors on the circulation pumps in bathing water and heating technology, as well as on the fans, will be equipped with the highest possible efficiency. Efficiency class 1 (EFF1 = IE2) is prescribed as the minimum standard. Circulation pumps and fan motors with long running times are already planned as IE3 electric motors. This ensures that the latest generation of motors with the highest levels of efficiency are used.

In the area of active heat recovery using a heat pump, attention is paid not only to the efficiency class of the motors, but also to a precisely designed cooling circuit and a speed-controlled compressor to achieve the highest possible performance figures (> 5).

is able to determine the current number of people in the water with little uncertainty. This system should also be used in new buildings, first at the leisure pool,
used will, around Circulation performance and
To be able to regulate the addition of disinfectant according to the actual requirements. In this way, further potential savings in electricity, heat, water and operating resources are to be tapped.

All parameters to be measured are measured during the first year of operation plus the adjustment phase (estimated 3 to 4 months) in a 10-minute grid and recorded on the building management system (BMS). The PHI accesses these GLT data, which are decisive for monitoring, and checks these min. weekly for plausibility. The further data preparation and evaluation takes place with regard to the energetic goals and a possible operational optimization.

5.9.2 Air pollutants

When it comes to the energetically motivated reduction of air exchange rates in an indoor pool, the decisive parameters of air quality must be taken into account. In the case of baths which ensure chlorine water hygiene, the resulting group of trihalomethanes (THM) must be taken into account. Existing studies (eg [Gundermann 1997]) do not allow any conclusions to be drawn about the relationship between the THM concentration in water and air with the air exchange rate. Therefore, this relationship should be examined in an investigation in collaboration with a chemical analysis laboratory. Under the direction of the Passive House Institute and in consultation with the pool company, around 200 to 250 room air samples are to be taken over several measurement days and analyzed for the THM concentration in the laboratory.

The PHI works out the positions of sampling in the bathroom, taking into account different sampling heights and different air exchange rates. At the sampling positions, the degree of turbulence of the air, the air temperature and the relative humidity are recorded by the PHI parallel to the sampling. The data are evaluated and interpreted with the laboratory analyzes, taking into account the respective air exchange rates and the number of people in the water.

5.9.3 Blower door measurement

A high level of airtightness of the building envelope is a prerequisite for the functioning of the ventilation systems and avoidance of structural damage due to exfiltration. In the case of an indoor pool, the need for an airtight cover is particularly important due to the increased indoor air humidity. This is further exacerbated in the desired mode of operation with even higher room humidities. Therefore, checking the airtightness by means of airtightness measurements is a central prerequisite and is also used for quality assurance during the construction phase. To carry out the measurement, a point in time must be selected as soon as possible after the building envelope has been closed. This is the only way to remedy any defects found. The most important defects can be assessed and, if necessary, to be reworked on site. Before carrying out the actual airtightness measurement according to EN 13829 with a vacuum and overpressure measurement series, the building preparation for the measurement day and the selection of the measurement date are the focus of the activities (pre-appointment).

5.9.4 Thermography

To check the realized quality of the building envelope, especially at potentially critical points such as the glazed areas (mullion-transom construction, glass edge, connections) and the remaining thermal bridges in the existing building (internal insulation), indoor and outdoor thermography is carried out in the cold season with a high-resolution thermography camera .

6 Energy balance / simulation

In order to be able to assess and optimize the individual components of the building and the technology of the planned indoor pool in Lünen, the energy requirement was calculated during the planning phase. A dynamic building simulation was carried out for a precise observation and analysis of the thermal and hygric behavior. In addition, a descriptive and simplified stationary calculation was created with a version of the Passive House Project Planning Package (PHPP) that was expanded for this purpose.

In this part of the report the current status of these calculations and the current results are described and the most important parameters are identified.

Some influential factors have not yet been finally determined at the current planning stage. In these cases, realistic assumptions and estimates were made. Both models should be tracked during operation and the planned metrological examination of the bath in order to be able to understand the energy consumption.

6.1 Stationary energy balance

Dynamic building simulations are complex and require a comparable amount of work and time to create and evaluate. Stationary energy balances are clearly more manageable, as they clearly display the energy requirements of a building using a simplified calculation method. The Passive House Planning Package (PHPP) has proven itself in practice for many years as a tool for planning energy-efficient residential and non-residential buildings. For the project planning of the indoor swimming pool, the existing PHPP was extended in order to be able to map the various additional components of this building type and the interactions between the zones. The model depicts the overall concept of the building envelope and building services stationary, based on monthly averages of the local climate,

6.1.1 Zoning

The basis for the stationary lance of the indoor pool in Lünen is a zoning of the building into six temperature ranges. The selected zones are listed in Table 3 and marked in the floor plans of the indoor pool for visualization in Figure 43. To simplify matters, individual areas of the building have been combined as far as possible and sensibly; For example, all hall areas with a volume-average temperature were mapped as one zone, as were the changing rooms with a target temperature of 26 ° C and the showers / toilets with a target temperature of 28 ° C.

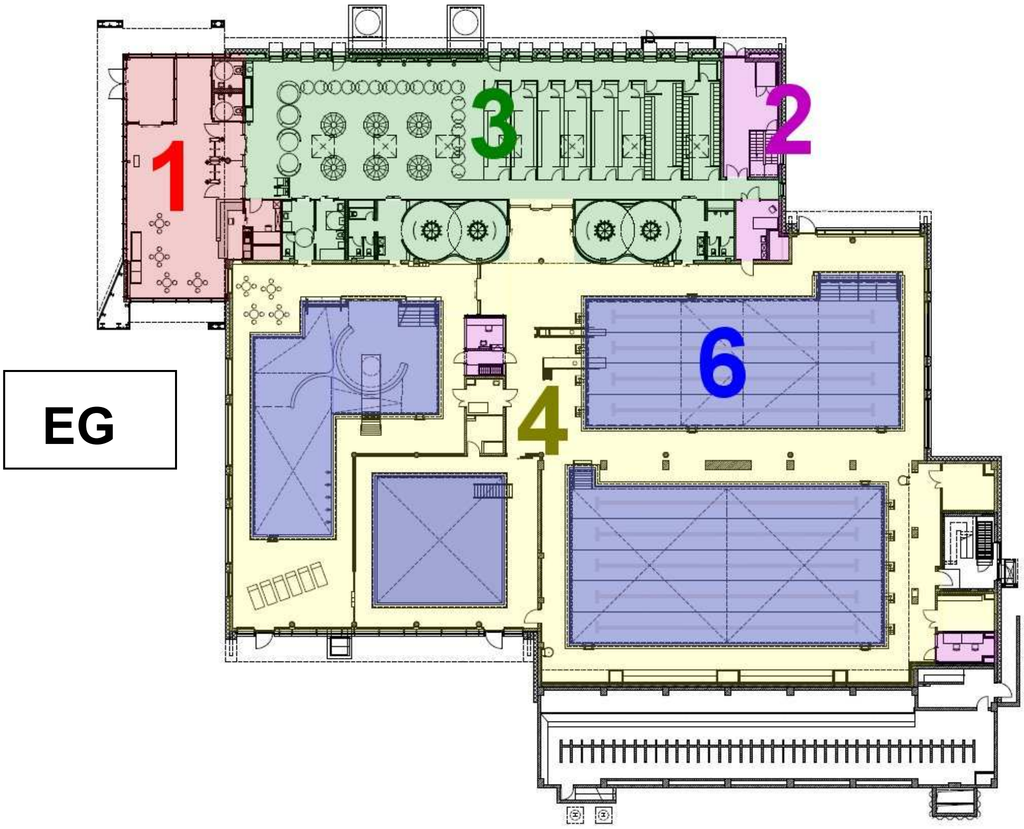
Table 3: Zonen of stational energy balance no.

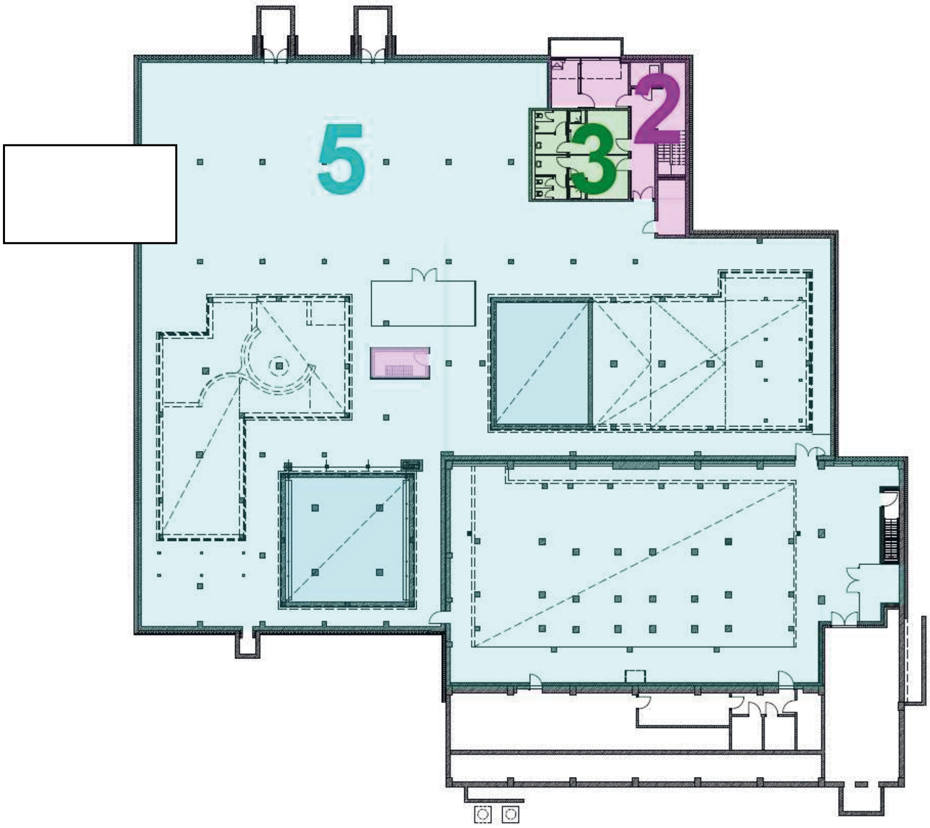
	Description of target	temperature [° C]	Energy reference area [m²]
Zone 1	foyer	22	121
Zone 2	All	22	106

	Side rooms zone		
3	Changing showers toilets	26.3 1)	606
Zone 4 hall	areas	31.3 1)	941
Zone 5	basement, cellar	2)	1288
Zone 6	pool	29.1 1)	850
total			**3912**

1) These temperatures are volume averages of the individual areas covered.

2) The temperature in the basement arises due to the internal heat sources and cross heat flows from the adjacent zones.




5
3
2

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	ββ

?

The energy requirement for the hot shower water was calculated based on the expected number of visitors of 230,000 visitors per year (based on a flow rate of the shower heads of 6 liters per minute and an average shower time of 3 minutes).

The distribution losses of the heating pipes, the hot water and cold water pipes can be taken into account in the energy balance. They were estimated but neglected in the results listed here, since the impact on the overall primary energy balance is comparatively small and no precise information is yet available.

consumer

The currently The values of the electricity consumers in the PHPP are based on Estimates by the building services planner. A distinction is made between building technology (auxiliary power heating, sanitary, swimming pool technology), lighting and other consumers (cash register, blow dryer, administration, possibly elevator etc.). These values are revised in the ongoing planning process.

Internal sources of heat and moisture

The bathroom's internal heat sources differ in each zone. They consist of the heat given off by the visitors, the lighting, the building technology, other applications and the distribution losses. In the basement in particular, the heat sources are quite high due to the central technical equipment in a comparable narrow space. With the help of the PHPP, the heat emissions can be calculated very precisely for each zone, provided the relevant parameters are known or can be reliably estimated. In order to be on the safe side when calculating the heating requirement, standard values from the non-residential sector were adopted for the balancing status listed here: 3.5 W / m² was added to each zone except for the basement and the basins.

Climate data

The climate data set of the test reference year TRY 5 (Essen) of the German Weather Service was used [Christoffer 2004].

6.1.3 Results

Final energy requirement

Final energy requirement according to the current project status (without air circulation): 549 kWh / (m²a)

The final energy requirement calculated with the PHPP is shown in Figure 44. A distinction is made here between the heating requirements of the room air, the heating requirements of the pool and shower water, and the electricity requirements of the building services and other consumers. It can be clearly seen that the overall heating plays a rather subordinate role - also thanks to the very well insulated and airtight passive house building envelope. The water has the greatest final energy requirement, with the evaporation of the pool water causing the greatest losses.

The main energy consumer "evaporation" is significantly reduced with the passive house concept. This becomes clear when you look at the balance of the same unchanged building with a standard indoor humidity of
14.3 g / kg considered (Figure 45). The total final energy requirement is then 793 kWh / (m²a), although this figure does not yet take into account the increased electricity consumption of the swimming pool and heating technology. Specifically, the higher hall humidity reduces the heating requirement of the hall by approx. 46% and that of the pool water (only transmission and evaporation losses) by approx. 36%. Further savings in this area are hardly possible for reasons of comfort and building physics, these limits should be validated during the planned metrological examination.

In addition to the heating requirements of the room air and the pool and shower water, the projected electricity requirements of the building are listed in the following graphics. These values are currently the most uncertain, the numbers listed here are based on estimates and projections that are on the safe side. The power consumption of the ventilation fans was, as described in the boundary conditions, with a current efficiency of the ventilation devices from

0.45 Wh / m³ calculated. It is divided into the electricity requirement of the amount of outside air required for dehumidification and the additional electricity requirement at maximum recirculation mode (difference between the design and outside air volume flow) during opening hours. Here you can clearly see that the required fan flow can be reduced significantly without recirculated air. In this case it is almost 50%.

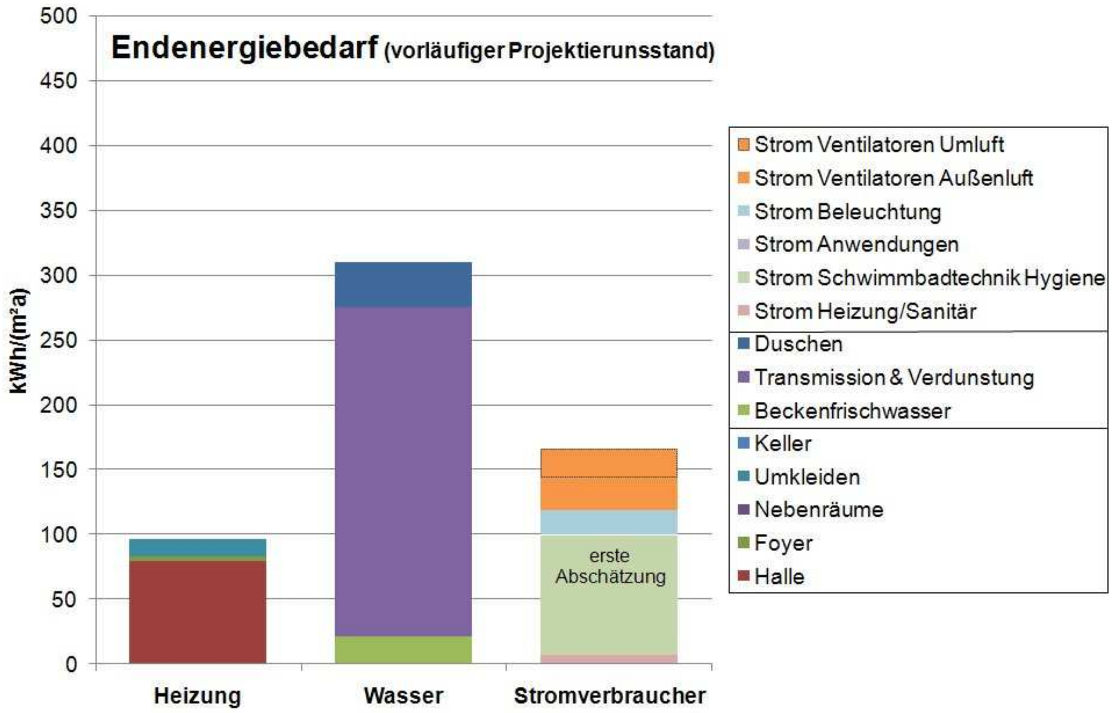

Figure 44: The final energy requirement of the building according to the current preliminary planning status, divided into space heating requirements, heating requirements for water and electricity consumers.

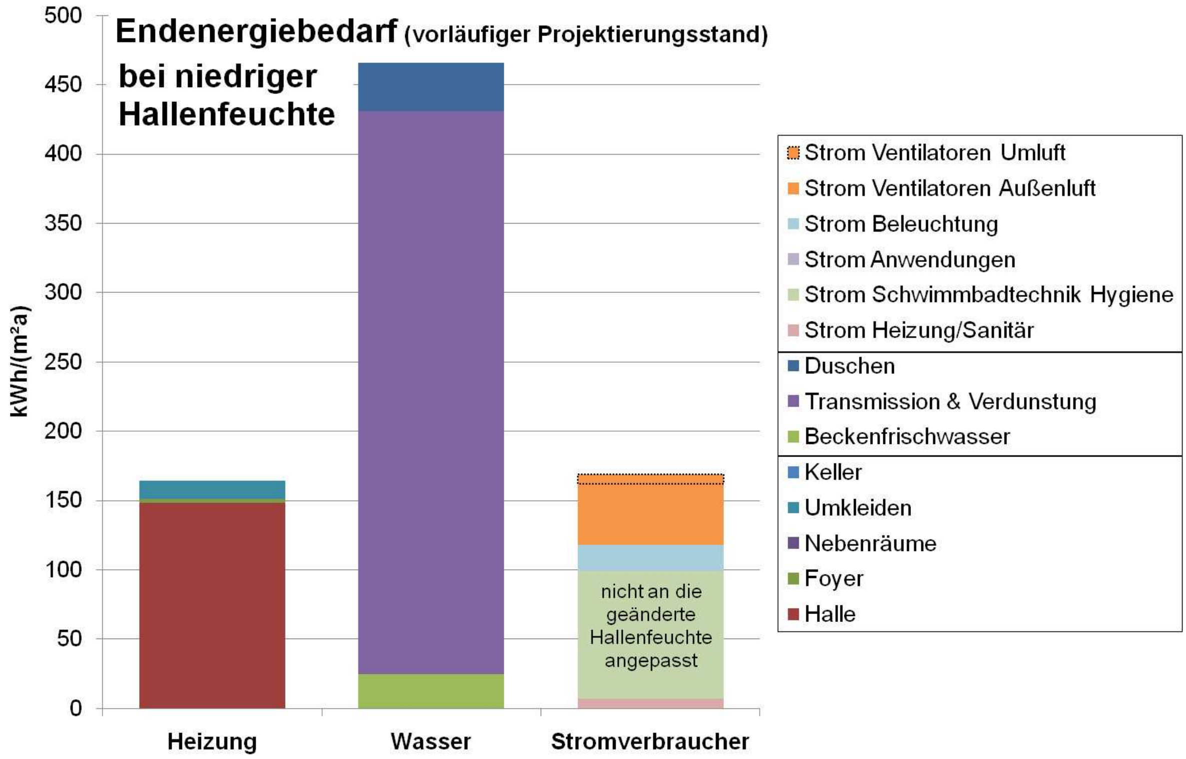

Figure 45: The final energy requirement of the building according to the current preliminary planning status, divided into space heating requirements, heating requirements of the water and electricity consumers with a lower hall humidity according to [VDI 2089].

Primary energy requirements

The statements made so far about the final energy and electricity requirements are interesting and relevant, since the energy flows can be understood in detail and clearly and potential savings can be identified. However, for the final energy assessment of the building, it is necessary and sensible to consider the primary energy balance, ie to take into account the type of heat supply and to weight the final energy requirement with primary energy factors. Primary energy requirements

according to the current project planning status (without air circulation):

409 kWh / (m²a)

Figure 46 shows the primary energy balance calculated with the PHPP of the current project status of the Lippe Bad, divided into the same areas as the final energy requirement in the previous text section. The weighting of these areas shifts considerably, since the primary energy factor for electricity (2.6) is significantly less favorable than that for district heating (0.17) [Wibera 2010]. In this special case, the waste heat from the CHP plant is also used to cover approx. 50% of the heating requirement, with a primary energy factor of 0 [1]

was scheduled.

At this point, it should be emphasized that the Lippe bath is built with a primary energy very favorable district heating connection and the possibility to use the CHP waste heat directly under advantageous conditions. In other cases, a heat pump must be used to recover enthalpy from the exhaust air in order to achieve similar primary energy parameters (see [PHI 2009]).

[1] The electricity required for the additional pumps required for this heating circuit was taken into account in the electricity consumption of the heating technology.

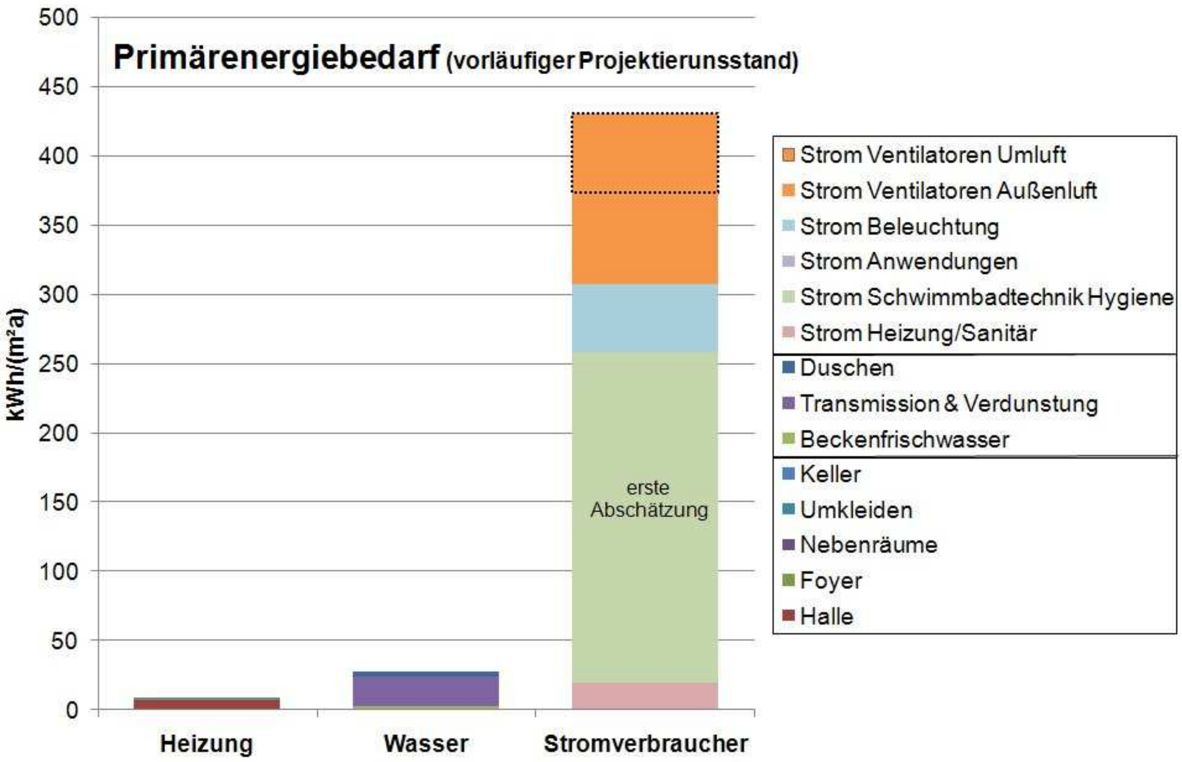

Figure 46: The primary energy requirement projected with the PHPP according to the current preliminary project status, divided into space heating requirements, heating requirements for water and electricity consumers.

In the primary energy balance, the focus is clearly on electricity consumption. This makes it clear that special care must be taken during planning to avoid unnecessary pressure losses and to use highly efficient devices. As already described, the values listed here are still very preliminary - however, the weighting of the individual areas is unlikely to change much. The main consumer is swimming pool technology, followed by ventilation and lighting.

6.2 Dynamic building simulation

PHI's own simulation program D YNBIL
used that has been extensively validated [cf. Feist 1994], has proven itself for many years in practice for the simulation of different building types and is continuously being developed. It enables a detailed prediction of the thermal and hygric behavior of buildings based on the physical relationships.

6.2.1 Zoning

The planned bathroom was depicted as precisely as possible and with a zoning into 13 temperature and usage areas. These zones and their respective target temperatures are listed in Table 5. In accordance with the planned building technology and the foreseeable use, internal heat sources or sinks, moisture sources and air exchange rates were set up separately for each zone.

Table 5: Zones d he dynamis c hen building simulation.

	designation	Target temperature [° C]
Zone 1	foyer	22
Zone 2	Changing rooms	26
Zone 3	Showers toilets	28
Zone 4	Activity area	34
Zone 5 teaching swimming area		34
Zone 6	Sports area	30th
Zone 7	Parent-child & warm pool	32
Zone 8 teaching pool		32
Zone 9	Sports pool 1 & 2	28
Zone 10	Basement (technology)	1)
Zone 11 swimming master's room (SM)		22
Zone 12	Speaker room	22
Zone 13	Side rooms NO	22

1) The temperature in the basement arises due to the internal heat sources and Cross heat flows from the adjacent zones.

6.2.2 Boundary conditions

The boundary conditions of the calculations correspond to those of the stationary energy balance, except in the following details:

Characteristic values of the components

The component structures were entered into the simulation model analogous to those of the stationary energy balance, with the difference that the heat transfer resistances on the surfaces are not assumed to be constant, but are recalculated in each time step according to the boundary conditions. The heat transfer through the components is therefore shown more precisely. The energy balance of the individual windows and inner glazing areas is also influenced by D YNBIL calculated much more complex and correct.

Adjacent old building

?

All zones are actively heated to the respective target temperature. In the current simulation model, the heating is ideally represented, ie DYNBIL calculates the theoretical heat demand and thus the heating load separately for each zone, without taking into account the side effects of a real heating system (distribution losses, limited heating output, etc.). In the next step, the heating is to be simulated as air heating in order to be able to map the actual conditions even better.

consumer

The individual consumers only go into the simulation indirectly via your Heat emissions. The annual electricity demand is calculated with DYNBIL not calculated.

Internal sources of heat and moisture

In the dynamic simulation, internal heat and moisture sources can be depicted more accurately, because instead of averages, an hourly distribution of the individual source powers can be expected. In the current model, a distinction is made between opening times and rest mode (no internal heat sources except in the basement).

In addition to pool evaporation, there are various sources of moisture due to the wet bathers, towels, showers, etc., which are difficult to estimate. For the shower zone, an entry of moisture into the air of 200 g / shower process was assumed, averaged over the opening period.

Hot water

The heating requirement for the hot water for shower use does not flow into the dynamic simulation a, there it as far as possible independently from to them Temperature conditions of the individual zones shown and can be calculated separately.

In this model, the heating requirement of the fresh pool water is not set separately, but analogous to evaporation as a heat sink for the individual pools.

6.2.3 Results

Final energy requirement

Final energy requirement according to the current project status: 389 kWh / (m²a) This value only includes the heating requirement of all zones and the energy requirement for pool water heating.

Figure 47 shows the calculated values of all 13 temperature zones, divided into room air and pool water heating. Here too

it can be clearly seen that the water is the main
Represents final energy consumers. The calculated values of the individual zones are listed in descending order in Figure 48 for a closer look at the heating requirements of the indoor air. As expected, the heating requirement of the largest hall area is highest, followed by the smaller (but warmer) hall sections and the changing area.

Despite the higher temperature of 28 ° C, the heating requirement of the showers is lower than that of the changing rooms, since only the room air of the changing rooms, which has already been heated to 26 ° C, has to be reheated. This is a good example of advantageous ventilation planning and room layout. The warm shower area acts as a kind of "buffer" between the significantly warmer hall area and the cooler changing area. The adjoining rooms have a very low heating requirement, since they are almost completely heated by the cross heat flows from the adjacent warmer zones. In addition, the waste heat from building technology is used indirectly to heat these rooms,

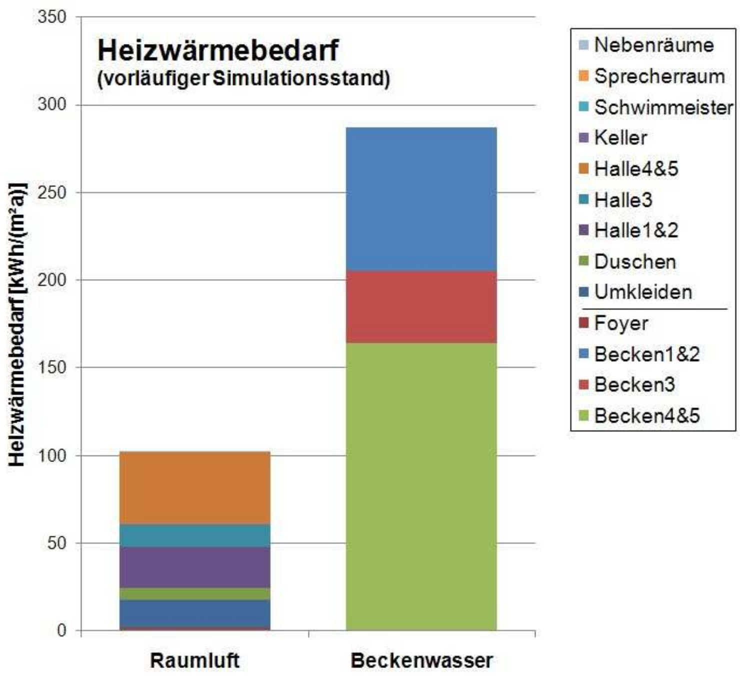

Figure 47: The heating requirement of the individual zones calculated with the dynamic simulation for the current, provisional status, divided into room and pool water heating.

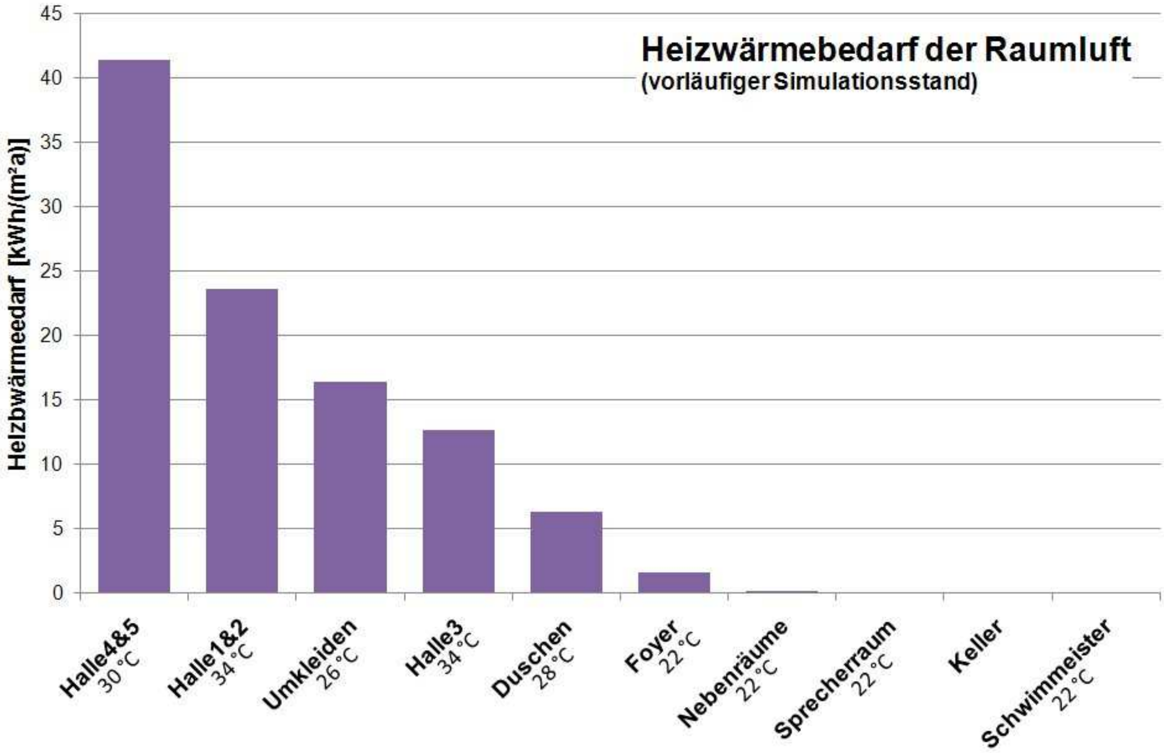

Figure 48: The heating demand of the room air calculated with the dynamic simulation, sorted in descending order.

In individual rooms (swimming master and speaker room), heating is no longer of central importance, but rather the risk of overheating. The dynamic simulation has the great advantage that the temperature profiles of the individual zones can be viewed precisely; It can thus be checked whether the comfort margins set are also observed in individual rooms. The results of the simulation can then be used directly

For example, to further optimize ventilation and summer bypass control.

6.3 Comparison of the calculation methods

The results of the two calculation methods agree very well, as shown in Figure 49 to Figure 52. The slight differences in the results of the two calculation models described can already be expected simply because of the different zoning and the calculation steps (monthly values / hourly values). In addition, the thermal interactions can be mapped much more precisely with the dynamic simulation. An example of this is the supply of several zones via one ventilation unit, which is the exhaust air temperature

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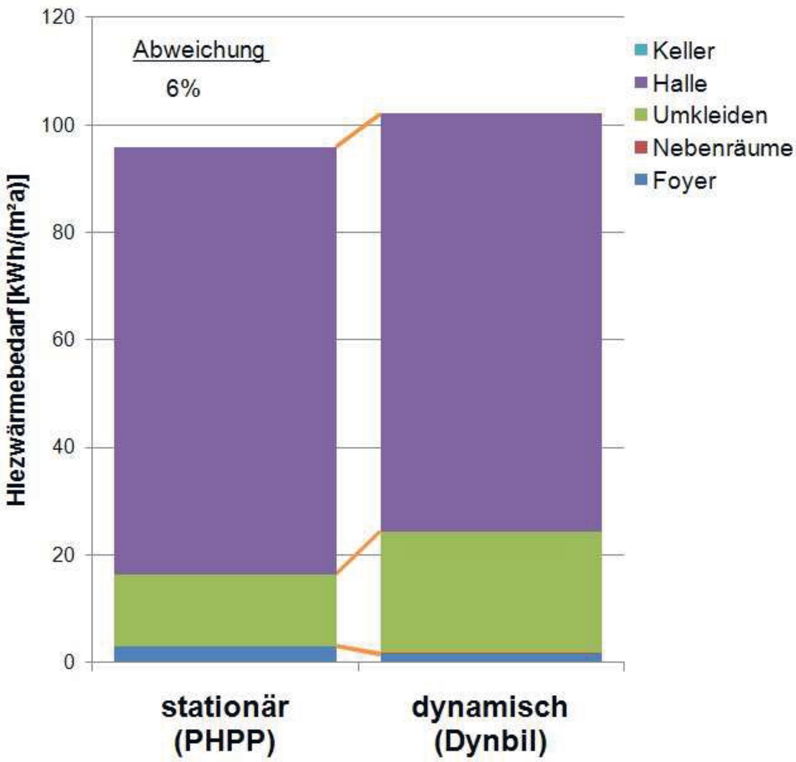


120
100
80
60
40
20
0
Abweichung
6%
Keller
Halle
Umkleiden
Nebenräume
Foyer
Heizwärmebedarf [kWh/(m²a)]
stationär
(PHPP)
dynamisch
(Dynbil)

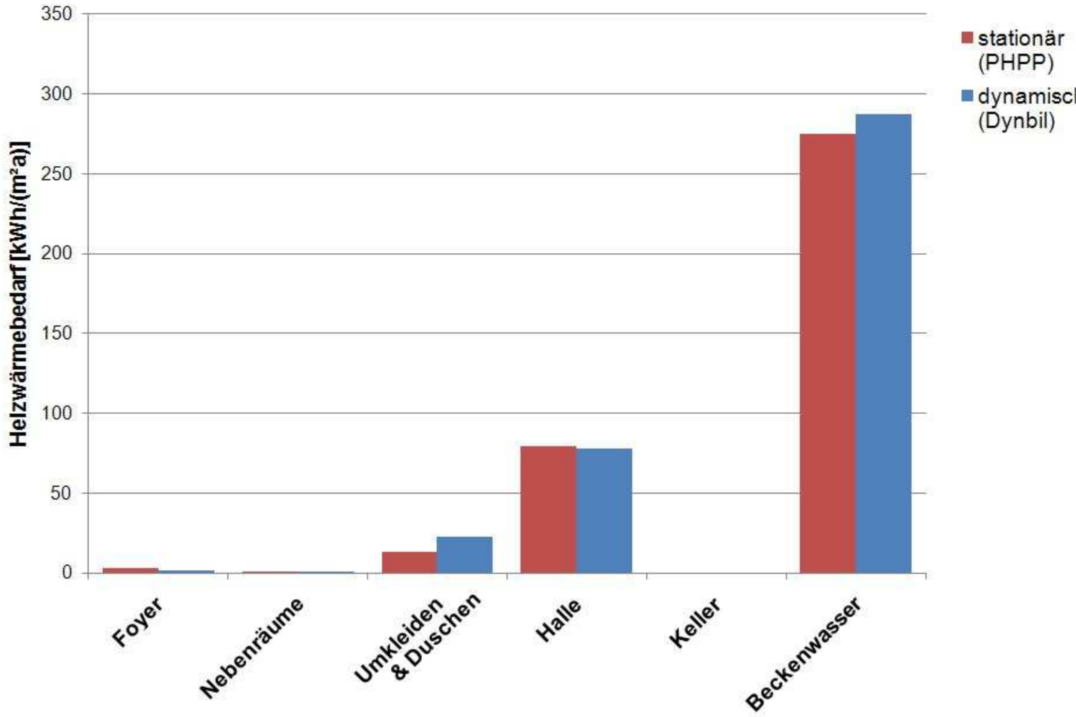


Figure 50: Comparison of the stationary and dynamically calculated heating requirements of the individual zones and the total deviation of the result.

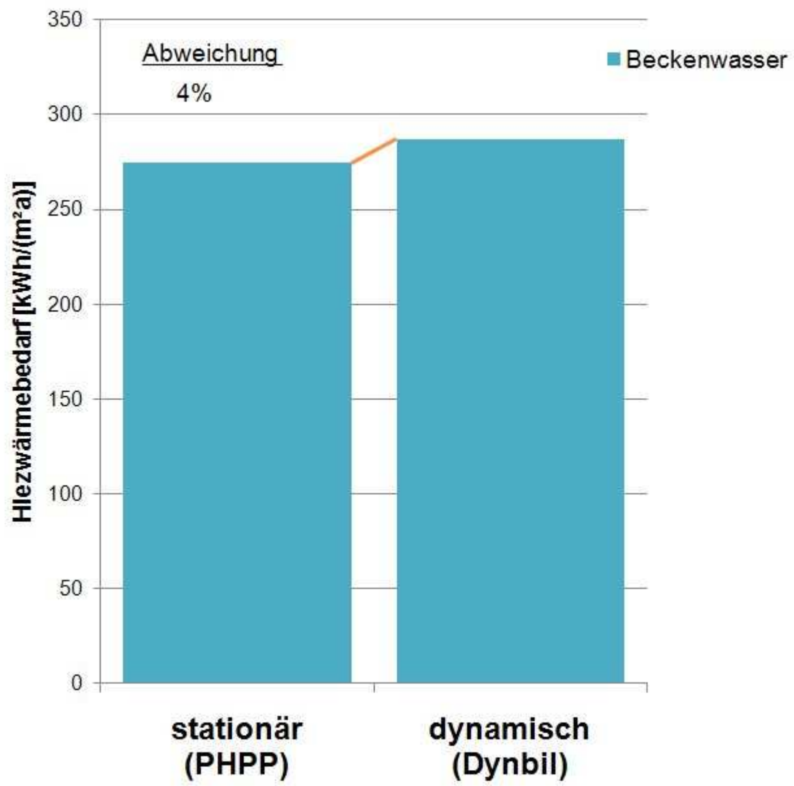


Figure 51: Comparison of the stationary and dynamically calculated heating requirements of the pool water (evaporation and transmission losses, fresh water heating) and the total deviation of this result.

When comparing the results, a closer look at the zones that were more precisely divided in the dynamic simulation is particularly interesting, ie the area of the changing rooms and showers and the PHPP zone "ancillary rooms", which includes the swimming master and speaker room. The relevant temperature profiles (monthly mean values) are shown in Figure 52 and Figure 53. In the adjoining rooms (Figure 52), the temperatures of the dynamic simulation averaged over the room volumes agree very well with the stationary calculated values throughout the year. However, it can be clearly seen that the swimming master's room in particular deviates significantly from these monthly averages: due to the central location, surrounded by the warm swimming pools, higher temperatures are set here. This phenomenon cannot be mapped with the stationary energy balance. The situation with the changing rooms and showers is similar: On average, the values agree quite well, the actual temperatures of the smaller zone (showers) deviate somewhat, as expected.

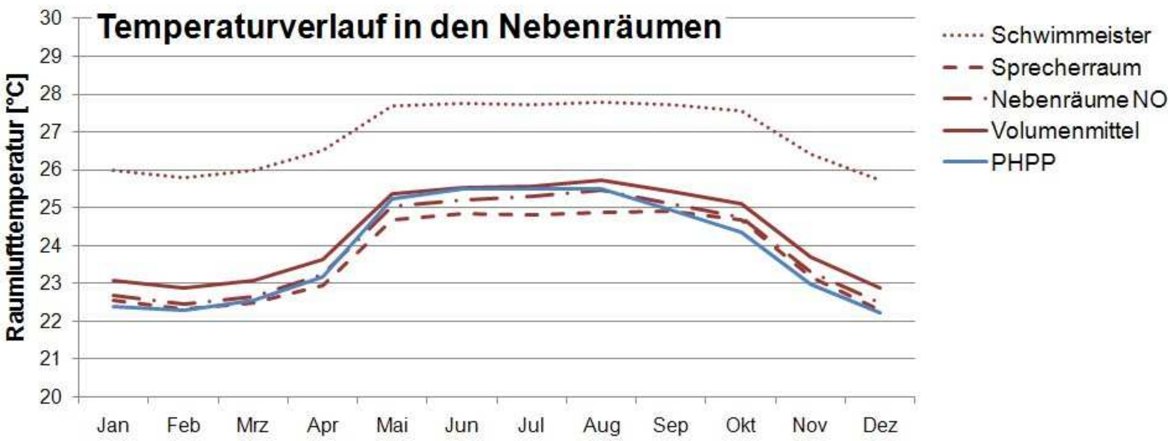


Figure 52: The monthly average temperatures of the adjoining rooms. The results of the dynamic simulation in red and those of the stationary energy balance in blue.

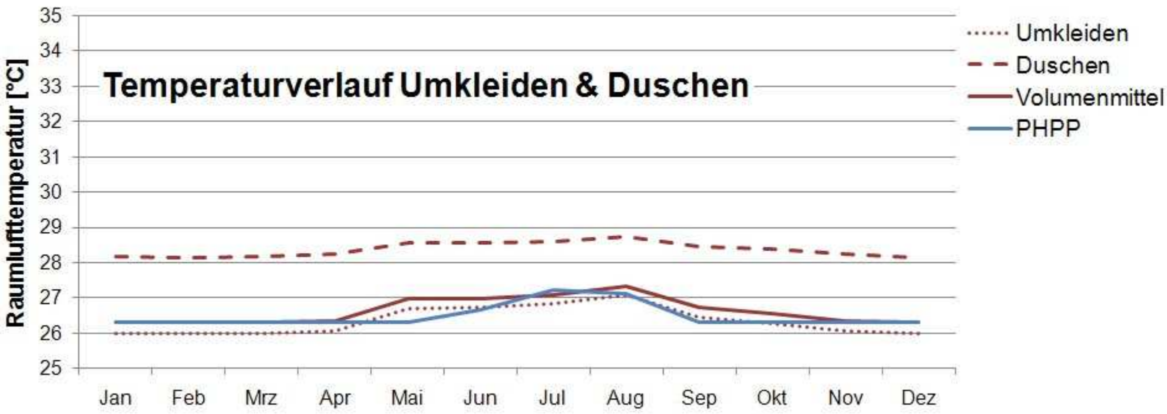


Figure 53: The monthly mean temperatures of the changing rooms and showers. The results of the dynamic simulation in red and those of the stationary energy balance in blue.

The very good agreement of the results qualifies the stationary calculation method according to PHPP. However, the comparison also shows that in individual cases it must be ensured that the temperature conditions in special rooms differ significantly from the calculated mean values. Deviations of the calculated energy requirement from the actual energy consumption cannot be excluded and may even be expected due to unforeseeable usage parameters. These parameters are difficult to predict in such a complex building, but can have a significant impact on the end result. This applies in particular to swimming pool technology and visitor behavior or usage profile of the bathroom.

The results clearly show the great influence of evaporation, which in turn u. A. is influenced by the movement of water, i.e. the operating state (use by recreational swimmers, splashing children, school swimming, etc.). It is also difficult to precisely estimate the required pump outputs and lighting times, since they depend on the use of the bathroom. All results listed here are therefore to be seen as preliminary forecasts.

6.4 Comparison of the energy balances of the Lippe Bad as a passive house as planned and according to EnEV

In order to assess the amount of energy saved in the indoor pool presented in this report with a PH approach compared to a conventional indoor pool, a variant of the energy balance was created. The same PHPP was used for this, in which the building properties were adjusted to represent a new building in accordance with EnEV. The main differences between the variants are listed in Table 6. The table contains a third column for completeness additionally the updated characteristic values of the passive house bath (as of July 2011). All values were developed in collaboration with the PHI and ENERATIO. Figure 54 shows two Sankey diagrams that graphically compare the results for both buildings. The calculated heat quantities are shown in red and the various components of the electricity requirement in brown.

In the left part of the graphic is the coverage of the individual
Areas of demand (space heating, hot water, as well as the balance of electricity requirements from the four available energy sources (CHP space heat, CHP condensation heat, district heating and electricity) are shown As mentioned above, a significant part of the heat demand of the bath is covered by otherwise useless waste heat from the CHP plant. Since this waste heat is not available in unlimited quantities, its share of the total heat demand is reduced with the EnEV variant. This increases the primary energy factors for this variant.

With the passive house indoor pool described in this report (preliminary project status), around 52% final energy or approx. 46% primary energy can be saved compared to a typical new building.

Table 6: Characteristics de r Passive House and EnEV variants

measure	Passive house indoor pool		EnEV standard
	Preliminary status September 2010	Changes until July 2011 [2nd]	
Indoor humidity	64% relative humidity	unchanged	14.3 g / kg absolute humidity (corresponds to 50.6% rel. Humidity)
Minimum external volume of electricity hall ventilation	15% of the design value according to EnEV	unchanged	30% of the design value according to EnEV
Indoor air	No air circulation	Difference to 50% of the outside air design value according to EnEV as circulating air [3rd]	Difference to the design value of the ventilation units as circulating air
Ventilation in the secondary zones	Constantly according to the planning of the house technician, demand regulation is provided	Air volumes depending on the air quality	Constant
Current efficiency of the ventilation units	0.45 Wh / m³	0.25-0.4 Wh / m³	0.9 Wh / m³
WRG [4th]	Halls: 70% changing rooms / showers: 75% foyer: 79% side rooms: 65% basement: 62%	Halls: 77% changing rooms / showers: 80% foyer: 86% side rooms: 86% basement: 64%	Halls: 65% changing rooms / showers: 65% foyer: 69% side rooms: 55% basement: 52%
Airtightness	0.2	unchanged	1
U values (on average) W / m²K	External walls (including partitions to existing buildings): 0.13 W / (m²K) floor / basement walls: 0.13 W / (m²K) roof: 0.11 W / (m²K) all partitions inside: 1.7 W / (m²K)	unchanged	External walls (including partitions to existing buildings): 0.88 W / (m²K) floor / basement walls: 1.19 W / (m²K) roof: 0.53 W / (m²K) all interior partitions: 2 W / (m²K)

2nd There are also updates to the preliminary status presented in this report at other points in the energy balance. For reasons of clarity, they are not listed here.

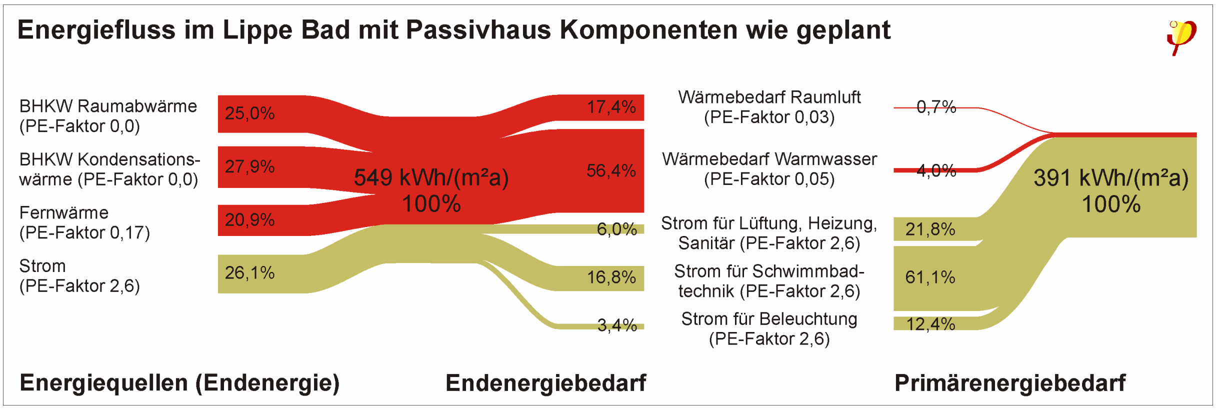
3rd A validation of how far the amount of recirculated air can actually be reduced in practice without affecting the air quality is part of the monitoring. The aim is to get by without any circulating air.

4th The values of the preliminary PH project planning status mentioned here were deliberately calculated on the safe side; for the EnEV standard, a flat rate of 10% was deducted for the secondary zones. Since the ventilation units of the sub-zones supply different temperature ranges in some cases, the heat recovery of the units was converted to the corresponding zone temperatures with mixed exhaust air, so they do not directly reflect the efficiency of the units used.

Window quality	Average U-value (with frame): 0.715 W / m²K g-value: 0.46-0.55	Average U-value (with frame): 0.745 W / m²K g-value: unchanged	Average U-value (with frame): 1.446 W / m²K0 g value: 0.64
Filter rinsing	Ultrafiltration [5] 13,500 m³ / a	unchanged	Pressure filter system 13,000 m³ / a
Filter water treatment	approx. 70%	unchanged	approx. 70%
Shower water	18 l / person	30 l / person	30 l / person
Heat recovery from wastewater	30%	unchanged	0%
Electricity of consumers [6]	Heating Sanitary: 28,354 kWh / a SBT: 359,939 kWh / a Applications: Not yet known, therefore neglected. Savings compared to EnEV possible! Lighting: 73,200 kWh / a	Heating Sanitary: 22,875 kWh / a SBT: 221,981 kWh / a Applications: To be determined Lighting: 61,857 kWh / a	Heating Sanitary: + 50% of the provisional level SBT: + 30% of the provisional level Applications: Neglected. Lighting: + 10% of provisional status
Pelvic irrigation	Circulation also during the day depending on the actual number of people (laser person scanning)	unchanged	Constant revolution

[5] With ultrafiltration, more water is required for filter rinsing, but the circulation volume can be reduced considerably, which affects the pump power consumption.

[6] The power consumption depends not only on the devices used, but also strongly on user behavior and the control. The figures used are estimates based on the known parameters and probable running times of the main consumers.



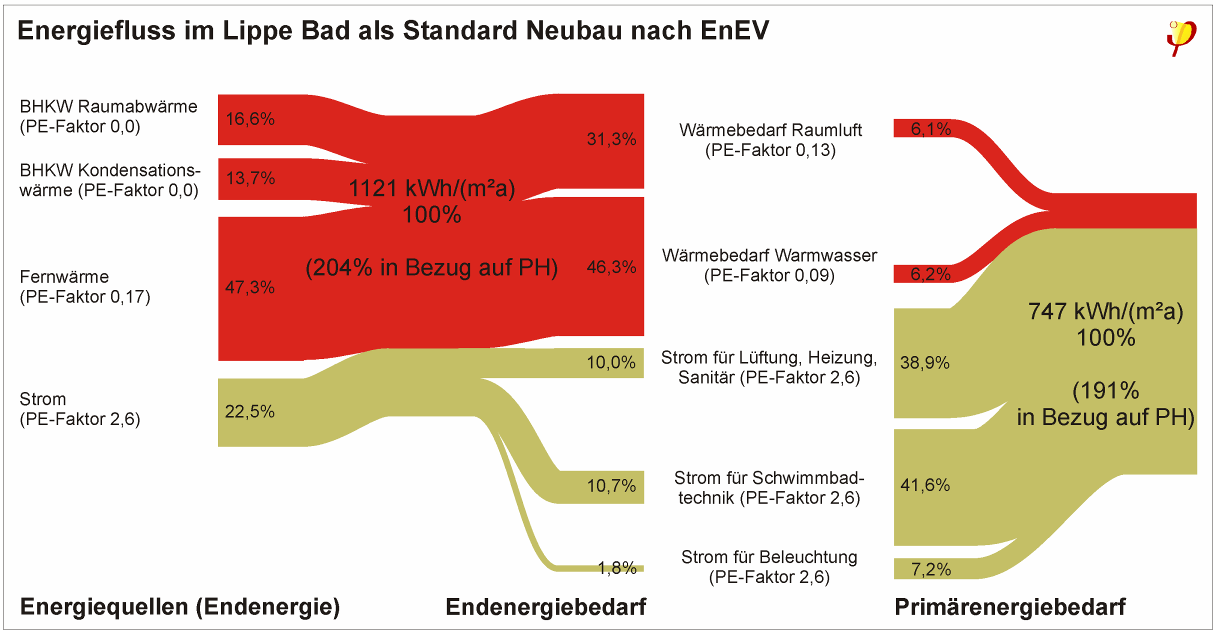


Figure 54: Graphic representation of the energy requirements of the PH and EnEV variants

7 Cleaning concept

Ensuring and maintaining hygiene in all areas is a first-class comfort factor that determines the well-being of bathroom users.

In teamwork with the employees of the Lünen spa company, who had many years of experience in the operation of the old indoor pool locations, a requirement profile for the cleaning concept was drawn up right at the start of the planning. The individual characteristics of the requirement profile have a very decisive effect on the entire design process of the new indoor swimming pool.

In this report on the integrated planning of the new indoor swimming pool, the focus is on the structural elements for an inexpensive cleaning concept.

7.1 Requirement profile

clean-off zone

In order to reduce the amount of dirt entering the bathroom via visitors' footwear, a combined clean-out zone must be designed.

Flooring and covering joints

There is a demand for a cleaning system that is as uniform as possible. The fulfillment of this requirement is fundamentally favored by the use of a uniform floor covering.

As experience has shown that joints are problematic areas for cleaning, is the
To keep the joint percentage of the flooring absolutely low. Covering joints in the transition area between floor and standing wall should also be avoided as far as possible. The formation of a throat in the transition area from floor to standing wall is regarded as a solution.

Machine-assisted wet floor cleaning

The design of the inner traffic routes (including the pool surrounds and the changing and sanitary areas) is intended to ensure favorable operating conditions for machine-assisted wet floor cleaning (scrubber drier). In order to optimize the cleaning processes, consultations with different manufacturers of coverings, cleaning machines and cleaning agents should be held at an early stage in order to incorporate their requirements and experience into similar solutions in the solution approaches. To optimize the use of personnel, the maintenance cleaning of the pool surrounds

in opening times with a small number of visitors sought
(Low load times such as the first 1.5 hours of opening from 6:15 a.m. to 7:45 a.m.).

Glazing areas

Avoid vertical glazing areas reaching to the floor. Large areas of glass in the swimming pool area are usually permanently and heavily contaminated with water spray. Appropriate cleaning frequency is required for a clean appearance. That is disadvantageous. In addition, they are close to the ground

Glass surfaces are difficult to clean from a work physiological perspective (kneeling / crouching with the back bent / twisted, overall poor posture weighting).

Slope in wet areas

Functional slope formation in the water-contaminated floor areas, especially around the pool.

Water is permanently carried to the pool surrounds via the water drain from the wetted body surface of the bathroom user. The water on the pool surrounds should be drained off effectively, because on the one hand surfaces contaminated with moisture generally lose safety-related slip resistance (water acts as a lubricant) and on the other hand the wet surfaces of the pool surround create a larger phase interface water / indoor air (evaporation into the indoor air), which tends to increase the energy requirement in the indoor pool under normal operating conditions.

7.2 Approaches to the requirements profile

7.2.1 Design of the clean-out zone

Based on an average step length of around 63 cm, the first separation area of the clean-out zone consists of three steps on a grating on the outer, covered access area to the main entrance door (separation of coarse dirt). This is followed by 6 to 7 steps on a special cleaning mat inside the vestibule to the foyer (separation of finer dirt build-up on the footwear).

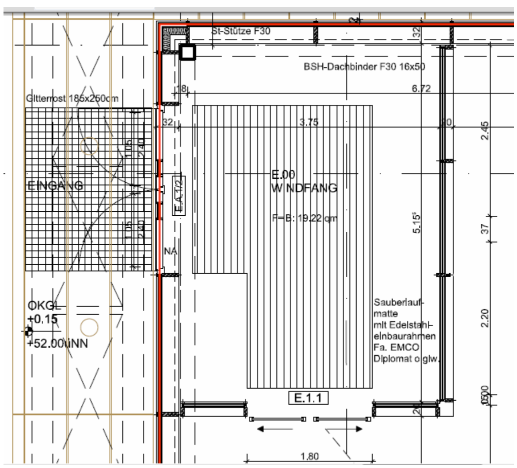


Figure 55: Clean-out zone in the building entrance, detailed section of the ground floor plan (source: ntspv)

The 90 ° change of direction within the vestibule (see Figure 55) was deliberately planned in order to reduce the passage speed and stride lengths of the visitors. It is also suspected that additional shear forces between the sole of the shoe and the surface of the cleaning mat will result in improved dirt separation when walking around the curve area.

7.2.2 Floor covering for the requirement profile

Structured plastic coverings are recommended as floor coverings with the least amount of joints. Theoretically, they can be laid seamlessly as sheeting over 40 m² (common dimensions are 2.0 m * 20 m). Individual locations are known (primarily abroad), where PVC web products were used in swimming pools and the associated sanitary rooms, sometimes also as wall coverings. The design options and designs are diverse. This is an elastic, waterproof, dense floor covering, with dimensionally stable glass fiber fleece generally used as the support layer. The slip resistance of such floors (e.g. R10 according to BGR 181) is usually achieved by structuring using surface knobs (depending on the manufacturer, different knot diameters, different number of knobs per unit area, if necessary also supplemented by mineral interferences). Different flooring manufacturers offer solutions with the title "wet room concept".

In other areas of application such as trains and buses and also in clean rooms, this type of flooring has proven itself due to its wear behavior, extensive resistance, tightness and generally good cleanability. In many areas of application, the impact sound improvement that can be achieved with PVC coverings is also considered advantageous.

In barefoot areas, a low heat penetration coefficient, which is similar to that of wood, is considered to be suitable for the area of use. Using comfort tests (bare feet on different surfaces), Fanger showed that the barefoot comfort floor temperature for wood, cork or PVC flooring is around 2.5 K lower than that for concrete, stone or marble coverings. Accordingly, the use of a floor covering with a low heat penetration coefficient is a suitable component for the Lippe bathroom, since due to the simulated air temperatures in the basement (stationary operation, basement air temperature expected to be around 29 ° C) there is no floor heating within the barefoot walkways on the ground floor.

The processing and laying characteristics of a PVC floor covering can also largely meet the requirement profile (gluing, welding (PVC to PVC), clamp). The floor covering can be seamlessly installed as a wall base using a fillet profile (tub design), cf. Figure 56. Special transition or connecting strips are available for the material transition from PVC covering (base) to wall covering.

The relevant expert Torsten Grotjohann from the institute was responsible for the further detailed planning for the use of PVC flooring for floor construction (iff, http://www.fussboden-gutachter.de) integrated in the planning team.

7.2.3 Approaches to machine-assisted wet floor cleaning, to the glazing surfaces and the floor slope in wet areas

The constructive features of these approaches to solving the requirements are interrelated. An overall presentation was therefore chosen for explanation (see Figure 56).

To avoid glazing reaching to the floor, a parapet was provided in the area of the glass facades. The parapet height was chosen so that it can also serve as a seat.

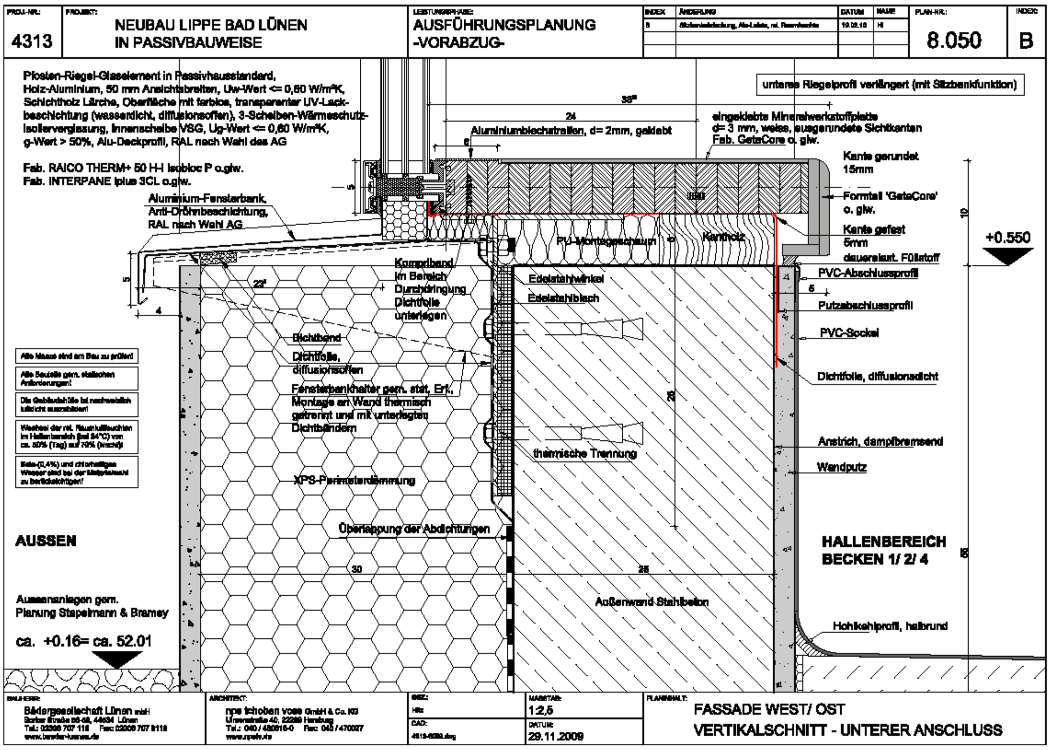


Figure 56: Detail of vertical section of glass facade / parapet in the area of the outer wall (source: ntspv)

In relation to the daylight supply in the room depth, there is no disadvantage with the parapet situation shown, since the lower, near-ground glass portion of a facade does not make any significant contribution to this. With regard to the construction costs, it can be assumed that the area-related construction costs of the parapet, despite the significantly more favorable U-value, are lower than that of the facade construction with triple glazing.

With the usual pool design, where the level of the water surface corresponds approximately to the level of the pool area, there are two things that would not match the requirement profile. On the one hand, the pool surrounds could not be cleaned during periods of low load usage and, on the other hand, the swimmers would look at the parapet surfaces below the glass surfaces.

If the water surface and the pool surround are at approximately the same level, the overflow channel of the pool must be switched during the wet cleaning of the pool surrounds, ie it must be ensured that no dirty liquor gets into the bath water circuit. This changeover would require maintenance cleaning of the pool surrounds

at the same time

Do not allow (light load) swimming operation.

Furthermore, the largest possible line of sight for swimmers from the level of the respective water surface to the outside is an important quality feature of modern swimming pools. This outlook is adversely restricted by the parapet described in the facade area.

As a solution, the pool water surface was raised analogously to the window sill. The pelvic head can also be designed and used as a seat. For the swimmers there is an unobstructed line of sight to the outside and a channel changeover during wet cleaning of the pool surrounds

is due to the difference in height between floor and

Pool water surface not required.

A joint between the floor covering and the standing pool wall is avoided by continuing the PVC floor covering on the outer pool wall by forming a fillet. The design details of the covering are comparable to those of the facade parapet, cf. Figure 57.

With this design there are further aspects:

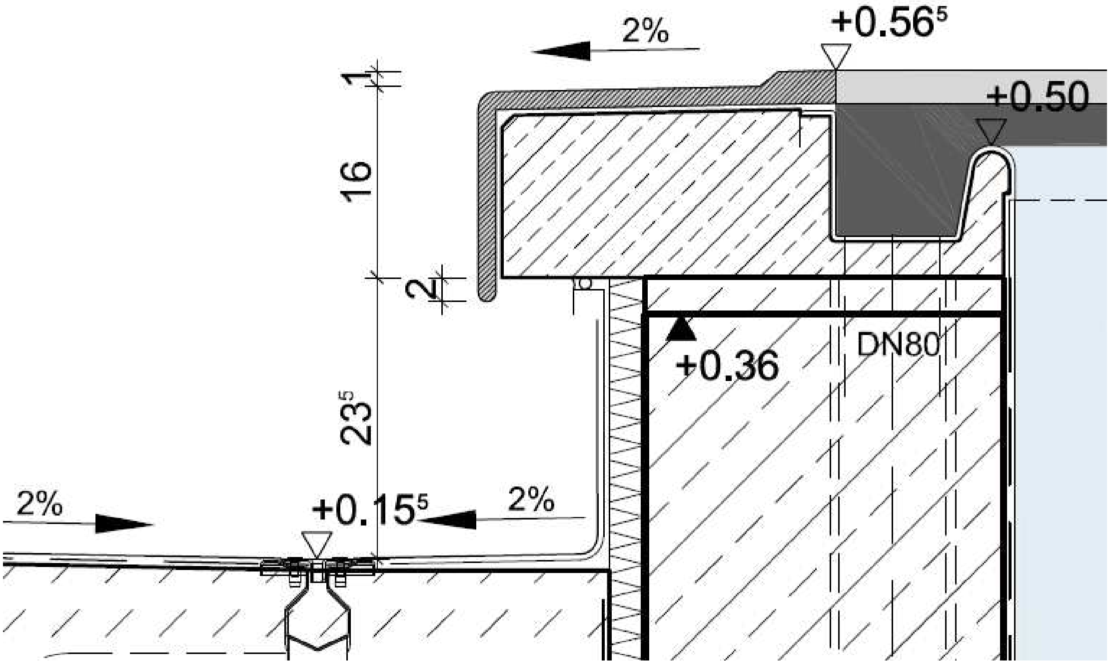


Figure 57: Vertical section of the pool head and pool surround, slot channel in the pool area with a slope, floor cross slope to the slot channel, connection of the PVC floor covering to the slot channel by means of a clamping flange, seamlessly raised flooring on the pool wall (tub formation via fillet), pool head designed as a seat. The plastic floor covering can be connected tightly to the slot channel using a clamping flange (source: ntspv).

Figure 58 shows a stainless steel model (stainless steel) of the slotted channel with bottom slope manufactured by Blücher Germany (www.bluecher.de).

Figure 58: Stainless steel model of the slotted channel with a slope and clamping flange for the watertight connection of plastic floor coverings (source: Blucher)

The appearance of the design explained and presented via sectional representations is then reproduced using photo-realistic visualizations of the lip bath from the integrated planning phase (Figure 59 to Figure 61).

Figure 59: Visualization of the area with lifting floor basin (graphic: npstv)

Figure 60: Visualization of the area with the 5 lanes (25 m long) sports pool in the hall of the former district heating plant, refurbished according to the passive standard (graphic: npstv)

Figure 61: Visualization of the area with the 4 lanes (25 m long) swimming and diving pool (3 m diving platform, 1 m diving board) (graphic: npstv)

The slotted channel drainage system is also to be used in the sanitary and changing areas for functional slope formation, as is the plastic flooring already described in the aforementioned. Stadtwerke Lünen has developed special shower columns with 8 shower spaces each for the shower rooms (2 shower columns per gender). Figure 62 shows a side view and a top view of the shower column.

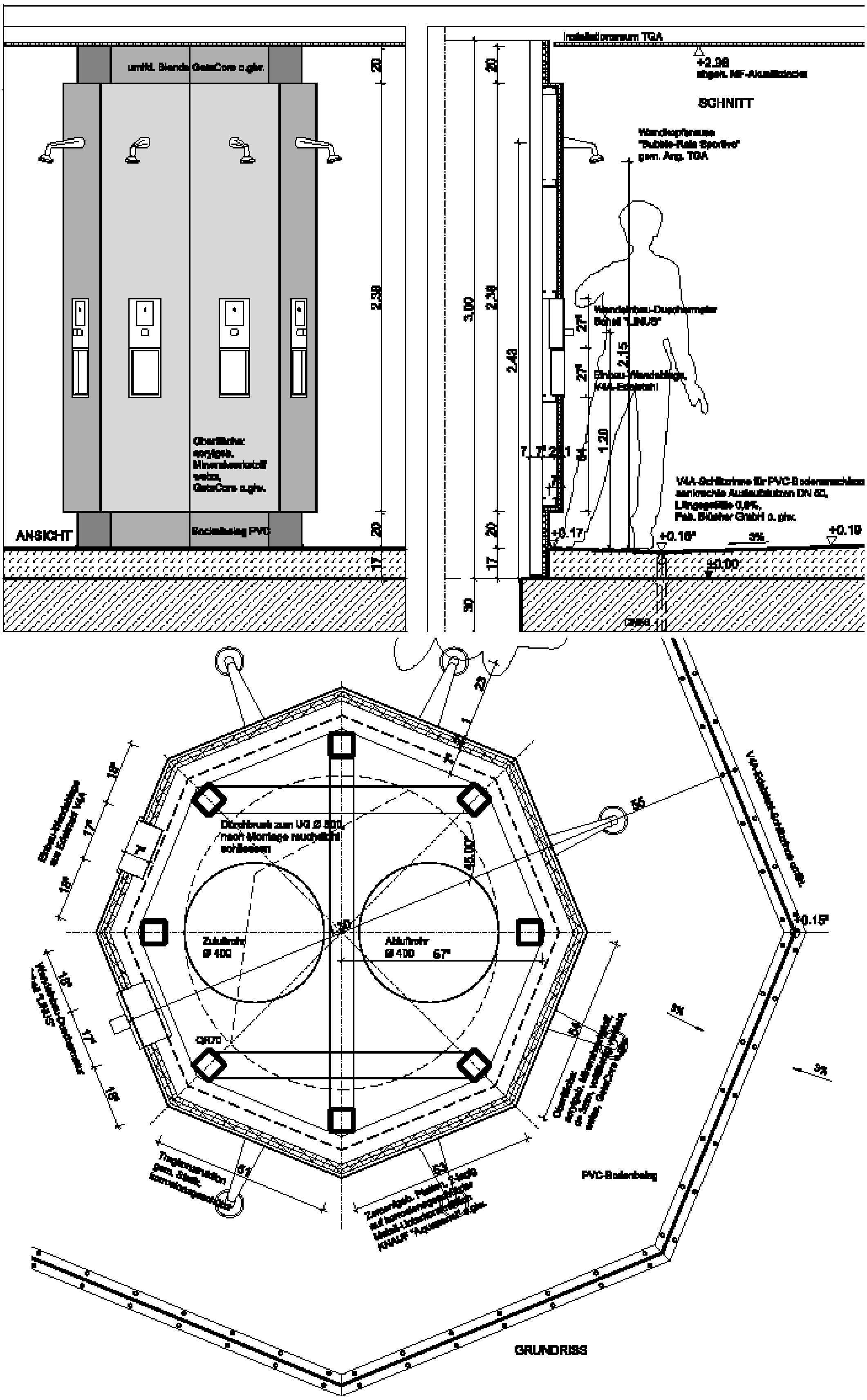


Figure 62: Side view and top view of the shower column (detail) (Source: npstv)

The placement of the shower columns in the middle of the room should minimize the splashing water on the room walls and also guarantee improved framework conditions for the use of guided cleaning machines.

The shower waste water is drained off on the floor via a circumferential slotted channel. This slot channel also has a clamping flange. The functional components of the shower columns (water pipes, fittings, ventilation pipes) prepared for installation are supplied from below through the basement ceiling. The interior of the shower columns is designed to be accessible from the basement for inspections after the removal of ventilation pipe fittings.

As part of preparatory work on the cleaning concept, several discussions were held with manufacturers of plastic floor coverings (e.g. www.altro.de), cleaning machines (Gansow, Nilfisk, Kaercher, Hefter-cleantech) and cleaning chemicals (e.g. Witty, Dr. Nuesken). Here

showed that an optimization of the

The cleaning system for the respective floor (type of floor covering and individual contamination, device technology and brush type, need-based / minimal chemical set) cannot be derived in general terms, but will have to be achieved through practical experience of different system configurations. With regard to the cleaning machines, two configurations are recommended depending on the area of the room or the path taken after viewing the building plans. A personal scrubber drier (electric drive, battery around 180 Ah, maximum speed of the drive 4 to 5 km / h) with two counter-rotating brush plates is recommended for use on the pool surrounds and other comparable wide traffic routes. Here

are the working widths

between 600 and 700 mm (suction widths between 900 and 1,050 mm). The cleaning chemicals are dosed automatically while the machine is in use and the fresh water and suction water tank holds between 60 and 90 liters. The empty weight of such a machine is between 160 and 210 kg. This machine requires sufficient space in a cleaning device room equipped for this purpose (electric charging station, fresh water supply, suction water disposal, chemical filling).

A personal scrubber drier (electric drive, battery around 80 Ah) with a brush plate is recommended for use in smaller rooms and on narrow traffic routes. Here

the working widths are around 450 mm

(Suction widths around 700 mm). Depending on the equipment, the cleaning chemicals can also be dosed automatically while the machine is in use. The fresh water and suction water tank holds approx. 25 liters. The empty weight of such a machine is between 40 and 50 kg. Also for this machine

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and the professional support of the cleaning staff in all matters by the company Dr. Nüsken convinced for the cooperation to ensure perfect swimming pool hygiene.

After several trial phases of scrubbing / suction machines for floor cleaning by our own, experienced specialist staff, the decision was made in favor of machines from the manufacturer Hefter-cleantech. The practical testing across all cleaning areas led to the decision to use two identical machines (Turnado 55 pro, working width 55 cm) (general quality features, good handling, cleaning under superstructures, 360 ° rotating scrub and suction head, low operating noise, uniform spare parts).

8th Acoustic concept

During the planning of the indoor pool Lippe Bad designed as a sports pool by the architects nps tchoban voss GmbH & Co.KG, Hamburg, Bädergesellschaft Lünen mbH involved various specialist planners in the planning process at an early stage in order to achieve the best possible results within one for all departments to achieve the specified budget. As a special feature, it had to be taken into account that the existing building of a former heating plant (pool 5) should be integrated into the newly planned building complex with various swimming pool areas and adjoining rooms. The new indoor sports pool will be available on the one hand for school and club sports (parallel use by several classes / groups) and on the other hand for the population for unorganized leisure sports.

At the request of the pool company, the room acoustics within the new indoor sports pool should be of special importance right from the start. The task was therefore to specify the room acoustical measures required for the setting of an acoustically "high quality" room climate (high room sound insulation, low noise level, good speech intelligibility) for the following areas: 1 recreation pool 1 + 2

	(Warm and relaxation pools and parent-child pools)
2 training pools 3	(with lifting floor)
3 pools 4	(Sports pool with 4 lanes)
4 pools 5	(Sports pool with 5 lanes)
5 entrance foyer	(with checkout area)
6 changing area 7	
shower rooms	

The "Guidelines for Bath Construction" of the Coordination Group for Baths (KOK) and DIN 18041 "Acoustics in Small to Medium-Sized Rooms" were used for orientation when defining the acoustic requirements / recommendations.

The room volumes V determined for the 4 indoor swimming pool areas and the reverberation time T to be aimed for according to the "KOK guidelines" $_{should, KOK}$ as well as the reverberation times T desired for swimming pools in accordance with DIN 18041 $_{should, DIN}$ are listed in a table below:

room	**Volume in m 3rd**	**Target reverberation time in s**	
	V	**$T_{should, KOK}$**	**$T_{should, DIN}$**
Recreation pool 1 + 2	3,000	1.7	1.9 (unique)
Training pool 3	1,300	1.7	1.5 (single)
Swimming pool pool 4	3,550	1.7	1.6 (multi-pass)
Swimming pool pool 5	6,000	1.7	1.9 (multi-pass)

The reverberation time of a room depends on the room size (volume) and the sound absorption capacity of the room-limiting components (ceiling, floor, walls) as well as any fittings (e.g. wardrobes). The longer the reverberation time is selected or this is due to the selected components, the higher the sound levels will appear later in the room. Simplified: long reverberation times = high room noise levels

short reverberation times = low room noise levels

8.1 planning

When determining and planning the required room acoustic measures, the roof areas and partial areas of the walls were primarily used in the swimming pools. In the adjoining rooms such as the entrance foyer, changing rooms and shower rooms, only the roof and ceiling areas were taken into account. Various variants of acoustically highly effective cladding were first examined and recommended for these areas. The special requirements of a sports pool such as ball safety in the swimming pool areas and moisture resistance were taken into account. Through early participation

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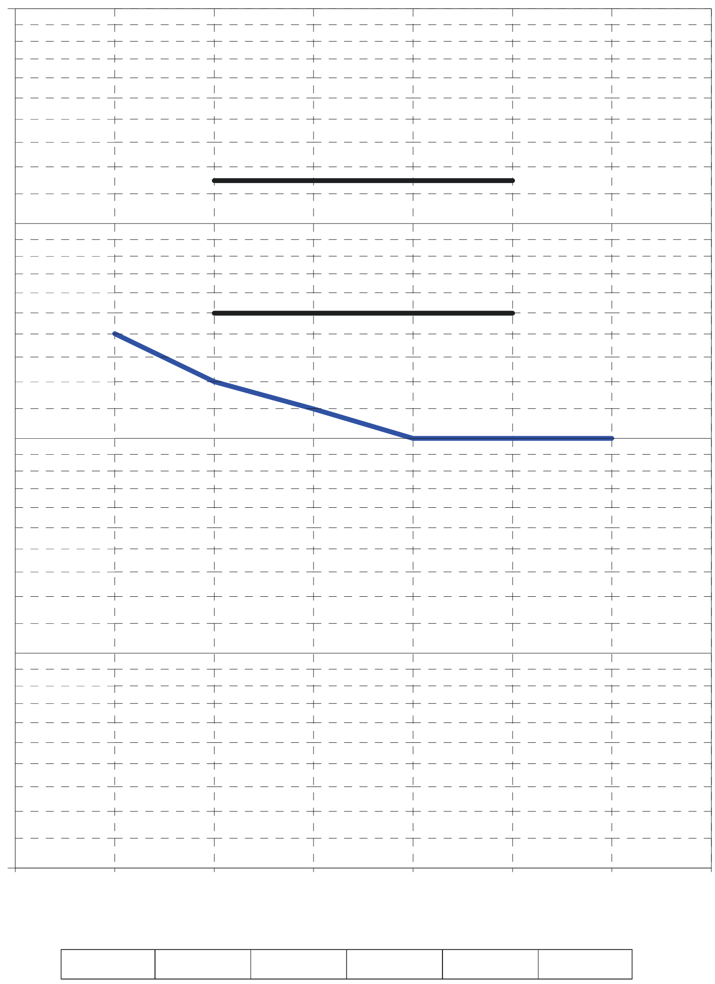

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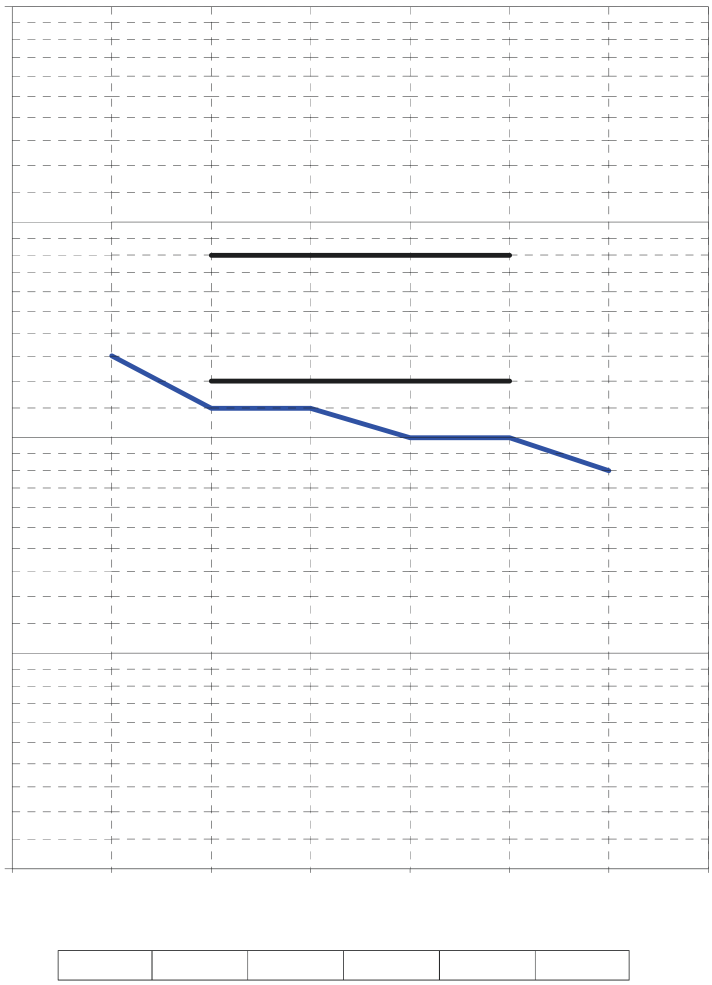

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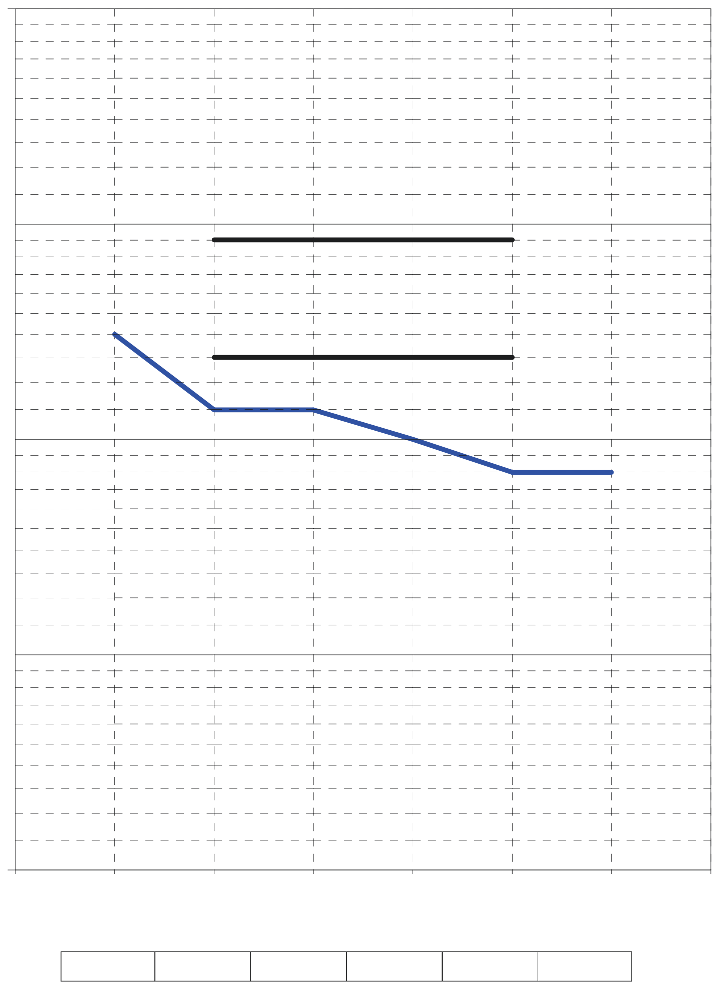

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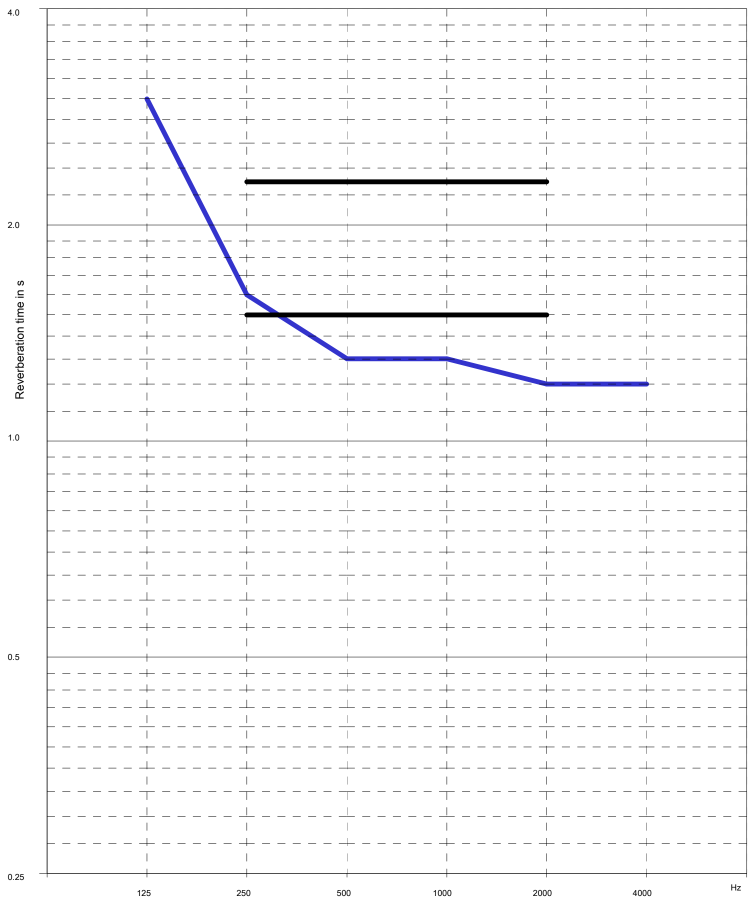
Room acoustic measures

1) Roof Ligno Trend wall
Ecophon

$T_{m,1}$ = 1.3 s

Tolerance range according to DIN 18 041 for sports halls and swimming pools



Room condition 1)	3.0	1.6	1.3	1.3	1.2	1.2

The tolerance range to be aimed for according to DIN 18041 is almost completely undershot by the frequency-dependent reverberation time curve, which is not only to be regarded as desirable (better than the standard specifications) but also acoustically advantageous (high room sound attenuation).

According to the room acoustics calculations carried out, the planned versions of the swimming pools meet or even fall below the requirements / recommendations for reverberation time (high room sound insulation), which means that when used later, both low noise levels and good speech intelligibility (instructional operation) can be expected. In the adjoining rooms, the use of acoustically highly effective cladding or suspended ceilings also achieves high room sound attenuation. An acoustically "high quality" room climate is thus ensured in the areas examined.

9 Fire protection

9.1 introduction

Due to the peculiarities of this type of building, the construction of a building in the passive house standard requires a fire protection perspective. Characteristic here are increased insulation thicknesses and the use of components according to the passive house standard. Possibly. special ventilation measures are required. In the case of the Lippe Bad Lünen, wood is the preferred building material.

When used as a swimming pool, the fire load in this building use is essentially determined by the building envelope. Further measures were developed as part of the fire protection concept,

by one

Effectively prevent fire transmission into the building envelope.

9.2 Construction law classification

The building regulations of the State of North Rhine-Westphalia apply to the building. The existing building is classified as a medium-height building, while the new swimming pool is to be assessed as a low-height building. The building is a special building within the meaning of the building regulations, for which special facilities or additional requirements can apply. However, the special building regulations were not applied because the criteria for the scope of this regulation are not exceeded or affected. At best, this would have been necessary due to the number of users, if a number of 200 people is exceeded and thus there is a classification as a meeting place. Since this can only occur occasionally at special events,

he follows in these cases after consultation with the

Approval authorities approval in individual cases.

The fire protection concept serves the holistic view of the building, taking into account the building protection goals. The protection goals are as follows:

- Prevent fire
- Limiting the spread of fire and smoke
- Allowing people to be rescued
- Enabling effective extinguishing work

These protection goals are closely correlated with each other and need to be specified in the context of a fire protection concept. The fire protection concept is an integral part of the building application. The structure of a fire protection concept is specified by the BauPrüfVO. The key points of the fire protection concept are described below, taking into account the construction according to the passive house standard.

9.3 Fire and smoke zones

Overall, the building forms a fire compartment. With a maximum extension of approx. 76.35 m and a fire compartment area on the ground floor of approx. 3,200 m², this represents a deviation from the permitted extension of 40 m in accordance with the building regulations. This deviation was essentially due to the low fire loads or the Encapsulation of fire loads and the execution of the roof structure

as well as the upper room closure in the Fire resistance class F 30.

The basement (see Figure 63), which is mainly used to accommodate technical systems, is separated by solid ceilings in fire resistance class F 90. With regard to the room termination, due to the low fire loads of the system technology and the direct allocation to the swimming pool with regard to the room termination, the requirement for smoke-tight design was made on this floor ceiling. For example, the installation of fire dampers in this floor ceiling was dispensed with.

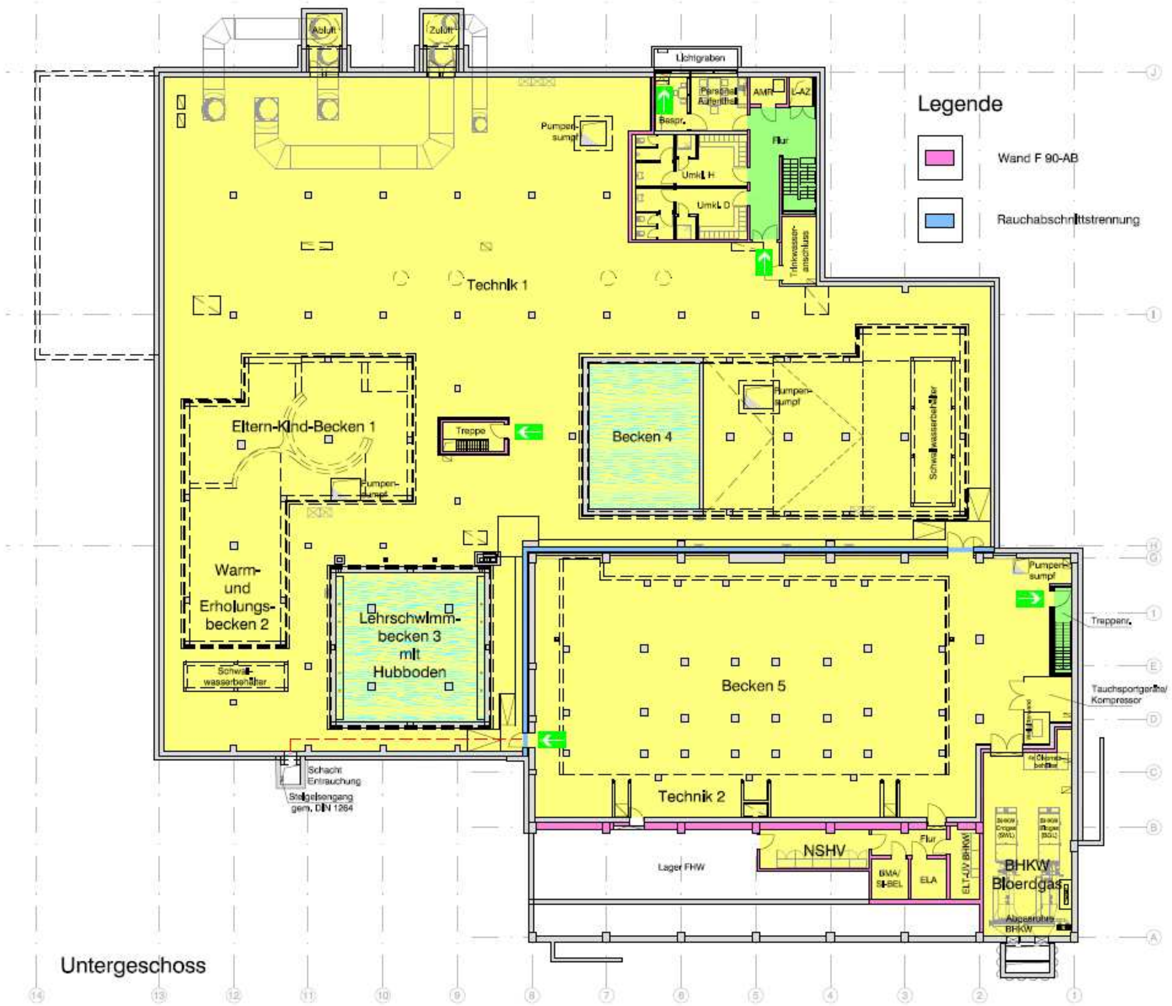


Figure 63: Overview plan fire protection basement (source: skp)

The switch house of the former heating plant and the upper floors within the existing building are separated by ceilings and walls in fire resistance class F 90.

The swimming pool is divided in two room areas, each one
Form smoke section. Furthermore, a subdivision is made between the new and the old building using a smoke apron (see Figure 64).

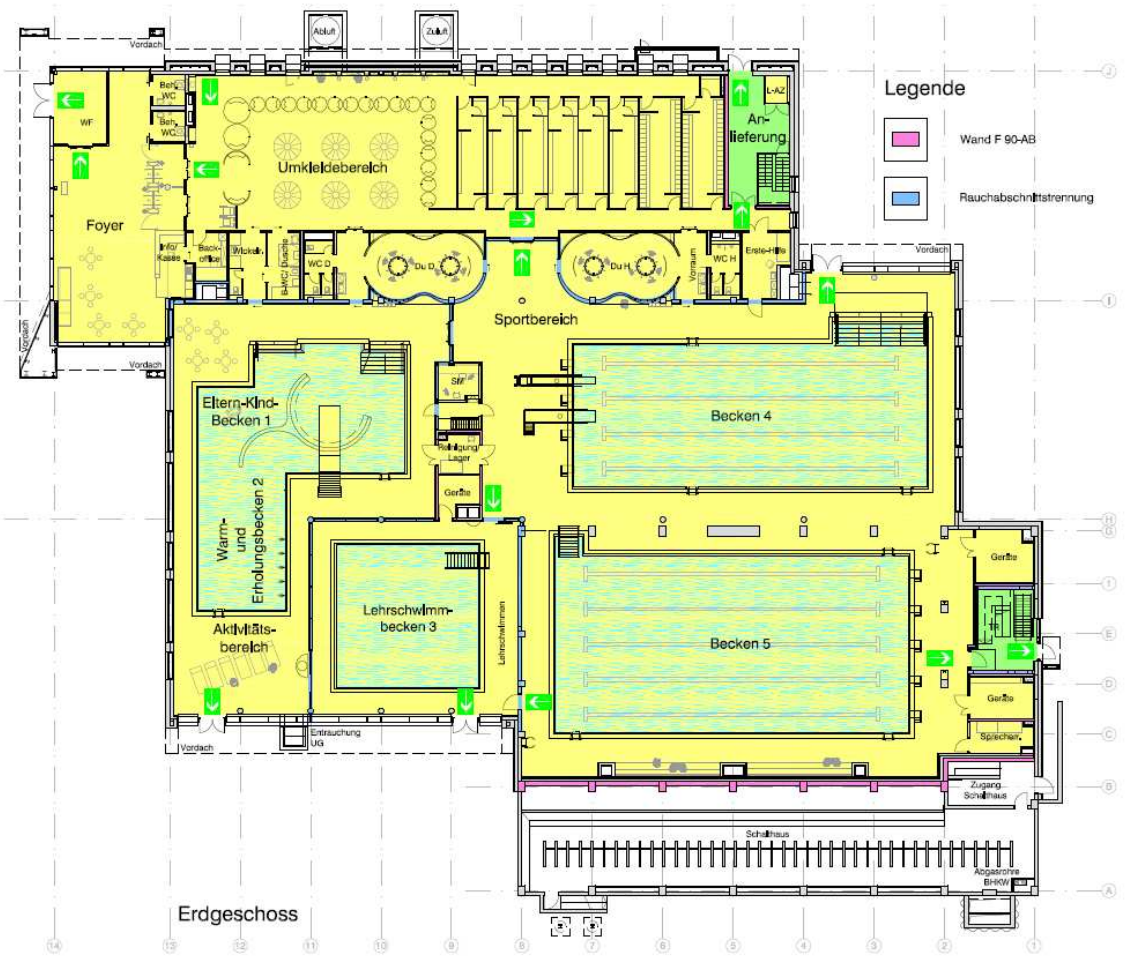


Figure 64: Ground floor fire protection plan (source: skp)

9.4 Structural fire protection

The structural fire protection includes essentially the description of Requirements for the components and building materials in the building as well as the description of the structural implementation. For the basement and for the former thermal power station as a medium-high building, the fire resistance class F 90 is required, which is met by the reinforced concrete construction.

For the area of the swimming pool, requirement F 30 is made for the load-bearing and stiffening construction in accordance with the building regulations. This requirement is met by the reinforced concrete columns in connection with the Glued wood trusses met. From a building law perspective, there are no requirements for the room termination through the roofing.

The prefabricated wood parts are strip-shaped cross-laminated timber elements that are built up as a box element. The individual elements are with groove and

Spring connected. These wooden prefabricated parts are clad on the underside with wooden acoustic panels. Due to their design, the cross-laminated timber elements have fire resistance class F 30. The execution takes into account the protection goal of limiting the spread of fire, so that in the event of a fire in the building, it is not transferred directly to the roof insulation. Particular attention should also be paid to roof penetrations that have been designed so that fire transmission is also prevented. This was achieved by executing the roof penetrations in accordance with DIN 18234. Due to the size of the roof areas of the swimming pool, the fire service as the fire protection agency required further measures to limit the spread of fire via the roof insulation. A structural division is already given by the different heights of the roof areas. A further division within the largest roof area in the area of the new swimming pool is given by a strip with non-combustible insulation in two halves (see Figure 65).

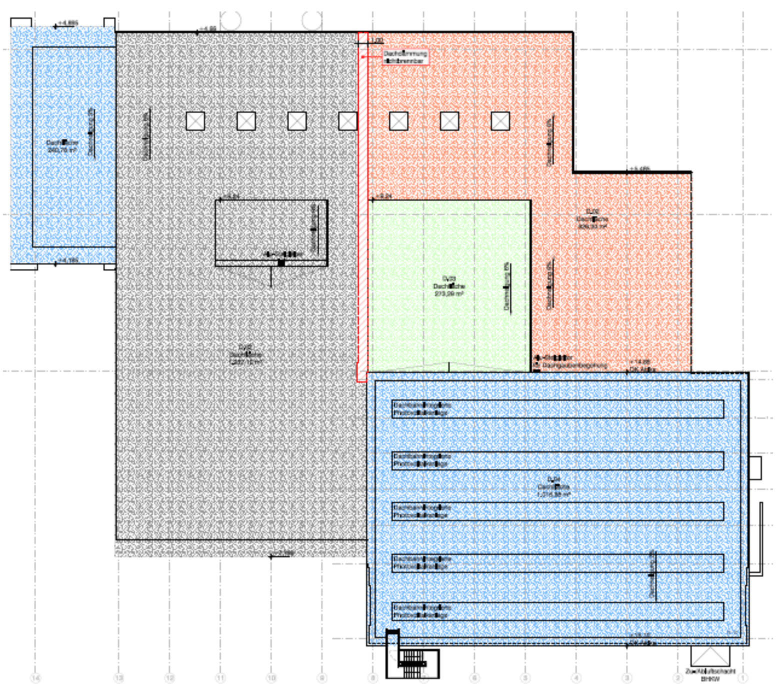


Figure 65: Segmentation of the roof areas (source: skp)

The building regulations only place requirements on the flammability or flammability of the outer walls in the area of the existing building of the combined heat and power plant, since this part of the building is to be classified as a medium-height building. According to the building regulations, the design of the non-loadbearing outer walls was made non-combustible. This requirement is met by the solid construction. The insulation or the outer wall cladding must consist of at least flame-retardant building materials in accordance with the requirements of the building regulations.

This becomes by the thermal insulation composite system with flame retardant insulation (EPS rigid foam) fulfilled.

The walls of the new building are made of KSV masonry / reinforced concrete with a thermal insulation system or glazing. There were no special requirements for structural fire protection.

9.5 Escape routes

The escape routes for the basement form a necessary stairwell within the changing room. There is also a staircase in the middle of the building.

There are direct exits to the outside for the ground floor areas. The number of exits has been optimized so that the smallest possible number of building openings in the outer shell was required, but the permissible escape route length of 35 m was not exceeded.

The first escape route on the upper floors of the former thermal power station is the first escape route via a necessary staircase. The second escape route for the 1st and 2nd floors is guaranteed by instructable windows. Due to the expected increase in the number of people, a structural escape route in the form of an external staircase tower was designed for retrofitting on the third floor.

Illuminated signs are used to mark the escape routes. The escape routes are shown on escape and rescue plans.

9.6 Technical fire protection

The basement forms an independent smoking section. The smoke extraction from the basement is guaranteed by mechanical smoke extraction using a fire gas fan to enable effective fire fighting.

No specific requirements have been formulated for smoke extraction from the swimming pool, so that a protection goal-oriented consideration was necessary. Smoke extraction was therefore designed in the swimming pool based on the special building regulations. This formulates easier requirements for smoke extraction for rooms with an area of 200 to 1,000 m². These can be smoke discharge openings with a free opening area of at least 1% or 2% free opening area in the form of windows and doors, each based on the base area. The areas of the swimming pool were covered with

Smoke discharge openings equipped with 1% of the base area. The windows provided for smoke evacuation in accordance with the passive house standard do not meet the requirements of EN 1201 Part 1. However, since this is not a smoke extraction device in accordance with the technical regulations, there were no objections to the deviation from this standard from a fire protection perspective. Approved drives are used that are adequately dimensioned for the windows.

The building is not equipped with an automatic fire alarm system. In order to ensure personal protection, an alarm system for the house alarm with manual fire detectors has been installed in the area of the exits in accordance with the expected fire scenarios. The alarm system is connected to the permanently manned control room of the Lünen municipal utility.

In order to prevent fire from being struck by lightning, a lightning protection system was installed in accordance with technical regulations. Within the building, two combined heat and power plants are operated to generate heat and electricity, which are operated with natural gas or biogas. These combined heat and power plants are housed in fire protection areas. For the shutdown by the fire department

during a

Fire-fighting equipment was installed.

The building's ventilation systems are designed as ventilation systems with a recirculating air component. The ventilation units are installed in the basement. In the event of a fire, the ventilation systems are switched off by smoke detectors in the ventilation systems.

9.7 Conclusion

From a fire protection point of view, the construction of the building in the passive house standard does not lead to problems that represent a significantly higher investment. The compensation measures taken for fire protection were essentially not determined by the passive house standard, but by the building cubature and the type of use. The use of wood as a building material does not contradict structural fire protection if this is already taken into account in the planning.

10 Costs and economy

The Lippe Bad project is the innovative development of the first example of an indoor pool built according to the passive house concept. In the Lippe Bad example, scientifically managed monitoring in the company will bring transparency and experience to the technical systems. This gain in knowledge in the first work alone is worthy of funding. On the other hand, the handling and marketability of passive house technology and the additional approaches to saving (energy, drinking water, waste water, chemicals, work processes, need for renovation) depend in particular on the additional investment costs in addition to the experience in operation.

The different individual measures with the aim of saving energy and water cannot be assessed economically in the indoor swimming pool system. The savings potential is not only exhausted by stringing together several individual measures, but only results from the combination of these. The simulations carried out via the specially expanded passive house project planning package show the interdependencies in the indoor pool system. The high thermal quality of the casing only opens up the possibility of exploiting the potential savings that can also be achieved by reducing evaporation and the ventilation system. Warm water savings also have an effect on the water balance (drinking water, waste water), the heat balance and indirectly also on the electricity balance through the concept of heat recovery. As always, there are also certain risk positions in the innovative first plant Passive Indoor Pool. The still uncertain state of knowledge regarding the development of pollutants in the indoor pool atmosphere harbors the risk, for example, of having to increase the air changes contrary to the passive house concept. to ensure the operating conditions of the indoor pool. In order to counter this risk, the ventilation in the Lippe bathroom was designed for indoor swimming pools according to the usual general conditions and the state of the art. Corresponding

let themselves be in the first work none with the Passive house concept Realize potential savings on ventilation system technology (lower volume flows, reduced device sizes, smaller dimensioned duct network ventilation). The energy savings associated with the passive indoor pool ventilation concept will also be unsecured until the results of monitoring pollutants in the indoor pool atmosphere clarify the functionality and suitability of the passive indoor pool ventilation concept. This makes monitoring a key task in the Lippe Bad, because the findings are also so important for the conception of follow-up projects. The innovative approaches for the Lippe Bad, the still open risk position and the need for monitoring were supported in the Lippe Bad project by sponsors (Deutsche Bundesstiftung Umwelt, Ministry of Economics, SMEs and Energy of the State of North Rhine-Westphalia, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety). Taking into account funding, risk positions that are still unclear and the monitoring findings that are still outstanding in the company, it is unsuitable to derive statements on profitability from the first project Lippe Bad with a view to follow-up projects. In order to develop an idea nevertheless, a standard project (EnEV

2007) and a "functioning" passive indoor pool project in terms of costs. The framework data for this consideration are largely derived from the concrete, integral planning process.

Looking at the life cycle costs of an indoor swimming pool project, it can be further deduced that additional investment costs are very economically invested, provided that sustainable operating cost savings are achieved without sacrificing the requirement profile and quality of use. While the life cycle costs on average of different building types (from residential buildings to administration buildings, hospitals to schools and kindergartens) are determined by 20% through the investment and 80% through the operating costs, the shares for standard indoor pools are around 10% investment and 90% operating costs.

The final energy savings theoretically derived in the planning of the Lippe Bath are 426 MWh / a (around 70 T € / a net) and 1,811 MWh / a (around 100 T € / a net) for heat. On the drinking water side, savings of around
15,000 m³ / a (approx. 19.5 T € / a net) expected. Based on the location of the indoor pool, a direct introduction into the lip was provided in order to be able to discharge virtually unpolluted water (rainwater, excess gray water) without the usual wastewater fees, which means avoided wastewater / drainage costs of around 41 T € / a net. The total savings prospect for electricity, heat, drinking water, wastewater and rainwater is currently around 230 T € / a net.

Assuming that the results of the monitoring will confirm the functionality of the passive indoor pool, there are a total of around € 2.1 million in additional costs for the implementation of a passive indoor pool, with a view to follow-up projects. For further calculation, each additional cost measure was assigned a useful life and a maintenance effort in order to calculate the total annuity and service / maintenance amount with interest (3.5%) and useful life (between 10 and 30 years). The following annual cost calculations were then carried out with these figures.

Table 7: Numerical values of the annual cost accounting

Additional costs	2,100,000	€
Total annuity amount	159,200	€
average useful life of system technology	18th	Years
interest	3.5	%
Redemption	4.1	%
Inflation of water, wastewater and energy costs	3.5	%
Inflation of maintenance / repair costs	2.0	%
Energy / water cost savings in the 1st year	230,000	€
Maintenance costs in the 1st year	26,900	€

All amounts in €

	1 year	2 years	3rd year	….	**9th year**
Debts	-2,100,000	-1,884,700	-1,661,888	….	-151,394
interest	-73,500	-73,500	-73,500	….	-73,500
Redemption	85,700	85,700	85,700	….	85,700
saving	230,000	238.050	246.382	….	302,866
maintenance	-26,900	-27,438	-27,987	….	-31,518
Remaining debt	-1,884,700	-1,661,888	-1,431,293	….	**132.155**

This calculation shows the amortization of the additional investment in the year in which for the first time no residual debt is shown. This is the case in the 9th year.

Table 8 compares the results of the calculations for the life cycle costs over 40 years of operation. It can be seen that despite the higher investment (additional costs € 2.1 million) for the passive construction and the additional technology systems, a total of € 11.5 million in life cycle costs was saved will. If one looks at the calculated development of the life cycle costs over the years, it can be seen that in the 10th year of operation the life cycle costs for passive construction become smaller than those of the standard project (specifically € 23.5 million to € 23.7 million).

Table 8: Life cycle costs of the different project standards compared

	Standard project (basis EnEV 2007)		Indoor pool with passive house technology	
investment	€ 9.5 million	10.0%	€ 11.6 million	13.9%
rough dismantling costs	€ 600 thousand		€ 650 thousand	
initial operating costs	€ 1,263 thousand / a		1,060 T € / a	
middle Increase in operating costs	2.5%			
Total operating costs calculated over 40 years	€ 85.2 million	89.5%	€ 71.5 million	85.4%
Life cycle costs calculated over 40 years	€ 95.2 million	100%	€ 83.7 million	100%

With further optimizations and results of the monitoring, which safeguard options for reducing technology as a cost driver, there is the prospect of further improved efficiency for indoor pools in the passive house concept. In order to secure new knowledge and practical handling, the topic of passive indoor swimming pools must be intensively worked on. Innovations are in high demand in the market, because existing regulations and customary concepts are not to be considered sufficient to tap the savings potential that is already possible today.

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