TECHNISCHE
UNIVERSITÄT
WIEN
Vienna | Austria

DIPLOMARBEIT

Architecture and technical aspects of the swimming hall building designs of Friedrich Florian Grünberger

unter der Leitung von

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E 259-3 Abteilung für Bauphysik und Bauökologie

Institut für Architekturwissenschaften

eingereicht an der

Technischen Universität Wien

Fakultät für Architektur und Raumplanung

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Wien, Juni 2018

DEUTSCHE KURZFASSUNG

Im Jahre 1968 entwickelte sich in Wien ein neues Konzept betreffend Sport und Freizeit, das „Bäderkonzept". Das Ziel dieses Konzeptes war es ein Netzwerk von leicht zugänglichen und leistbaren öffentlichen Schwimmhallen in Wien zu errichten. Von wesentlicher Bedeutung für diese Entwicklung war der Architekt Friedrich Florian Grünberger. Mit dem von ihm entwickelten "Bezirkshallenbäderprogramm", prägte der sogenannte „Bäderpapst von Wien" wesentlich die Wiener Bäderkultur. Bedauerlicherweise ist dieser Architekt, welcher einen großen Beitrag an Wiens kultureller und architektonischer Geschichte leistete, über die Jahre in Vergessenheit geraten. Diese Arbeit verfolgt zwei Ziele: Auf der einen Seite zielt sie darauf hin, die verschiedenen verstreuten Quellen über diesen Architekten zu sammeln und das Wissen über sein Leben und Werk wiederzubeleben, sowie den Kenntnisstand über die außergewöhnliche Badegeschichte Wiens um die Entwicklung aus dieser Zeit zu erweitern. Der zweite Teil dieser Arbeit konzentriert sich auf die bauphysikalischen bzw. Gebäude-Performance Aspekte von Schwimmhallen im Allgemeinen und auf die Sanierung eines der Bezirkshallenbäder von Grünberger, welches mit Hilfe eines Energiespar-Contracting Modells umgesetzt wurde. Dieses Energiespar-Contracting, ein Finanzierungsmodell, welches dazu beiträgt veraltete Konstruktionen ohne wesentliches Eigenkapital zu sanieren, ermöglichte der zuständigen Magistratsabteilung für Bäder in Wien, der MA-44, den Energiebedarf ihrer energieintensiven Schwimmhallen zu reduzieren. Zwischen den Jahren 2000 und 2017 wurde bei zwölf Schwimmbädern in Wien Energiespar-Contracting ein- und durchgeführt. Einige dieser Bäder wurden ursprünglich von Architekt Grünberger entworfen. Die Arbeit beschäftigt sich mit den durchgeführten Maßnahmen und den daraus resultierenden Energie-, Wasser- und Kosteneinsparung der europaweit wegweisenden Modernisierung eines dieser Gebäude, dem Floridsdorfer Hallenbad. Obwohl im Falle von Fernwärmekonsum die garantierten Einsparungen unter anderem aufgrund von Komplikationen der Solaranlagen nicht erreicht werden konnten, stellte die Gesamtoptimierung jedoch sehr gute Ergebnisse dar. Mit erzielten Einsparungen von Nutzstrom, Erdgas und Wasser, welche die erwarteten Werte überstiegen, konnte die finanzielle Gesamteinsparung des Bades auf ca. 55% reduziert werden. Die Untersuchung der tatsächlich erzielten Einsparungen wies weiters darauf hin, dass gezielte Ergebnisse in dieser Hinsicht immer über einen ausreichenden Zeitraum beobachtet werden müssen, um ihre volle Wirkung feststellen zu können. Ein weiterer wesentlicher Aspekt, der in dieser Arbeit diskutiert wird und bei den durchgeführten Untersuchungen hervorgehoben wurde, ist die große Verschränkung der jeweiligen Systeme (Haustechnik, Badetechnik, Gebäudehülle), die eine detaillierte Auflistung der Messwerte für die einzelnen Maßnahmen

schwer durchführbar machen. Diese Arbeit beabsichtigt, die derzeitige Machbarkeit von energetischen Sanierungen hervorzuheben und so neue Impulse für solche zu setzen.

ENGLISH ABSTRACT

In 1968 a new concept called the “Bäderkonzept” (eng. concept of baths) has been developed in the city of Vienna. The goal of this concept was to create a network of easily accessible and affordable swimming pools all around the city. One of the key roles in this development was held by the architect Friedrich Florian Grünberger. He was the so-called “Bäderpapst von Wien” *(eng. “Bathpope of Vienna”)* and substantially shaped the bathing culture of the second half of the 20th century in Vienna with his “Bezirkshallenbäderprogramm” (*eng. district indoor pool program*). Unfortunately, there is very little knowledge about this architect, -who undoubtably has made a notable contribution to the cultural and architectural history of Vienna (and the German-speaking neighbouring countries). This master thesis focuses on collecting the scattered information sources about him, - thus recovering the knowledge of this person`s life and work. Moreover, it is meant to enrich the knowledge about Vienna`s exceptional bathing history. The second part of this thesis focuses on aspects of building physics of swimming halls in general and the retrofit of one of Grünberger`s district indoor pools. This retrofit was conducted in the framework of energy saving contracting. Energy saving contracting is a financial model, where a private contractor implements energy saving measures and gets remunerated by a percentage of the energy saving expressed in monetary units. Measures to lower the energy consumption can encompass improvements of the buildings’ envelope, the corresponding technical systems, or the operational regimes in the buildings. The responsible municipal authority for swimming halls in Vienna, the MA-44 (magistrate department 44), has been able to reduce the energy demand of its high energy consuming swimming halls via this method. Between the years 2000 and 2017, twelve swimming-pools in Vienna have conducted energy-saving-contracting. Many of these have originally been designed by architect Friedrich Florian Grünberger. In this sense, this contribution furtherly focuses on the implemented measures and the resulting energy, water and cost savings. In the detail one of the retrofitted swimming halls is evaluated; the Europe-wide pioneering modernization of one of the Grünberger buildings, the Floridsdorfer indoor bath. Although the actual savings for district heating were not able to reach the guaranteed savings, inter alia, due to some complications with the solar panels, the overall optimization has severly improved the building. With active current, natural gas and water savings surpassing the guaranteed values, the overall financial savings of the bath were able to be reduced to approximately 55%. The study further points out, that targeted results always need to be observed over a sufficient period to discover their full effects. Another essential aspect, which turned out to be of high importance during this research, is the complex relationship between the different assets of the respective systems (housing technology, pool technology, building envelope). Encompassing highly complex building service systems and operational schemes, it is a challenge to identify a detailed list of measured values for evaluation of the success of retrofit measures This contribution intends to emphasize the current feasibility of energy saving renovations and intents to set new impulses for further renovations of comparable objects.

Keywords

Friedrich Florian Grünberger, Viennese Bath Concept, District Indoor Pool Program, Floridsdorfer indoor bath, Building Performance, Energy Saving Contracting

ACKNOWLEDGEMENTS

I would like to thank my supervisor Univ.Prof. Dipl.-Ing. Dr.techn. Ardeshir Mahdavi and my co-supervisor Univ.Ass. Dipl.-Ing. Dr. techn. Ulrich Pont for initiating this topic, as well as their time and mentoring. Additionally, I would also like to thank Ao.Univ.Prof. Arch. Dipl.-Ing. Dr.techn. Bob Martens for his support.

Special thanks go to Dipl. Ing. Oskar Böck and Michael Sturm from ENGIE Austria, Ing. Norbert Wacek and Dipl.-Ing. Robert Lautner from SIEMENS Building Technologies and Dipl.-Ing. Jochen Jandak from the municipal authority 44- baths in Vienna for their precious cooperation.

Finally, I would like to thank my family Alexander Walal, Mag. Dr. Christian Walal, BSc. Florian Prawits, Margarete Walal and Mag. Olga Hronikova for their continuous support. Without them, I would never be where I am today.

CONTENTS

1 INTRODUCTION

In Vienna, swimming and culture have always been closely linked to each other. From the so called “Tröpferlbad”, which were community baths meant mainly for hygienic cleaning, to beautiful swimming halls, even used for holding concerts and balls in winter, the Viennese bathing culture has shown a great development. One of the key stones of this development was the “Bäderkonzept” *(engl. concept of baths)* which was developed in December 1968. After the city of Vienna slowly recovered from the 2nd World War, this concept was established to expand the urban swimming opportunities and provide the population with quickly accessible and cost saving swimming pools for exercise and relaxation. One of the key roles of the “Bäderkonzept” was held by the architect Friedrich Florian Grünberger, who developed a standardized facility- concept during an additional district indoor pool program. (Redaktion wien.at 2016)

Although this architect has shaped the architecture of Vienna to such great extent, there are hardly any books or digital information about him, which is why his name is so unfamiliar to a great amount of people. The few existing information about this so called “Bäderpapst von Wien” *(engl. bathpope of Vienna)* has been lost with his death in 2007, as well as buried in the libraries, archives and magistrates in Vienna. (Online, Wiener Zeitung 2007)

In order to revive this “forgotten” architect, this thesis aims to gather these scattered sources, recover the knowledge of this person`s life and work and broaden our knowledge about Vienna`s exceptional bathing history.

The second part of this thesis focuses on the building physical aspects of swimming halls in general and the retrofit of one of Grüberger`s district indoor pools which was conducted in the framework of energy saving contracting. The city of Vienna, as one of the biggest public pool operators in Europe, is keen on reducing the energy demand of such high energy consuming buildings. High operating costs, increased energy prices, as well as international obligations towards the climate protection enhance the need of reducing the energy demand. In order to increase the energy efficiency of Vienna`s baths, the responsible municipal authority for baths in Vienna, the MA 44, has been entering so called energy-saving-contracting projects to be able to finance their renovation. This financing model is a form of Public Private Partnership (PPP) in which the contractor develops water- and energy-saving measures together with the customer, the contracting-taker. These are then further being constructed and financed by the contractor. The contractor gets remunerated based on the amount of saved energy and water costs. Therefore, the contractor`s income is solely success- oriented. This way the contractor is forced to high quality performance due to his responsibility of providing full warranty over the whole contracting period. (Magistrat der Stadt Wien 2008; Österreichischer Städtebund n.d)

Between the year 2000 and 2017 twelve swimming-pools have been modernized with the help of energy-saving-contracting in Vienna. Many of these swimming halls have originally been designed by architect Friedrich Florian Grünberger, such as the swimming pools in Brigittenau, Döbling, Hietzing, Großfeldsiedlung, Donaustadt and Floridsdorf. The renovation of two of these swimming halls have been so outstanding, that the responsible municipal authority in Vienna, the MA 44, has received international awards for these projects. While the energy savings contracting project "swimming hall Brigittenau" has received the "Best European Energy Service Project" 2007 from the European Energy Service Initiative, the second European award, the "GreenBuilding Partner Award" has been given to the "Hallenbad Floridsdorf" only one year later by the European Commission. Receiving these awards shows that the municipal authority for baths in Vienna, the MA 44, has proved itself as an environmental model operation within Europe. (Österreichischer Städtebund n.d)

Studying the building physical aspects of swimming halls in general and researching the details of the exemplary renovation of one of Grünberger`s buildings, the Floridsdorfer indoor bath, is the 2nd focus of this paper.

1.1 Motivation

Swimming pools in Vienna have always stood in close relationship with its culture. The creation of the baths did not only display a joy for the people itself, but it also constituted a political statement, an architectural development and even opened up the stage for cultural events. It is important to keep the Viennese culture alive, be aware of our history and not let great architects such as F.F. Grünberger be forgotten. Reviving him and his work, as well as investigating the building physical details of swimming halls, not only adds to the knowledge of our history, but it also enhances our architectural knowledge. By researching the measures and the resulting energy, water and cost savings of one exemplary swimming hall refurbishment shall broaden our knowledge about building physics, especially in regard to this specific building typology, helps to point out its current feasibility and intents to set new impulses for further energy saving renovations.

1.2 Background

Due to the lack of information about F.F. Grünberger, there is very little knownledge about him. Only a few unique pieces about this architect are kept in some archives/libraries in Vienna. Some biographical information by F.F. Grünberger can be found in an encyclopaedia of Viennese architects of the 20th century (Weihsmann 2005) as well as on a record card in the Achleitner archive in Vienna (Achleitner Archiv, Architekturzentrum Wien, Sammlung). The architecture centre Vienna further keeps some magazine articles referring to the works of F.F. Grünberger within its "Avery Index" database. The Wiener Stadt- und Landesarchiv (Viennese city- & state archives) stores one of Grünberger`s works in his library (Grünberger 1974). Additionally, in the Technical University of Vienna some literature about F.F. Grünberger, Viennas historical bathing culture and the Floridsdorfer indoor bath can be found (Bednarik et al. 1994/95; Feichtenberger 1994; Hofer 2004; Scheiböck Jänner 2002; Seemann and Lunzer 2004; Seledec and Kretschmer 1987). Plans to the baths designed by the architect are held at the responsible municipal authority for buildings, the MA37. Regarding special building types such as swimming halls, general information about the building physical demands can be found on the internet. Some articles or guidelines which cover the architecture of these particular energy demanding constructions can be found in some online- portals like the German Architecturepaper *(de. Deutsches Architektenblatt)*, Heinze or Passipedia. Concerning the architecture and building performance related aspects of the Floridsdorfer swimming hall, the responsible municipal authority (MA 44) and the contractor which has been instructed with the renovation (ENGIE), have provided relevant information.

1.3 Method

To gain material about F.F. Grünberger and his work, various libraries, archives and databases have been contacted and searched for information. Among these are the literature stock of the Technical University of Vienna, the architecture centre Vienna, the Austrian National Library, the Vienna-library in the city hall, the city and state archives of Vienna as well as the internet.

In addition to the above-mentioned approach, the building physics requirements of today's swimming pools, as well as the energy saving contracting, particularly within the framework of the renovation of public swimming halls in Vienna, have been researched and presented.

To examine the building performance related aspects of one of F. F. Grünberger`s swimming halls, one real case study has been investigated regarding the building physical improvements through refurbishment. In this sense, the architectural site of the studied indoor bath has been visited personally to gain on-site information about the construction. Furthermore, meetings with the municipal authorities- baths in Vienna (MA 44) and the contractor of the modernization project Floridsdorfer indoor bath (ENGIE) have been set up to gain relevant information about the implemented measures, as well as the energy demand and costs before and after the refurbishment. Additionally, the responsible municipal authority for buildings in Vienna (MA37), has been contacted to gain access to the plans of the Floridsdorfer indoor bath. These plans have been analysed based on the implementation of the concept of the "Bäderkonzept" and further used for an energy evaluation of the building envelope using Archiphysik 15.0.

2 FRIEDRICH FLORIAN GRÜNBERGER

2.1 Biography & Work

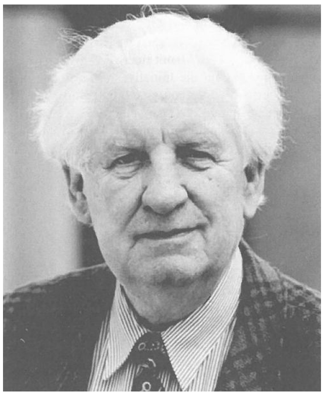


Figure 1: Friedrich Florian Grünberger (Weihsmann 2005)

Friedrich Florian Grünberger, the so called “Bädepapst von Wien” *(engl. bathpope of Vienna)* was an Austrian architect who shaped the bathing culture of Vienna substantially with his architecture including his so called “Bezirkshallenbäderprogramm” *(engl. district indoor pool program”)*, a concept to supply the city of Vienna with an adequate number of indoor swimming pools after WWII.

Friedrich Florian Grünberger was born on the 10th of May in 1921 at Loquaiplatz 9 in Trumau, Lower Austria. He was the son of Fritz Grünberger, a master roofer. After receiving his title as graduate engineer at the vocational school for structural engineering in Mödling, Vienna, he thereupon served in the fatigue duty during the 2nd World War. Thereafter, F. F. Grünberger started his studies in architecture under Professor Alexander Popp at the academy of fine arts from 1939 to 1941 in Vienna. Already during his first semester F. F. Grünberger received the price for the master school of architects for his outstanding achievements. Later, his studies were interrupted by the mandatory military service including war captivity. After F. F. Grünberger was able to continue his studies with Professor F. Adolf Lutz in 1945 and in the master class with Professor Lois Welzenbacher in 1946/47, he was given the silver Füger- medal, again for his outstanding achievements. Following his diploma examination in 1946, he became the first assistant of Professor Lois Welzenbacher. F. F. Grünberger completed his examination as a Master Builder in 1948 and received his license in 1950.

From 1954 onwards, F. F. Grünberger worked as a freelance architect in offices in Vienna (AUT), Düsseldorf (D) and Bad Homburg (D). These offices were actual engineering offices in order to plan and coordinate the architecture offices with engineering solutions. In the following years, he mainly focused on the construction of social residential buildings and structures in the agriculture and manufacturing section in Vienna and Lower Austria. His collection of outstanding achievements continued when Grünberger received the 1st price in a competition for reconstructing the city hall cellar in Traiskirchen, Lower Austria. Shortly thereafter, a contract for planning a bathing facility in Gloggnitz, Lower Austria followed. This project pushed him to create special studies for the construction of modern baths and further helped him create a name for himself as an expert for bathing facilities. He thereupon established his own baths department. The construction of the Alpenbad Wattens, including an underwater restaurant, followed in 1956 in Tirol. This bath not only displayed the first cost-covering bathing facility in Austria, it was also internationally referred to as the most modern bath in Europe. In 1964 Friedrich Florian Grünberger received the professional title "Professor". As part of the concept of baths in Vienna in 1968, Grünberger was responsible for almost all of the modern indoor swimming pools in Vienna.

(Achleitner Archiv, Architekturzentrum Wien, Sammlung; Bednarik et al. 1994/95; Universitätsarchiv der Akademie der bildenden Künste Wien n.d; Weihsmann 2005)

These were:

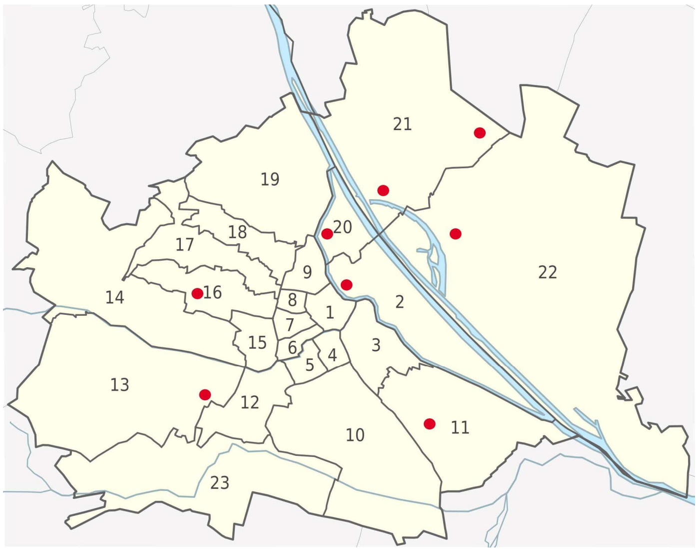


Figure 2: District baths in Vienna (stadtplanwien360.at)

- Indoor bath Floridsdorf (1963-1967) - Franklinstraße/Freytaggasse, 21st District
- Indoor & outdoor bath Ottakring (1986-1973)- Johann- Staud- Straße 11, 16th district
- Dianabad (1970-1974) – torn down in 1999- Lilienbrunngasse 7-9, 2nd district
- Indoor & outdoor bath Hietzing (1976-1978)- Atzgersdorfer Straße 14, 13th district
- Indoor bath Simmering (1977/78)- Florian- Hedorfer- Straße 5, 11th district
- Indoor & outdoor bath Donaustadt (1980-1982)- Portnergasse 38, 22th district,
- Indoor & outdoor bath Brigittenau (1981-1983)- Klosterneuburger Straße 93-97, 20th district
- Indoor & outdoor bath Großfeldsiedlung (1982-1984)- Oswald-Redlich-Straße 44, 21st district

(Weihsmann 2005)

Other works:

- Private bath Niarchos in St. Moritz, Switzeland (1961)
- Europe- bath Korneuburg, Lower Austria (1973)
- Indoor pool with Sauna for Bruno Kreisky, Vienna, Austria (1974)
- Restaurant for the exhibition centre in Vienna, Austria (1982)
- Educational centre in Vienna, Austria (1986)
- Indoor & outdoor bath in the federal sports center Südstadt in Maria Enzersdorf, Austria (1964-1975)
- Thermal bath in Vienna-Oberlaa, Austria (1972-1974)
  Kurbadstraße 14, 10th district
- Award winning designs for the city Steyr, Upper Austria (1966)
- Award winning designs for the city Bludenz in Vorarlberg, Austria (1956)
- Outdoor bath with indoor pool and ice- arena in Stockerau, Lower Austria (1966)
- Sports centre of the military academy in Wiener Neustadt, Lower Austria (1962)
- Hospital project in Düsseldorf, Germany (1963/64)
- Design of the biggest indoor pool in Europe in Düsseldorf, Germany (1966/67)
- Swimming pool in the federal college Vienna- Schmelz, Austria (1970)

- High-rise building in Wels, Upper Austria (1955)
  Roseggerstraße/Herrengasse
- Residential building, Vienna, Austria (1955)
  Münichreiterstraße 44, 13th district
- Residential building, Vienna, Austria (1955)
  Gymnasiumstraße 42, 18th district
- Residential building, Vienna, Austria (1956)
  Eslarngasse 4a, 3rd district
- Housing complexes in Vienna and Lower Austria

(Bednarik et al. 1994/95; Weihsmann 2005)

Although F. F. Grünberger has planned therapeutic centres, hospitals, restaurants, residential buildings, schools and kindergartens, the construction of indoor and outdoor swimming halls consisted of a particular extend. (Grünberger 1974)

Friedrich Florian Grünberger knew how to emphasize with the bather`s psychology, which most likely led him to be such an expert within this field. In his eyes, the visitors would enter the bathing area as an undressed person who would experience his/her environment differently. He/ She would feel more relaxed and therefore more open-minded to foreignness, unfamiliarity – abstraction. (Die Zeit Archiv 01.07.1966)

Grünberger`s work is not only characterised by his understanding of baths, it`s visitors and constant drive to encounter new technical and economic challenges, but also his ability to insert his constructions into their landscape and urban conditions by considering the choice of scale, construction, material and colour. Additionally, he has always payed attention to the functional room and access dispositions as well as reliability within building implementation and operating technology. (Grünberger 1974)

Overall, he has planned over 50 indoor baths, 29 outdoor baths, 53 Sauna baths and 30 thermal baths which is the reason he is named the "bathpope of Vienna". In order to display his 25 years of architectural contribution, an exhibition of his work was shown in the Künstlerhaus in Vienna in 1974. Not only did he shape the bathing culture through his works and bath concepts such as the "Europabad" *(eng. Europe-bath)* and the "Wiener Bezirkshallenbäderprogramm" *(eng. Viennese district indoor pool* *program)*, which will be discussed within the next chapters, he also passed on his knowledge by giving numerous lectures about the construction of baths at Universities at home and abroad. A detailed list of works, prizewinning competitions, lectures and publications from and about Friedrich Florian Grünberger can be found within the Appendix 10.1, 10,2 and 10.3. (Bednarik et al. 1994/95; Grünberger 1974; Online, Wiener Zeitung 2007)

Friedrich Florian Grünberger passed away at age 86 on the 22nd of May in 2007 due to the consequences of a stroke. (Online, Wiener Zeitung 2007)

2.2 Concept "Europe-bath"

During the post-war area in Europe, the growing interest in sports facilities and swimming baths supported the endeavour to create financially reasonable constructions in order to meet this demand. Therefore, a seminar with the topic "Preiswerte Sportstätten- Bau und Betrieb von Schwimmbädern" *(eng. Low-cost sportsfacilities- construction and operation of swimming baths")* was initiated by the council of Europe in fall 1967 in Cologne including all the experts of its member states. (Grünberger 1974)

Due to his outstanding knowledge about the construction of baths, the Viennese architect Friedrich Florian Grünberger was sent as a representative for Austria to this conference from the 25th -30th of September 1967. During this conference, the backlog demand of bathing facilities, especially indoor baths, and the lack of resources to build these constituted a main issue. During this conference, Friedrich Florian Grünberger's exceedingly successful presentation about low-price indoor swimming halls was decisive for him being suggested to become part of the European council for bathing culture.

Further on, the highlight of this conference was the realization of the idea of an economical and inexpensive concept for baths, "das billige Europabad" *(eng. "the low-cost Europe-bath")*. This concept combined all the knowledge about the construction of past bathing facilities in consideration with its requirements, cheap construction and maximal outcomes.

(Bednarik et al. 1994/95)

This “low-cost Europe-bath” did not refer to a specific construction type including an unalterable floor plan and defined dimensions and shapes, it rather described a concept which adapted to the specific needs of the public such as the priority user interests (relaxation, school & youth, sports etc.), size of the population and location. Additionally, the circumstances of land and landscape determine the component`s structure as well as its design. (Grünberger 1974)

Although the results of this concept seemed quite simple, it included elaborate considerations, such as:

1. Right proportion between water surface and usable area
2. Economical proportion between water area and total volume of the building
3. Possible step-by-step extensions of significant facilities necessary for sport swimming, general swimming, diving and swim teaching.
4. Reasonable combination of prefabricated construction and conventional manufacture under consideration of the respective construction companies.
5. Most economical and cheapest arrangement of dressing rooms.
6. Usage of the roofed indoor-pool during bad weather conditions and winter time, and usage of open outdoor-pool during sunny weather conditions.
7. Conduits within the constructive bearing basic system.
8. In case of desirable final construction, manufacturing of the loadbearing structure and step-by-step development of each construction stage under consideration of the financial resources.

(Bednarik et al. 1994/95)

The concept of this “Europe-bath” included the renunciation from the common combination-pool which, to a greater or lesser extent, included subsections for non-swimmers, swimmers and divers. Instead, this combination-pool was replaced by numerous pools with various types of construction for each utility use. This not only offered more efficient usage of each pool, but also individual adaption of pool- size. Although the customized water surface and depth for each usage commonly leads to increased water surface area, the overall amount of water reduces in size compared to the combined swimming pool. Consequently, it was possible to reduce the height of the ceiling within the swimmer and not-swimmer area. Only the diving pools required the specific ceiling heights. Overall this concept resulted in a decrease in space requirements, smaller wall and window areas as well as a reduction of water demands. Subsequently costs of the converted space as well as the technical installations were being reduced and operating expenses such as heating, ventilation, water circulation, lighting and cleaning decreased.

Furthermore, the “Europe-bath” concept included the idea of renouncing the single changing rooms, which also served as safekeeping of the wardrobe, and replacing them mainly by group changing rooms. Instead of tall single wardrobes, double-rowed stacked double wardrobes with Z-shaped intermediate floors, offering enough hanging height for clothing and coats, were being created. With this set up the amount of space was able to be reduced by 2/3rd, which further created lower investment costs.

One more way of reducing the amount of space and costs was reached by abandoning the separation of the corridor between walking with shoes and barefoot. This was compensated by installing automatic shoe cleaning devices, carpets and disinfection basins.

Depending on the local needs and the necessity to reduce operating costs, eligible leisure time facilities were able to be assigned to the indoor swimming hall. These leisure time facilities included sauna areas, medical baths, a restaurant, a milk bar, club- and fitness rooms, a bowling alley and so forth.

(Grünberger 1974)

The main characteristic of the “Europe-bath” concept constituted the possibility of stage construction according to its relevance. This variable concept allowed even municipalities with low financial resources to build such a bath. Individually developed spaces, such as dressing rooms, swimming halls, learning pools, diving halls, saunas, restaurants and other leisure time areas could be constructed within different stages. (Bednarik et al. 1994/95; Grünberger 1974)

Each subsequent stage of construction formed an extension of the respective preceding, functionally completed construction stage. The construction stages consisted of the following:

1.Stage: wind- and weatherproof swimming hall with a 25x10 m pool, including a power house.
2. Stage: Expansion of 200 dressing rooms.
3. Stage: Expansion of a teaching/ non-swimmer hall including an 8x10 m pool.
4. Stage: Expansion of 80 school/club dressing rooms or a sauna or a buffet.
5. Stage: Expansion of a multifunctional hall with a 7,65x10,50 m pool for high diving from a 1m- 3m- board, water slides, swimming and diving.
6. Stage: Expansion of a public gallery.

7. Stage: -
8. Stage: -
9. Stage: The possibility of perception of individual expressed wishes and demands.
10. Stage: Determination and warranty of a fixed price as well as a completion date.

(Bednarik et al. 1994/95)

The illustration in Figure 3 on the following page displays one version of the Europe-bath concept including some of the previously mentioned layouts and pools with small variations in size. When entering the bath at the entrance (Eingangshalle), the visitors have the possibility to directly access the milkbar (Milchbar) and view the swimmers through a glass wall or to enter the swimming area through the wardrobes. The gender separated dressing rooms (Umkleide Männer/Frauen) are created as group changing rooms with several wardrobes, in order to reduce investment costs. Before entering the swimming area, the visitors pass the showers, toilets and the wading area. The wading area is used for disinfection of the feet and therefore helps reduce space and costs by renouncing the separation of the corridor between walking with and without shoes. When entering the swimming area, individual pools for various purposes, instead of a unified combination-pool, can be found. A teaching pool (Lehrschwimmbecken) with a pool depth from 1.25m - 0.6m, a swimming pool (Schwimmbecken) with a pool depth of 1.8 – 1.35m and a diving pool (Sprungbecken) with a pool depth of 3.8m can be accessed. While the swimming pool and the teaching pool consist of a ceiling height of 3.5 meters, the diving pool requires a necessary height of 8 meters due to the diving towers. As previously mentioned, this individual adaption of pool utilization and dimensions leads to a more sufficient usage of pools as well as a reduction of water demand, energy costs and operating expenses. The water area of this layout consists of 466 m² and a pool perimeter of 316 m². The basement floor offers the opportunity for additional leisure time facilities, such as a sauna. Further, a paramedic area (Sani.), which can be accessed from the entrance hall as well as the swimming area and a heating room (Heizung) with access to the filter unit (Abgang zur Filteranlage) are included within this concept plan. (Grünberger 1974)

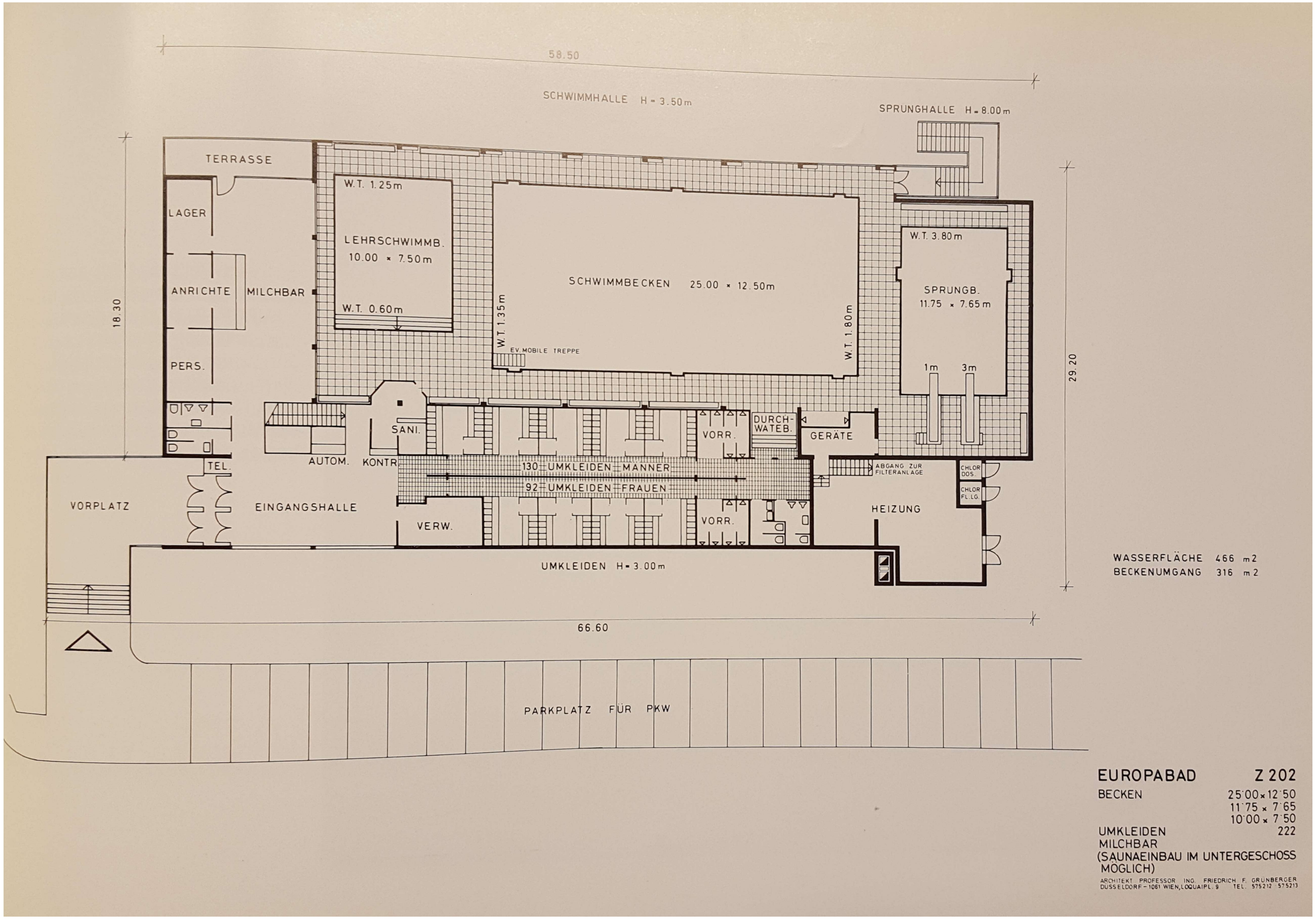


Figure 3: Europe-bath (Grünberger 1974)

Regardless of the individual possibilities of realization of the “Europe-bath”, a robust execution, including high-quality material and excellent technical equipment remained the fundamental groundwork of this concept. Beyond that, cost savings were not allowed to interfere with a short life-cycle, greater repair susceptibility and enhanced maintenance costs. (Grünberger 1974)

With the development of this “Europe-bath” concept as well as incorporating a well thought out engineering side of construction including heating, ventilation, electrical engineering and water preparation, Friedrich Florian Grünberger and his team created a genuine groundwork for the most economic and cheapest implementation of indoor swimming halls. Further on, the “Europe-bath” constituted the prototype of the so called “Bezirkshallenbäder” *(engl. Viennese district indoor pools)* which have been part of the “Wiener Bezirkshallenbäderprogramm” *(eng. Viennese district indoor pool program)*. This program is an essential part of the bathing sector development after WWII and will be discussed within the following chapter. (Bednarik et al. 1994/95)

3 VIENNESE BATHING DEVELOPMENT AFTER WORLD WAR II

3.1 Viennese bath concept

"During a time, in which rhythm of life burdens the people as hardly before, the creation of adequate recreational possibilities for the city population is of crucial relevance. It is necessary more than ever, to strive for a sufficient supply of the city area with recreational areas and facilities" (Hubert 1973)

In order to promote health, hygiene and exercise, as well as following upon on the population`s urge of vacation and relaxation, a range of summer baths were being built during the interwar area. Most of the people in Vienna were not able to afford vacation trips and therefore preferred to spend their leisure time in public baths. This development was supported by the construction of public swimming halls including big outdoor areas for playing and relaxation.

When the second World War broke out, the development of the urban baths stopped. Particularly at the end phase of the war, the bathing facilities were damaged or destroyed by airstrikes and ground attacks. In the spring of 1945 seven of the 72 baths in Vienna were completely destroyed and 23 severely damaged.

A rapid recovery of the demolished public baths was particularly necessary due to the non-usability of the bathing facilities within homes. Therefore, the city focused on reopening the public bathing facilities as soon as possible. Although obstacles such as fuel shortage and military occupation stood in the way of undisturbed bathing pleasure, in 1946 already 43 urban baths were put back into operation.

After the bathing sector was slowly able to recover from the ramifications of the second World War, the city continued its journey towards a bath-leading city. After extensive preliminary work, a future-oriented baths concept *(de. Bäderkonzept)* was developed on the 2nd of December in 1968. This concept was created under the order of city council Hubert Pfoch by the administrations of baths in corporation with the urban structure planning. The idea of this concept was to provide each inhabitant with the possibility of visiting a public bath in proximity to his or her home. These baths were meant as a place for relaxation as well as exercise. Within seven years a total of 14 baths and an investment volume of half a billion Schilling were intended. The responsible municipal authorities for urban structure planning and baths management *(de. Stadtstrukturplanung und Bäderverwaltung)* developed a concept which aimed at an optimal supply of bathing facilities for the population by creating a systematic arrangement of well-developed, indoor and outdoor swimming baths spread over the whole city area. A guideline to create such an ideal supply of baths was developed including a bathing area of 1m² per inhabitant (a value which complied with the international planning guidelines). For the indoor swimming pools, a standard value of 333 citizens per 1m² water area was intended.

In 1974 the baths concept was followed by a redevelopment concept of baths (de. Bestandsbäderkonzept). Within this development, the existing baths were examined and categorized due to their visitor frequency, occupancy rate, condition of the physical and technical structure, location issue and catchment area. Consequently, proposals for prospective usage of these constructions and further necessary measures, such as expansion and reconstruction, as well as disabling individual baths, were made. Subsequently, a variety of old municipal baths, the so called “Tröpferlbäder”, were shut down due to the increasingly better equipped home facilities. The summer baths were mainly focused on integrating additional pools and water preheating systems, as well as enhancing supplementary establishments such as sunbaths, play- and exercise facilities and children`s areas.

Within the Viennese baths concept, the following projects were realised:

- New construction of the (new) Dianabad
- General renovation of the Amalienbad
- General renovation of the bath in Hadersdorf- Weidlingau
- Construction of the Stadthallenbad
- Expansion of the Ottakringer Bad and new construction of a connected indoor swimming hall with sauna
- General renovation of the Kongreßbad
- General renovation of the Jörgerbad
- Construction of the Schafbergbad
- Construction of the Höpflerbad

- Construction of new children outdoor swimming pools
- Construction of the district indoor pools *(de. Bezirkshallenbäder)*

The construction of the above-mentioned district indoor pools was based on the intention of creating a greater number of indoor swimming halls inside the more densely built-up areas in order to compensate the supply of outdoor swimming halls around the peripheral areas of the city. To implement an efficient construction and to keep the costs as low as possible, the city of Vienna commissioned Friedrich Florian Grünberger to create this concept including a series of small and medium size district indoor pools.

(Feichtenberger 1994)

3.2 Viennese district indoor pool program

The concept for the Viennese district indoor pool program, created by architect F. F. Grünberger under the supervision of the city of Vienna, was meant to be implemented within two construction phases. The first phase included the districts Hietzing, Döbling and Simmering. The second construction phase encompassed the districts Donaustadt, Brigittenau and Großfeldsiedlung.

The baths created within this concept all displayed a common layout. They consisted of a 25 x 12.5m swimming pool, a 12.5 x 8 m teaching pool, a 6 m² children`s pool and a water temperature between 28- 30 degree Celsius. The basic amenities contained two gender divided sauna facilities with a buffet and restaurants which were accessible from the swimming area as well as from the street.

(Feichtenberger 1994, 1994; Seledec and Kretschmer 1987)

The concept Grünberger created for the city of Vienna showed similarities with his initial Europa-bath concept, which is illustrated in Figure 3 on page 9. While his Europe-bath concept included a subdivision of one combination pool into three swimming pools, the district indoor pool concept displayed the same layout. The only difference between these pool classifications was the different categorization of the pools. Instead of a swimming pool, a teaching pool and a diving pool, the new layout replaced the diving pool by a children`s pool. The swimming pools in both concepts showed the same dimensions of 25 x 12.5 m. The teaching pool within his new concept deviated slightly from Grünberger's Europe-bath measurements. The 10 x 7.5 m teaching pool became a 12.5 x 8 m pool within the new district indoor baths and therefore became larger in size. This change in dimension was most likely feasible due to the replacement of the 11.75 x 7.65 m diving pool by a much smaller 6 m² children`s pool. Furthermore, Grünberger kept his original idea of creating various leisure time facilities such as saunas and dual accessible restaurants, in his new concept as well.

Not before long, the district indoor pool program started to grow beyond the indoor pools and a combination of indoor and outdoor pools was envisaged. This unification allowed the guests to enjoy the facilities all year long, unattached to the current weather conditions. Additionally, a united and therefore more efficient operation of the combined indoor and outdoor pools as well as a more productive use of employees were created through this concept.

The first three district baths were put into operation only 14 months after the start of the construction period. These initial projects included the district indoor bath Hietzing (August 1978), Simmering (September 1978), and Döbling (December 1978). All three of these baths were expanded with an outdoor summer bath shortly after their construction and were further equipped with various technical water installations and recreational facilities such as waterslides, wild water channels, a minigolf course, playgrounds etc. Additionally, all three of these initial projects included a solar panel system which preheated the water of the pools.

The second construction phase started with building the district bath Donaustadt (October 1982) and was followed by the district bath Brigittenau (April 1983) and Großfeldsiedlung (April 1984).

While the first three baths created within the district indoor pool program already seemed to comply with modern water parks at that time, the baths created in the second construction stage were even better equipped. The experiences gained within the first construction stage were included within the following phase in terms of technical improvements. Further, a fourth thermal pool, solariums, relaxation areas as well as handicapped accessibility for visitors were created.

(Feichtenberger 1994; Seledec and Kretschmer 1987)

Although the baths constructed within the district indoor pool program seemed quite modern and technologically advanced during their time of construction, the energy consumption in indoor baths was extremely high nevertheless. Especially water appliances such as water slides, massage nozzles, wild water channels, wave pools etc. not only require energy-intensive water technology, but also consume tremendous amounts of water. Additionally, the ventilation technology, lighting, hot water preparation and water treatment, especially in connection with an increased indoor temperature and high heat losses, consume particularly high amounts of energy. (Garzia 2016; Passipedia 2014)

Ongoing technological advances and rising awareness of building in an environmental friendly and economical way constantly enhanced the requirements towards public baths. In order to support the technical understanding of such high demanding constructions types, the current building physical aspects of indoor swimming baths will be discussed within the next chapter.

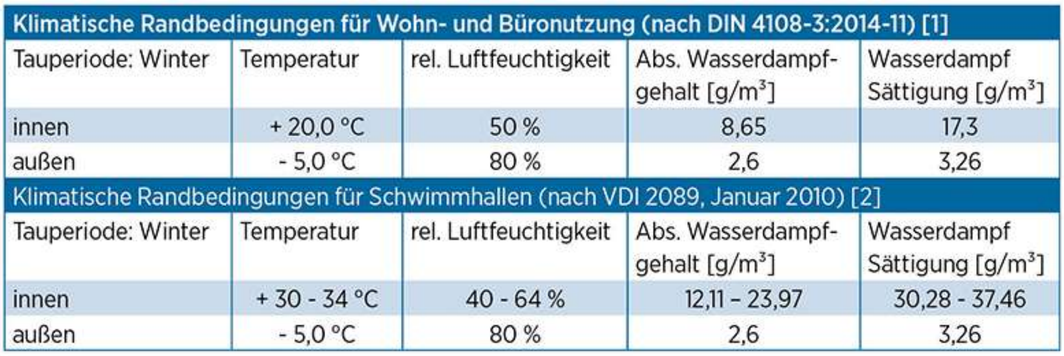
4 ASPECTS OF BUILDING PHYSICS IN INDOOR SWIMMING HALLS

4.1 Climate

The climatic conditions within swimming baths constitute the fundamental aspect of building physical evaluation. The indoor climate within such buildings significantly deviates from the normative circumstances of residential & office buildings. Increased indoor temperature and humidity in swimming halls represent a particular challenge within this context. (Duzia 2011)

The following illustration shall help gain a better understanding of the climatic differences between swimming halls and residential buildings. Table 1 displays a simplified comparison of the climatic boundary conditions of residential & office buildings to provide moisture protection in winter according to DIN 41083 and the actual climatic conditions in swimming halls according to VDI (society of German engineers) 2089. (Duzia and Mucha 2016)

Table 1: Comparison of the climatic boundary conditions of residential & office buildings and swimming halls according to DIN 41083 and VDI 2089 (source: Duzia and Mucha, 2016)



Klimatische Randbedingungen für Wohn- und Büronutzung (nach DIN 4108-3:2014-11) [1]				
Tauperiode: Winter	Temperatur	rel. Luftfeuchtigkeit	Abs. Wasserdampfgehalt [g/m^3]	Wasserdampf Sättigung [g/m^3]
innen	+ 20,0 °C	50 %	8,65	17,3
außen	- 5,0 °C	80 %	2,6	3,26
Klimatische Randbedingungen für Schwimmhallen (nach VDI 2089, Januar 2010) [2]				
Tauperiode: Winter	Temperatur	rel. Luftfeuchtigkeit	Abs. Wasserdampfgehalt [g/m^3]	Wasserdampf Sättigung [g/m^3]
innen	+ 30 - 34 °C	40 - 64 %	12,11 - 23,97	30,28 - 37,46
außen	- 5,0 °C	80 %	2,6	3,26

It is however important to keep in mind that within swimming baths, the climatic conditions may vary according to the individual usage of the spaces. (Duzia and Mucha 2016)

In the following, several design parameters concerning the climate of swimming baths are listed according to Robatherm (n.d.):

Temperature outside

Winter: -16 °C to -12 °C

Summer: 28 °C to 35 °C

Temperature Inside

Room temperature	min	max
Swimming hall:	30 °C	34 °C
Dressing areas.	22 °C	28 °C
Shower- & sanitary areas	26 °C	34 °C
Swimming supervisor-/ staff- & sanitary rooms:	22 °C	26 °C
Entrance Hall:	≥ 20 °C	
Secondary rooms:	≥ 20 °C	
Staircases:	≥ 18 °C	

Room temperature in wet areas (unclothed bather) around 2 to 4 K above the pool water temperature (max. 34 °C)

Water temperature		
Non-swimmer-, swimmer-, diving- & wave pools:	28 °C	
Recreational pools:	28 °C	32 °C
Paddling- & motion pool:	32 °C	
Therapy pools & hot tubs:	36 °C	
Warm pools:	35 °C	
Cold pools:	15 °C	

Room air humidity:

Swimming hall interior: 40 % to 64 % rel. hum.

Volume flow:

Minimum amount of outside air:	30 % to 100 %
Supply air:	Same as max. outdoor air volume flow according to VDI 2089
Entrance hall:	5 m^3.hm^{-2}
Single- dressing room:	15 m^3.hm^{-2}
Community- dressing room:	20 m^3.hm^{-2}
Supervisor rooms:	25 m^3.hm^{-2}
First- aird rooms:	25 m^3.hm^{-2}
Toilets (per seat):	100 m^3.h^{-1}
Shower rooms (per shower):	220 m^3.h^{-1}

These values present designing parameters and can differ in accordance to the contractor or operator. (Robatherm n.d)

Maintaining the climatic conditions within swimming halls constitutes a challenging task. Due to the evaporation of high amounts of water from the pools, the humidity within the indoor air increases significantly. This process can further negatively affect the comfort of the indoor climate as well as the building structure, which will be discussed more detailed within the following chapters. Additionally, a deterioration of the atmospheric condition is induced due to the large quantity of dispensed chlorine into the indoor air. Increased evaporation of water in swimming halls additionally causes an energy- and water loss, which must further be compensated by supplying the pool with new water. However, if the large amount of humidity in swimming halls is responded by increased dehumidification, the evaporation of the water repeatedly starts to enhance due to the affiliated rise of the difference between the water vapour partial pressures. (Garzia 2016; Robatherm n.d)

Overall, the climate within swimming halls is very sensitive and therefore needs to be well considered. By complying with the recommended air and water temperatures through a well-planned building structure and ventilation- & water treatment system, the condition of the construction, as well as the well-being of the bathers can be maintained. Due to the strong correlation between the indoor climate in swimming halls and the well-being of the bathers, thermal comfort will be discussed within the next chapter

4.2 Thermal Comfort

One of the main impacts of a person`s thermal well-being in swimming baths is the temperature of the surrounding room surfaces such as walls, floors and ceilings. This is led back to the constant radiation exchange between the people and the building surface. Furthermore, an increased sensibility towards ambient temperature differences is perceived due to lack of clothing of the bathers. In this regard, the ambient air temperature and the relative humidity play an important role for a comfortable swimming environment. According to the Sopra- planning guidelines, the following climatic conditions are perceived as comfortable for the human being:

Water temperature: 28 °C

Room temperature: 30 °C

Relative humidity: 60%

(Duzia 2011; Passipedia 2014; Robatherm n.d; Sopra Pool & Wellness n.d.)

According to the KOK- guidelines (coordination circle baths), floors of swimming halls may not surpass 26 °C within the barefoot areas.

Wet skin surface increases the amount of thermal energy which is withdrawn from the body due to evaporation of the adhering water film. In order to limit heat flow, the room temperature should be kept around 2-4 °K above the pool temperature. (Robatherm n.d)

One of the main aspects which negatively affect thermal comfort are high air velocities or radiation asymmetries. These radiation asymmetries depict a structural situation in which surfaces which deviate from each other of more than 3 °K adjoin or lie opposite of each other. Specifically glass facades, which consist of colder surface temperatures than most other materials, can create uncomfortableness. The high temperature difference of these facades towards the floors create a colder sensation of the environment. Additionally, air streams arising along the glass walls can be disturbing for the bathers. These streams result from the room temperature cooling down at the glass surface and consequently dropping towards the floor. In this case, displacement ventilation at the facades along the floor area can help keep the glass walls free of condensate. (Duzia 2011)

In order to evaluate the people`s thermal comfort, a certain calculation method, the predicted mean vote- index (PMV) according to the DIN EN ISO 7730 can be used. The evaluation of the thermal comfort is based on the factors operative temperature, room air humidity, clothing, activity level and air velocity. In the following, a calculation model of an adapted index based on the ASHRAE2005 and the Gagge1986 for an undressed, wet bather is presented:

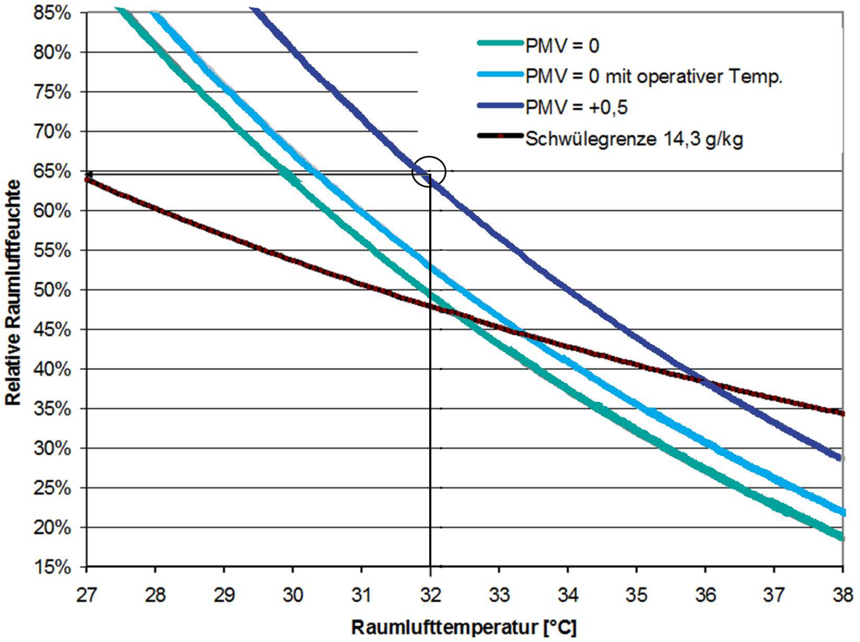


Figure 4: PMV- index for an undressed, wet person based on the ASHRAE2005 and Gagge1986 (source: (Passipedia, 2014)

PMV grading scale according to DIN EN ISO 7730:
0 = neutral; +1 = slightly warm; +2 = warm; 3 = hot; -1 = slightly cool; -2 = cool; -3 = cold

Figure 4 shows the PMV line for three different cases:

PMV = 0:

This line designates the course of a neutral/ pleasant state of comfort of the bathers.

PMV = 0 with operative temperature:

The operative temperature designates the mean value of air temperature and surface temperature of the surrounding building components. As previously mentioned, ambient surface temperatures influence the thermal comfort of a human being. Consequently, cool exterior walls also result in a slightly cooler sensation, which further increases the amount of tolerable perceived indoor air humidity. The “PMV = 0 with operative temperature” therefore incorporates the shifted perception of the surroundings.

PMV = + 0.5

The PMV = + 0.5 designates the values for a slightly warmer tolerable sensation.

(Passipedia 2014)

Overall Figure 4 shows that an increase in room air temperature causes a decrease in humidity which is perceived as comfortable. Therefore, higher permissible room temperatures allow a lower tolerable humidity for the human body sensation. Ideally, a balance between the tolerated relative humidity and room temperature should be maintained. An average indoor temperature of 32 °C, as stated in the Robatherm design parameters on page 17, therefore tolerates a relative humidity of almost 65 %, when a PMV of +0.5 is accepted. A relative humidity of 65% also closely complies with the Robatherm design parameters which states a relative humidity of up to 64%. Nevertheless, it is notable that even though the thermal comfort is an important part of designing swimming halls, the tolerated relative humidity within the indoor climate is mainly based on preventing structural damage of the building.

Before getting more detailed into the various sectors which are responsible for keeping the indoor climate of swimming halls intact, the overall energy consumption of such buildings needs to be examined. The correlation between the specific climate of indoor swimming halls and the great amount of energy consumption of these constructions are decisive within this context and will therefore be discussed within the following chapter.

4.3 Energy Demand

The specific climatic conditions of swimming halls lead to a much higher heating demand than standard residential- & office buildings. Furthermore, due to the energy intensive water technology and the ventilation heat losses, swimming halls present a challenging case concerning the aspects of energy efficiency and environmental sustainability of constructions. (Garzia 2016; Passipedia 2014)

The overall primary energy balance of swimming halls consists of the heating demands of the air, the water and the power demands of the building- & swimming bath technology. In the following graph, an exemplary final energy consumption of a swimming bath is visualized. The graph displays the heating- and electricity demand categorized into individual sections of utilization.

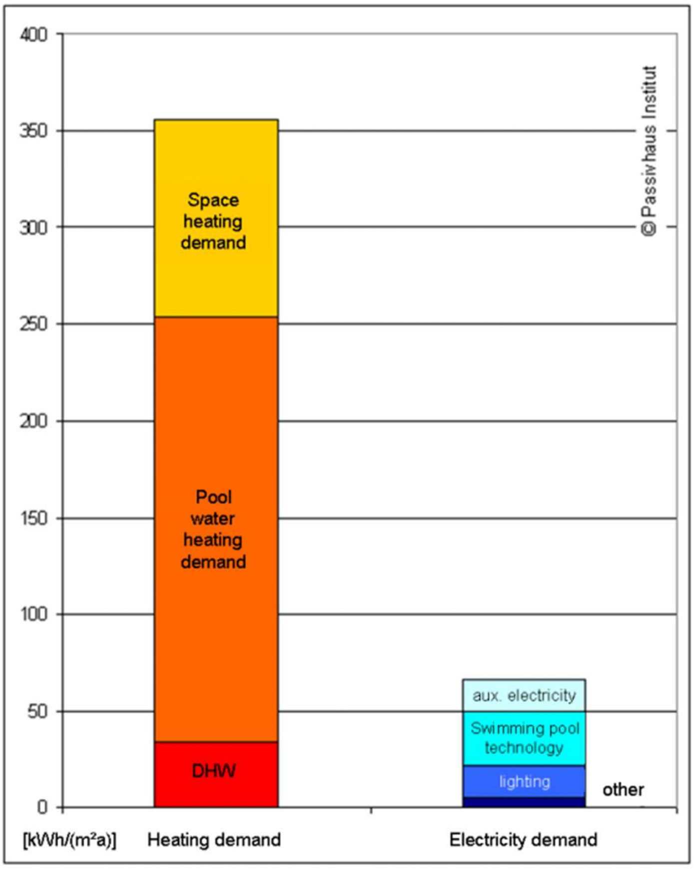


Figure 5: Exemplary final energy consumption of an energy optimized swimming bath in kWh per energy reference area and year (source: (Passipedia, 2014)

In Figure 5 it is visible, that the biggest share of the energy balance consists of the heating demand of the water. This is mainly led back to its evaporation enthalpy. As mentioned in the previous chapter, the continuous evaporation of the water in swimming halls withdraws great amounts of energy from the pool which further must be compensated by constant reheating. The heating demand for water can be influenced by the humidity of the air. An increase in humidity leads to reduced evaporation, since the partial pressure of water vapour approaches the vapour pressure at the fluid. Therefore, less water needs to be heated, as well as fresh water refilled. It is however important to keep the humidity within an acceptable range. Too high humidity can lead to construction damage as well as a decrease in indoor air quality. By covering the pool during closing hours to reduce evaporation, the heating demand of the pool water can be decreased. Additionally, utilizing efficient heat recovery installations and filter systems for water reutilization help increase energy savings. (Garzia 2016; Passipedia 2014; Robatherm n.d; Sopra Pool & Wellness n.d.)

Of all the different zones within an indoor swimming bath, the swimming hall requires the greatest heating demand for air. The reason for this is that the swimming hall contains the highest indoor temperature with approximately 32°C. The specifically warm indoor air temperature tolerates a higher amount of humidity within the air and therefore requires an increased air exchange rate for dehumidification. (Passipedia 2014)

The continuous treatment of great amounts of air and water require a large quantity of energy. Optimizing the interaction of these two thermal masses is the key of creating a well working system. Both entities need to be kept at a certain temperature, but at the same time continuous circulation is required in order to ensure exchange. Details regarding these processes will be covered within the following chapters, ventilation- & water technology. (Garzia 2016)

Another mentionable aspect of the energy consumption in swimming baths is the following: Besides the basic swimming pools, many swimming baths are equipped with additional recreational facilities such as water slides, wave pools, saunas and so on. These installations additionally strain the energy demand extensively. By optimizing the pumps, as well as timed regulation can help reduce the energy consumptions. Saunas should be well insulated. Additionally, it is primary energetically more advantageous to prefer gas-operated saunas over power heated ones. Also, individual ventilation devices including heat recovery systems help decrease the usage of energy in such facilities. (Passipedia 2014)

Overall, as also visible in Figure 5 on page 22, the heating demand is typically much greater than the electricity demand for building- & swimming bath technology. It is however notable that when calculating the energy balance, it is vital to incorporate the form of energy needed. The production of electricity is much more complex than the production of heat. Consequently, in most cases, the heating demand can be covered by a much lower primary energy demand compared to the power demand. (Passipedia 2014)

Moreover, another major point which must be mentioned regarding the general energy management is the investment in modern, environmental friendly technology and renewable energy sources such as for example photovoltaic systems, district heating, solar collectors, geothermal energy, biomass boilers and heat pumps. Especially heat pumps are particularly useful for swimming baths due to their capacity of regaining sensible and latent heat. Based on the high amount of water and increased room temperature, swimming halls offer a great amount of heat sources, which can be reused for other appliances. (Garzia 2016)

A well-constructed swimming hall with the right technology represents the foundation of energy efficient and environmental sustainable swimming baths. By reducing the ventilation- water- & transmission heat losses, the energy demand can be decreased. The following chapters provide a more detailed insight on swimming bath ventilation- & water technology. (Passipedia 2014)

4.4 Ventilation Technology

Due to the challenging climatic conditions of swimming halls in terms of temperature, humidity and volume flow, a well working ventilation system is indispensable. An optimized ventilation cycle not only provides a long lasting and damage free building structure, it further creates a pleasant interior climate.

In order to meet the requirements of such high demanding climatic atmospheres, modern ventilation technologies with demand- driven, multifunctional, efficient applications are required. The regulation of air temperature, humidity as well as heat recovery in combination with the removal of harmful substances constitute such applications.

Planning an air distribution system is influenced by the building`s floor plan, as well as the space arrangement. An optimized ventilation system includes a well-considered arrangement of installation locations. Rising the length of air conducts leads to augmented heat loss. Therefore, the routing of the conducts needs to be kept as short as possible. Furthermore, the conduct arrangement, as well as its insulation, needs to be planned accordingly to the ambient room temperature to provide energy loss. Air conducts must not be installed between suspended ceilings due to the risk of corrosion. Diffusers should be controllable with flaps to withstand pressure in case of fluctuating volume flow. Low and uniform pressure drops within duct openings of the same network provide low volume flow and even exhaust. Additionally, a well working perfusion of the swimming hall can be achieved by installing the diffusers in the middle of the ceiling and the exhaust air suction circumferential near the ground. This way the carbon dioxide, which is heavier than oxygen and therefore closer to the ground level, can be lead away. Furthermore, the correct evaluation of operational hours, locational weather data, targeted humidity, as well as the respective ventilation settings are essential for an optimized air conditioning system.

(Passipedia 2014; Robatherm n.d)

Due to the warm and humid indoor climate in indoor swimming halls, different energy streams arise compared to regular room conditions. A light negative pressure within wet zones should be planned to create a draft from the dry area towards the wet area. This way, the moisture stays within the wet zones and therefore prevents the adjacent building materials of damage due to humidity. In case of strong temperature deviations within different zones, thermal decoupling by insulation of the partition walls or separate ventilation systems are required. In this way transverse flow, which might lead to unintentional temperature distribution, as well as increased transmission- & ventilation heat loss, can be prevented. (Passipedia 2014; Robatherm n.d)

While transmission heat losses display the greatest influence on the energy balance within residential-& office buildings, ventilation heat losses are paramount in indoor swimming baths. These losses are caused by the additional effort for heating up the supplied fresh outside air which serves as dehumidification of the indoor climate. Thus, the accepted amount of humidity within a swimming hall is an indicator for the provided, heated up fresh air and therefore increases the heating expenses. (Passipedia 2014)

One fundamental aspect of reducing such heating expenses is the reutilization of air. For example, in case of odourless air within the entrance hall, the air can be reused for the ventilation of adjacent rooms. Furthermore, it is feasible to use partial flow of the exhaust air of the swimming hall for supply air of shower areas. Moreover, high temperatures and increased amount of humidity within exhaust air streams can be very useful in terms of heat recovery. (Robatherm n.d)

Heat recovery is an essential part of an optimized ventilation system and highly influences the energy balance. By utilizing highly effective heat exchangers, ventilation heat losses can be decreased to a great extent. Heat pumps for example, as mentioned before, help regain sensible, as well as latent heat, which can further be utilized for heating up air and water. (Passipedia 2014)

However, even the most modern air ventilation technology can only work properly if steady and reliable function can be provided. Therefore, constant device maintenance is required. In this regard, it is essential that the sensors provide accurate measurements for them to react to the accurate indoor climate. Consequently, regular device calibration and manual measurement verification need to be conducted. (Robatherm n.d)

4.5 Water Technology

Besides the treatment of air, water technology plays an important part in swimming hall operation as well. The reutilization of worn-out water constitutes a major aspect of energy consumption within these constructions. Furthermore, hygienic provisions, such as stated in the DIN 19643, as well as the drinking- & bath water ordinance, need to be considered to inhibit impairment of the human health due to pathogens. In order to provide clean and sterile swimming water, continuous chemical and physical processing needs to be implemented. With the help of a well- structured circulatory system, the contaminated water is transported through a pipe system to the processing facility, where the water goes through various cleaning stages, and is then led back to the pool through an hydraulic system. (Delfin Wellness n.d; Schwimmbad + Sauna n.d)

At the start of this circulatory system, the water at the surface, which contains approximately 80% of the contaminations, is captured by gutters on the margin of the pools and further transported to the water reservoirs. The water reservoir serves as an intermediate storage tank. Additionally, fresh water is added by the water pipeline. Subsequently, the liquid is transported by a water pump towards the filter unit. By the addition of flocking agents, bigger particles of the contaminations are formed in order to be held back by the filter system. Multi- layered filters for example contain one layer of sand and one layer of activated carbon or a similar material. These kinds of filters not only withhold pollutant particles, but aromatic substances and flavours as well. By backwashing the filter, accumulated dirt is led to the sewer and replaced by fresh water. Thereupon, the cleaned water is heated up to bathing temperature, for instance with a heat exchanger. The heat exchanger increases the temperature of the filtered water by transmitting the warm water from the central heating system. The last step of the water cycle contains the pH-correction, as well as the disinfection, before it is led back into the pool through an appropriate hydraulic system. (Eisele n.d; Schwimmbad + Sauna n.d)

The heart of the water treatment cycle lies in the technology room, where the necessary equipment, such as the filter, the circulating pump, the heat exchanger, the disinfection system and air conditioning installations are stored. The water treatment technology should be located as close as possible to the pool to prevent energy loss. Additionally, moisture-, frost- and noise protection should be given. Furthermore, the filter room must be ventilated in order to provide condensate and corrosion. (Sopra Pool & Wellness n.d.)

The foundation of an energy efficient water technology system is the application of a highly efficient technology in combination with a well thought out regulatory strategy. This way, the auxiliary electricity can be minimized. In this context, circulating pumps with variable speed and high efficiency should be implemented. Installing pumps with frequency converters, connected with an optimized control technology, can lead to power savings of 15-20 %. Furthermore, a short piping system with low pressure drops and the right area of application are essential for energy reduction. In many cases, water treatment pumps are forced to cover two different operating points, such as the pool water circulation and the filter backwash, at the same time. This might further lead to poor efficiency of the pumps. In this case, the operation of separate pumps for the respective area of applications might be more advantageous in regard to energy savings. (Garzia 2016; Passipedia 2014)

Moreover, a regular maintenance of the water technology equipment is decisive to provide a well-functioning water preparation cycle. The storage tank, as well as the filter system need to be cleaned regularly to meet hygienic requirements. Modern filters often include an inspection glass which helps evaluate the clearness of the backwashed water. This way, redundant water- and energy waste can be prevented. Further, high- quality measurement- and control technology, as well as automatic dosing systems for parameters such as pH- value, chlorine and redox potential help precisely adjust the bathing water without redundant consumption. (Schwimmbad + Sauna n.d)

Finally, in order to maintain a well-functioning energy circulation with as little energy losses as possible, the heat leakage through the building surface needs to be kept as low as possible as well. Therefore, it is essential to create a well- constructed building envelope, which will be discussed within the following chapter.

4.6 Construction

Compared to conventional building constructions, indoor baths consist of a heat transferring surface which displays heat flow from inside to outside at each time of the year. The reason for this steady unilateral heat flow is the constant room temperature of swimming halls of 30 to 34°C which cause heat losses even in the summer period. In order to keep the energy leakage as low as possible, well-constructed exterior walls and a compact building envelope are required to keep the heat transferring surface to a minimum.

One of the main characteristics of such a well-constructed building envelope is its ability of tolerating a certain amount of harmful condensed water within the structure to prevent damage. Constant moisture within the building construction might destruct the structure due to corrosion, frost damages as well as fungal decay. Furthermore, humidity protection is well connected with thermal insulation since its functioning requires a certain drought. In order to minimize heat loss, as well as inhibit construction damage, the dew point must not at any point permanently be falling below. Therefore it is essential to keep the temperature of the indoor wall surfaces as high as possible to prevent harmful condensate. The following graph visualizes the various areas of risks of a 30°C room of a swimming hall in respect to the surface temperature (Oberflächentemperatur) and the current relative humidity (relative Luftfeuchtigkeit).

(Duzia 2011; Duzia and Mucha 2016)

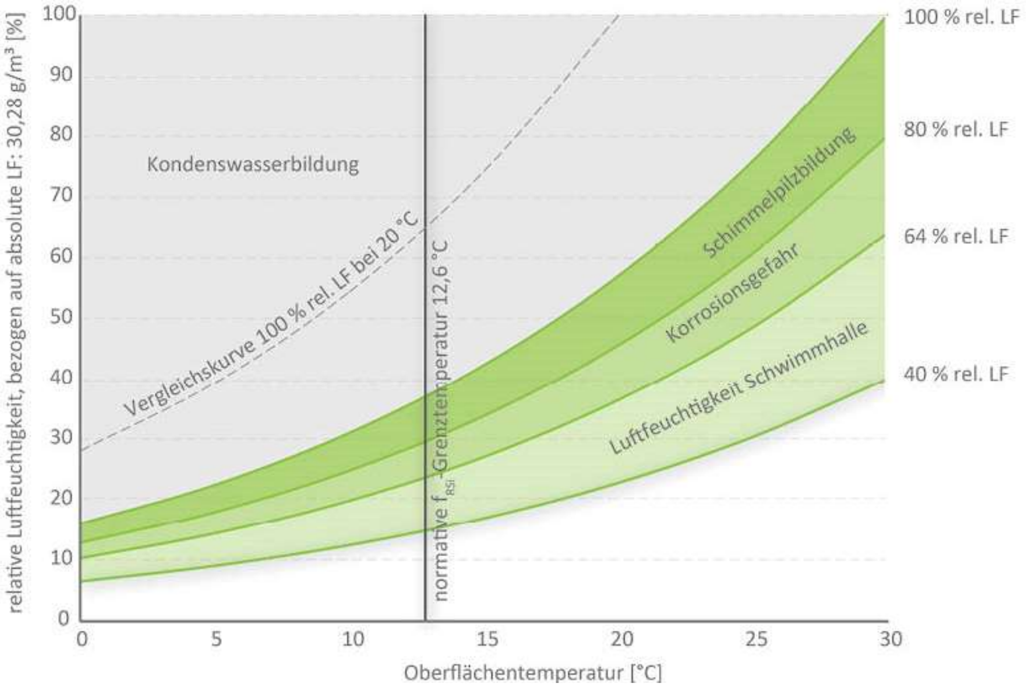


Figure 6: Areas of condensation in swimming halls referring to a room air temperature of 30°C (source: Duzia and Mucha, 2016)

As visible in Figure 6, mould growth and corrosion can occur even before the room humidity has condensed on the wall surface. Therefore, these areas need to be considered as well, when planning the wall construction and the associated surface temperatures.

The requirements towards insulation and moisture protection of swimming hall building constructions deviate from the ones of regular residential- & office buildings due to the different climatic conditions. Under the circumstances of deviations from the typical atmospheric conditions, the standards towards insulation according to the DIN4108-2 are likely not suitable. In this case, the minimum requirements of the room sided surface temperatures of swimming halls need to be determined for each individual case. Therefore, building physical verifications are created on the basis of the actual indoor climate, as well as adapted to the user. (Duzia 2011; Duzia and Mucha 2016)

Due to the necessity of creating wall structures which are adjusted accordingly to the given room conditions, a differentiation of walls to outside air, walls to soil and partition walls towards heated and unheated rooms are essential. Depending on the atmospheric circumstances, the appropriate building material and the necessary thermal insulation need to be determined individually. In this context, the Energy Saving Ordinance (EnEV), as well as the DIN 4108 (part 2 & 3) present two essential planning directives. Within the Energy Saving Ordinance all building components towards outside air with a temperature difference of 4 K (°C) to the inside are defined regarding thermal insulation and the corresponding recommended U- values for each construction are evaluated. As mentioned before, due to the exceptional high amount of humidity in swimming halls, the requirements towards moisture protection, as stated in DIN 4108, need to be determined by specific thermal bridge calculations for each individual case. In the following, three common constructions of different local conditions in swimming halls are presented. The displayed constructions comply with the previously mentioned planning directives. (ISO-PLUS-SYSTEM 2010)

Wall towards outside air (U-value ~ 0.25 W.m^{-2}.K^{-1})

Massive wall with 30 cm light brick

10-16 cm outside insulation

3-5 cm inside insulation with vapour barrier to keep the construction continuously dry

High quality indoor plaster which enhances the room acoustics in a way that no additional acoustical actions need to be taken

If no outside insulation is intended, the inside insulation can be increased instead.

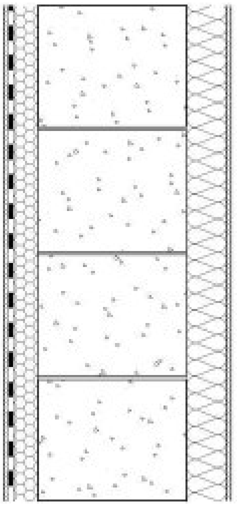


Figure 7: Wall towards outside air (source: ISO-PLUS-SYSTEM, 2010)

Inside wall towards heated & unheated rooms (U-value ~ 0.3- 0.5 $W.m^{-2}.K^{-1}$)

Heated- (offices, utility rooms etc.) and unheated rooms (storage rooms, hallways, garages etc.) need to be separated from the swimming hall climate.

Massive walls with inside insulation and vapour barrier. Depending on the used stone, the thickness lies between 3-5 cm towards heated rooms and 5-10 cm towards unheated rooms.

This construction presents a hermetically sealed envelope with warm surface temperatures.

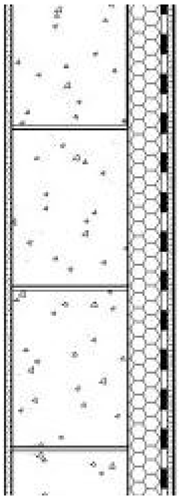


Figure 8: Inside wall towards heated & unheated rooms (source: ISO-PLUS-SYSTEM, 2010)

Wall towards soil (U-value ~ 0.25 $W.m^{-2}.K^{-1}$)

Outside sealing with perimeter insulation (~ 12 cm) on a concrete wall.

Inside supplementation with insulation so that the U- value lies between 0.25 and 0.3 $W.m^{-2}.K^{-1}$.

(ISO-PLUS-SYSTEM 2010)

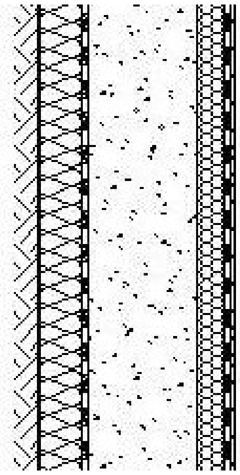


Figure 9: Wall towards soil (source: ISO-PLUS-SYSTEM, 2010)

Inside insulation helps improve the room sided surface temperature of walls. As previously mentioned, keeping the inside surface temperature as high as possible is necessary to minimize heat loss, as well as inhibit construction damage due to water condensation. Moreover, attaching insulation on the inside plays a specific role in the renovation of existing buildings. In order to achieve energy savings without having to create complex façade constructions, inside measurements prove to be the superior solution.

Other than the structure of the construction, the selection of the insulation material constitutes a decisive characteristic of a well-built building envelope as well. In the following, the key requirements of creating a long-lasting and well-functioning inside insulation for humid environments, such as swimming halls, are listed:

- No capillary activity
- Vapour proof
- Dimensionally stable
- Resistant against chemicals & detergents
- Save against vandalism

In most cases, the occurrence of moisture penetration is not notable right away. The reason for this is that various insulation materials consist of a pore volume which absorbs humidity without any occurrence of damage. This can consequently, among other damages, cause an increase of loads acting upon the construction and further lead to static problems. Vapor diffusion tight insulation materials, such as for example foam glass, provide a solution for reducing such risks. Foam glass combines insulation and vapour barrier. Because of its closed cell structure, moisture damage in the construction through condensed water is prevented due to the non-occurrence of water vapour diffusion flux within the material. Therefore, insulations such as foam glass provide advantages in cases of increased indoor air humidity.

According to the Glaser-method following the DIN 4108-3, only 1.0 $kg.m^{-3}$ of water within the construction are permitted. In case of condensed water within a layer which is not able to absorb water through capillary activity, only 0.5 $kg.m^{-2}$ are accepted. The amount of tolerable water within a construction requires the ability of exiting it within the given vaporization period. A drying reserve of additional 250 $g.m^{-2}$ should be incorporated in order to provide precautionary wood preservation.

In case of vapor proof inside insulation, the infiltration of water into the construction from the outside especially presents a risk of damage due to the disability of drying on the inside. If water is captivated in the wall structure, the moisture horizon shifts upwards due to the capillary properties of the mineral building materials. Consequently, in case of implementing vapour barriers in form of foils, the areas along the building component connections, installations and penetration areas, such as cabling and overlapping of the foils, are prone to error. Therefore, in order to prevent penetration of water into the construction, it is essential for massive outside walls to be equipped with a driving rain proof facade.

The main source of error within roof structures are faulty roof seals, inadequate laying of the insulation layers, as well as destruction of the vapour barrier through installations etc.

Due to the high water vapor diffusion resistance (s_d-value) of vapour barriers and roof sealings, the drying capacity of the construction is prone to be hindered, even though the standards state a decline of the s_d- value towards the outside. Although this decline of water vapor diffusion resistance facilitates the moisture of leaving the construction due to uneven drying capacity (higher s_d-value towards the inside), it is more difficult for the moisture within the room facing layers to exit the structure. The moisture which accumulates on the inner sides needs to pass all remaining layers before it can exit the construction. Consequently, an accumulation of the moisture is built within the inner levels. Therefore, a moisture-saturated insulation layer and a cumulative built up of moisture are consequential if sufficient pore volume to capture the water is available.

Penetrated water in form of liquid water from the outside or in form of water vapor generally cause malfunction of the insulation and therefore increase the heating demand within a building. Furthermore, as mentioned before, if the amount of water within the construction surpasses the maximum permissible limit according to the DIN, damaging consequences such as corrosion and wood rot can be expected. Hence, it is essential to pay special attention to the choice of suitable and coordinated layer structure, as well as appropriate insulation material to keep the structure stable.

(Duzia and Mucha 2016)

Apart from the previously discussed wall structures, glazing in form of windows display an important component of swimming hall constructions as well. Besides offering an outside view, windows are essentially important for providing daylight and therefore add to the people´s well-being. Additionally, the implementation of glass surfaces helps reduce the lighting demand by increasing the amount of artificial lighting needed. By maximising the light transmission of the glass, the amount of captured light can be optimized. Furthermore, due to the admitted solar radiation, windows contribute to the heating of the building as well. Although solar radiation adds to the energy gain, heat losses through windows need to be considered as well. In order to keep solar gains as great as possible and heating losses low, windows with high solar energy transmittance (g-value) and a small heat transfer coefficient (U- value) need to be integrated. However, since even the best window glazing produces much greater heat losses than insulated facades, the window surface area needs to be considered as well. According to the planning guidelines for swimming baths of SOPRA, the amount of glazing must not exceed 50%. Windows should be positioned as high as possible to maximise daylight utilization. Additionally, the orientation of the glass surfaces need to be considered. In case of overheating during the summer period, sun protection installations such as blinds and awnings constitute a good solution in the context of energy management. The formation of condensate on the glazing surface during the colder seasons can be inhibited by using thermally insulated glass with a U-value between 0.9 and 1.2 in combination with an optimally insulated frame construction. Additionally a constant stream of air should be conducted onto the glass surfaces in order to prevent cold air streams as well as condensate. (Duzia 2011; Paschotta 2017; Passipedia 2014; Sonne Licht Schatten 2017; Sopra Pool & Wellness n.d.)

Apart from the walls and ceiling of a swimming hall, the foundation of the construction needs to be well considered as well. Due to great amounts of water which must be carried by the construction, the foundation of swimming halls needs to withstand high demands. The weight of the pools and the water filling require a concrete floor plate which needs to be able to carry a weight of ~1.5 $t.m^{-2}$. The size and the form of the pool greatly impact the investment- and operating costs and therefore need to be considered thoroughly. The following values serve as indicators for the determination of pool size according to Duzia and Mucha 2016:

Pool width:

For swimming, a pool width of 2.75 m is required for one person. At a pool width of 3.5- 4 m, two people can easily swim next to each other.

Pool length:

The initial stroke of a grown-up person needs 3.5 m and 1-2 m for every subsequent stroke, depending on its intensity. Consequently, a pool length of 8 m is adequate for approximately 4 strokes.

Pool form:

The most frequent used form for pools constitutes the rectangle form due to its economic advantages. Not only does it provide the highest utilizable value, it also features the lowest investment- and maintenance costs in comparison to free forms.

Pool depth:

According to practical experience, a water depth of 1.35 m has shown to be sufficient for swimming as well as an optimal depth balancing costs and usage. By increasing the depth, the construction- and maintenance costs are being elevated without any additional benefits. In public swimming baths, the threshold between non-swimmer areas and swimmer areas is determined as 1.35 m. The following figure displays an overview of the recommended pool depths.

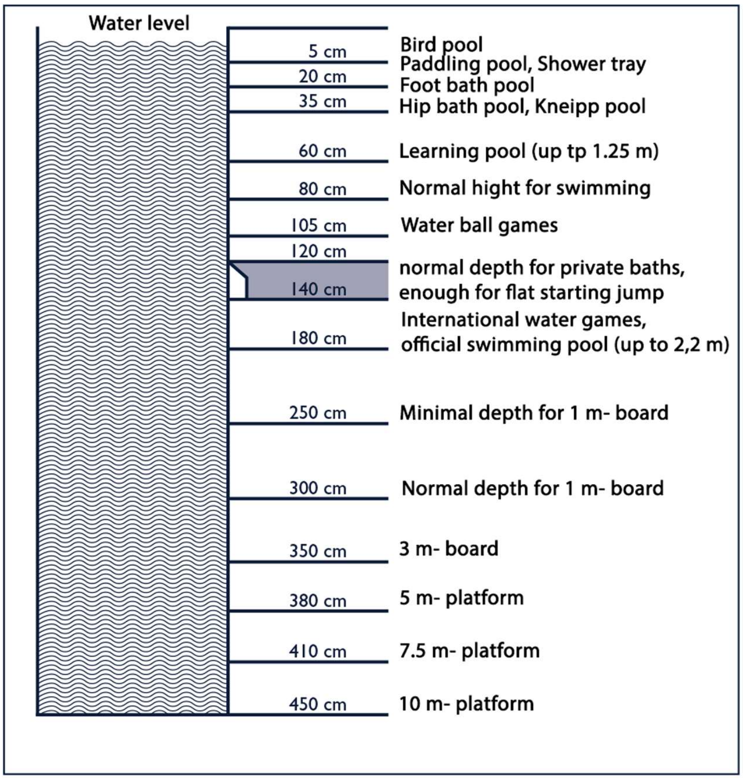


Figure 10: Overview of the recommended pool depths (source: (Sopra Pool & Wellness, n.d.)

Planning a swimming hall properly is always influenced by the specific requirements that require to be met, as well as the given climatic conditions. Nevertheless, regardless of the specific constructions used within swimming halls, they all have the following in common: Due to the increased indoor temperatures and humidity, swimming halls require very resilient materials.

These materials need to be humidity-resistant, hygienic as well as easy to clean. Additionally, the durability, as well as the freedom of maintenance of the materials must be considered.

(Duzia and Mucha 2016; Sopra Pool & Wellness n.d.)

4.7 Retrofitting

Overall, the ventilation technology, lighting, space heating as well as the water treatment in indoor swimming halls not only cause high operating costs, but also seem to be obsolete in many cases. Poor building envelopes, old pumping systems, inefficient ventilation installations, as well as aged lighting and the lack of efficient heat recovery systems contribute to very high operating costs. (Garzia 2016)

Consequently, energetic retrofitting is essential to improve the energy efficiency and environmental sustainability of deprecated swimming hall constructions.

When retrofitting obsolete constructions, the current condition regarding energy- and water consumption of all energy sources need to be measured with appropriate sensors and counters. Subsequently, the measures which must be implemented to retrofit the construction, are specified. This way, the specific areas of intervention can be determined and arranged according to their priorities. In the following, the measures which need to be conducted to increase the energy efficiency of the construction need to be specified. (Garzia 2016)

In the following, a short overview of possible measures for the refurbishment of sports facilities according to Garcia (2017), are listed. The subsequent measures also apply for the renovation of swimming halls.

1. **Short-term measures**

   - Flow regulators
   - Water saving cisterns and valves

2. **Medium- term measures**

  - Improvement of the distribution devices:
    - Pumps renewal
    - Insolation of the distribution network

  - Lighting:
    - LED- lamps
    - Installation of motion detectors
    - User- adapted lighting control over a time switch
    - Daylight controlled luminaries

3. **Long- term or structural measures**

  - Insulation:
    - Building envelope (roof surface & facade)
    - Inside- insulation
  - Window/ door replacement
  - Installation of efficient power supply systems:
    - Micro- cogeneration plants
    - Condensing boilers with electronically controlled heating circuit pumps
    - Solar hot water systems
    - Photovoltaic systems
    - Other renewable energy sources

(Garzia 2017)

Furthermore, as mentioned in the previous chapters, specifically in swimming halls, heat recovery in form of heat exchangers or heat pumps are particularly useful and should therefore be integrated within the procedure of energetic retrofitting. Additionally, modernising the water filter installations and thoughtful handling with chemicals are an essential aspect of modernizing indoor swimming halls. (Garzia 2016)

Overall, it is quite challenging to identify a detailed list of measured values for evaluation of the success of retrofit measures. The implemented measures need to be weighed in regard to their energy- and operating cost savings in order to create a coherent overall concept. (Passipedia 2014)

Although outdated swimming halls create particularly high costs due to their high energy and water demand, a great amount of savings potential is existent. In order to improve the energy efficiency and environmental sustainability of Vienna`s outdated swimming halls, a variety of these constructions have undergone technical renovations within the previous years. Several of these modernised swimming halls were originally planned by the “bathpope of Vienna”, Friedrich Florian Grünberger. Before discussing the renovation of one of Grünbergers` swimming halls in more detail, the energy saving initiative, which enabled these renovations, as well as the Green Building Program will be discussed in the following chapters.

5 ENERGY SAVING INITIATIVE

As one of the biggest public pool operators in Europe, the city of Vienna is keen on reducing the energy demand of its high energy consuming public swimming pools. Great operating costs, increased energy prices, as well as the international obligations towards climate protection constantly enhance the need of reducing the energy demand.

Within this framework, the municipal authority for bath in Vienna, the MA 44, has proved itself as an environmental role model operation within Europe. Between the year 2000 and 2017, twelve deprecated public swimming halls have been renovated in Vienna with the intention of increasing energy efficiency. Many of these public baths have originally been designed by the architect Friedrich Florian Grünberger, such as the swimming pools in Simmering, Brigittenau, Döbling, Hietzing, Großfeldsiedlung, Donaustadt and Floridsdorf. The renovation of two of these swimming halls turned out so successful, that the MA 44 has received international awards for these projects. With guaranteed energy- & water savings up to almost 60%, the energy-saving-contracting project “swimming hall Brigittenau” has received the “Best European Energy Service Project” 2007 from the European Energy Service Initiative. The “Hallenbad Floridsdorf”, has not only received the Austrian contracting price “Energie-Profi”, but was also awarded the “GreenBuilding Partner Award” by the European Commission in 2008. By reducing the energy savings down to approximately 55% through renovation, the bath has proved worthy of wearing the Green Building Logo, an award which is initiated by the European Green Building- program. (Holler 2005; Magistrat der Stadt Wien 2008)

5.1 Green Building Program

The European Green Building- program is an environmental organization which was funded to reduce the energy consumption in public and private service buildings. This program was initiated by the European Union in 2005 and mainly focuses on improving the energy efficiency and promote holistic renovations of existing buildings. Within this program public and private constructions, which have reached energy savings of at least 25% through renovation, can be submitted. In case of new constructions, a 25% less amount of energy consumption than customary building regulations for new buildings is required. Besides benefitting from higher energy savings and increased building comfort, the Green Building partners also emphasize a pioneering role in energy efficiency and shell therefore set new impulses for further renovations by demonstrating feasibility within this area. (Magistrat der Stadt Wien 2008)

The Green Building program focuses on the renovation of private or public service constructions which have been performed after the year 2000. The participation requires an application to the European commission, as well as a central contact person accountable for the project execution. Furthermore, an energy audit including the energy balance for the last few years needs to be implemented for the nominated project. A plan of measures including the intended remediation possibilities to reach at least 25% of energy savings need to be submitted as well. The analysis of the constructions` energy consumption and the conception of the plan of measures receive organizational and content-related support. In Austria, energy consulting and technical guidelines relating energy management, solar energy, financing etc. are additionally provided for private service constructions. (Austrian Energy Agency 2006)

Overall, renovation is a quite cost intensive project which is often impeded by lack of financial resources. However, modern business models, such as energy saving contracting, enables the implementation and financing of energy consuming and cost intensive constructions without significant self- investment. The MA 44 has worked with this business model within the frame of several public swimming hall renovations of Vienna`s obsolete baths, including the Floridsdorfer indoor bath. With the help of energy saving contracting, the Floridsdorfer indoor bath can now proudly carry the Green Building logo as the first institution in Europe.

5.2 Energy Saving Contracting

Contracting in general is a business model which helps modernize facilities without any additional liability of the internal budget. Within contracting projects, an agreement between a performance provider (contractor) and the object owner/ user (contracting- taker) is made. The contractor is obligated to create a system on his own costs and responsibility, and to administer, operate and maintain it over the contracting period. The contracting- taker on the other hand, is obligated to regular payment, covering current expenses for management and compensation of the adopted risks. During the contracting period, the contracting- taker can transfer all services, responsibilities and risks over a certain period of time over to the contractor. Overall, the contractor is the executing enterprise, whose responsibility includes consultancy, planning, financing and partial maintenance within the contracting period. In general, contracting unites risk shifting, reduction of complexity in business processes, a reduction of capital lock-up and contribution to environmental protection. (Ernst 2010)

Energy saving contracting, is one established form of contracting. This form of contracting, which is also known as performance-contracting, is a contractually agreed model in which energy saving measures and energy management are identified, implemented and pre-financed by a contractor. It is a public private partnership (PPP) in which the contractor`s wage is based on the achieved energy cost savings, and is therefore solely success oriented. (Ernst 2010; Magistrat der Stadt Wien 2008)

The selection of the contractor by public sectors is typically based on negotiation procedures with preceding public tenders. The specification of the assessment criteria and the necessary details for the proposal preparation are being presented within tender documents. (Hermann n.d)

The contractor analyzes the energy situation and further develops measures for increasing the energy efficiency and reducing energy costs. Based on the current energy consumption, which displays the “baseline”, the targeted savings are being guaranteed to the contracting- taker within the energy saving contract. Overall, depending on the contract arrangement, the following services are taken over by the contractor:

- Development and execution of the saving measures
- Warranty for the achievement of the targeted savings
- Operation and maintenance of the facilities
- Pre-financing of the measures
- User instruction

(Ernst 2010)

It is however mentionable that the involvement of an additional consulting firm is highly recommended. Due to the complexity of energy saving contracts, thorough preparation is essential. For this reason, it is advisable to include the assistance of an unbiased consulting firm, which can provide necessary market expertise and offer support regarding the following aspects:

- Preparation of the contractual documentation
- Advice regarding technical and economic goals
- Coordination of the tendering process
- Recommendation for the award
- Project monitoring

(Hermann n.d)

The contract is being entered over a certain period in which the investment is bound to be refinanced over the savings. All expenses which incur by the contractor must be covered by these savings. The contracting-taker pays the actual energy costs to the energy providers, as well as the monthly/yearly contracting rate in the amount of the actual savings to the contractor. The contracting-taker immediately profits from the improved facilities, as well as resource conservation, decrease in energy consumption, environmental relief of pollutants and improved CO2-balance. After the contracting period, the contracting-taker profits from the full savings. Furthermore, it is also possible for the contracting-taker to participate in the savings during the contracting period. In this case, the contract is entered over a longer period in order for the contractor to receive his full pay. If savings are not able to be refinanced over a reasonable period of time, a cost subsidy can be given by the contracting-taker to reach the targeted savings. On the other hand, if the guaranteed savings are to be exceeded, the corresponding amount is to be reimbursed, the payback period shortens, and the contracting- taker gets to profit from the cost savings much sooner. If the guaranteed savings cannot be reached, the contractor is bound to compensate the costs and his fee is cut accordingly. (Energieleben Redaktion 2011; Ernst 2010; Österreichischer Städtebund n.d)

One of the key features of energy contracting is the relation between the investment volume and the potential savings. The payback period of conventional energy saving contracts should lie between 8 and 14 years. These contracting periods generally do not enable refinancing of a full building insulation through energy savings. Comprehensive building renovations are normally only possible with additional building cost subsidies by the contracting-taker. (Hermann n.d)

Energy saving contracting in general is sensible for all constructions in which technical and economical savings are existent. With the help of this contractual model not only energy, but water, operating resources, as well as personnel costs can be decreased. Especially constructions in need of rehabilitation display suitable cases for this model. Leaky windows, inefficient lighting, outdated heating systems, expensive energy sources, and lack of insulation not only cause high energy costs, but also constantly keep rising. Especially in cases in which adequate personnel, time and financial resources are not sufficiently available, energy saving contracting offers a great solution to facilitate necessary renovations. (Ernst 2010)

In the following, a quick overview of the various advantages and disadvantages of energy saving contracting is given to support a better understanding of this contracting model. The following information is based on a master thesis on energy saving contracting by Ernst (2010) and an internet document from the Berliner Energieagentur GmbH by Hermann (n.d.).

Common advantages

- Environmental relief – reduction of CO2, fossil fuel consumption and water
- Positive advertising (eco-labelling)
- Same motivation – optimization of investment costs & maximum savings

Advantages contractor

- Total profitability – appropriate risk margin, optimally calculated risk, low maintenance required
- Employment creation
- Supplementary contract – easier to hire existing contractor in case of additional energy saving potential recognition
- Inclusion of additional refurbishing orders – outside of the energy saving contract
- Long contracting period
- Contractor as full-service provider – increases employment and earnings

Advantages contracting- taker

- Structural improvement without self-investment
- Reduction of maintenance costs
- Value enhancement of the construction
- Increased user comfort
- Financial profits after payback period – often earlier due to rising energy prices (increased savings)

- Installing high quality products with low maintenance – keeps maintenance & replacement costs for contractor low as well (during contracting period)
- Economic success – installation of high quality products without self- investment
- Technical support by contracting partners
- Maintenance by contractor (during contracting period) – better know-how of own products
- Yearly reviews – through water and energy consumption calculation
- Improving environmental awareness
- Risk relocation
- Contractor as specialists
- Fresh view through contractor – revision of entrenched routine
- Just one contact partner
- Experienced work relationship in case of familiar corporation – no start-up difficulties
- Guarantee of success- non-compliance of guaranteed savings leads to contractor`s loss
- Greater independence of rising energy prices

Common disadvantages

- Focus on short-term efficient measures/ economical advantageousness for contractor – exact contract formulation necessary
- Credit risk/Insolvency

Disadvantages contractor

- Credit risk – possible unfeasibility of repayment due to unpredictable events (business loss etc.)
- Operational risk – altered energy savings due to modification of operational hours (pricing consideration within contract necessary)
- Risk due to user change – deviation of the actual energy consumption compared to the calculated one (contractual consideration/adaption of reference consumption necessary)
- Energy price risk – impact on monetary savings due to development of energy prices (classification into fixed & variable costs)
- Technical risk – operational disturbances etc.
- Economical risk – loss to be compensated in case of non- achievement of the agreed savings

Project risks in general can be minimized by precautionary risk assessment and specification of appropriate provisions

Disadvantages contracting- taker

- Maintenance by contractor – might lead to more subjective inspections (the level of inspection of companies close to the contracting-taker usually show a higher standard of quality)
- Difficulty of comparing price offers of potential contractors – price evaluation before contract award based on rough analysis
- Non-transparent disclosure of risk potential – due to average based calculation (detailed risk listing necessary)
- Equipment requests not possible – contractor has freedom over equipment application
- Dependence on contractor – due to increased equipment complexity (software)
- Lack of documentation – due to internal company confidentiality, complexity etc.
- Elusive interface definition – f. ex. difficult evaluation of the condition of existing equipment can lead to unclear area of responsibility
- Unforeseeable events – financial resources necessary
- Long communication paths – contractor stands between contracting-taker and subcontractors
- Maintenance work & replacement of wear parts – often difficult to coordinate (different time schedules/ necessary advance order of interchangeable parts often not possible)
- Time consuming & complex fault repairs – administrative elaborate interference of contracting-taker (not directly)
- Additional effort for each new project – for project management, monitoring etc. (time & budgetary resources)
- Long contractual obligation
- Release of internal information to the contractor
- Small market of potential contractors – lack of competition

Although the advantages of the energy saving contracting seem quite convincing, the implementation of this model has had some difficulties of reaching its necessary maturity and acceptance. It is mainly granted to economically better situated countries to deal with this topic. Energy saving contracting does not provide instant savings, but savings within a predictable future. One aspect, which further made the distribution of energy saving measures difficult was not the absence of know-how, but the lack of knowledge about the potential savings of the individual facilities and its importance. Nevertheless, climate change, renewable energy, resource-saving construction, primary energy demand etc. constitute an increasingly important topic. For this reason, enterprises all around the world are striving to develop the market of energy saving capabilities. Nowadays, energy saving contracting has become an established financial instrument for energy- and renovation projects, which is able to adapt to the customer`s needs.

(Ernst 2010; Hermann n.d; WELLNESS WORLD Business n.d)

Especially in the baths sector, the city of Vienna has proved itself as a leading role model operation regarding energy contracting. The MA 44 has gained quite an amount of experience and know-how within the course of the realization of numerous energy saving projects. Therefore, a more detailed glance on contracting in Vienna`s public baths will be given within the following.

5.3 Contracting in Vienna`s public baths

Since the city of Vienna is one of the biggest public pool operators in Europe, the costs for operating resources, such as water and energy, are extremely high. Therefore, the municipal authorities for baths are eager to improve the energy efficiency of these baths. With the help of the previously discussed energy saving contracting, the city of Vienna`s has been able to modernize a variety of its public baths over the last years to increase energy efficiency. Before discussing Vienna`s contracting projects more detailed, an overview of the bath`s consumption rates are given to provide a deeper understanding of the energy usage in these constructions. Within the year 2000, which states the beginning of the entered contracting agreements, the average values for the 28 baths (without family baths), operated by the MA 44, were as follows:

Bathers: 4,1 million
Water/ waste water: 1,8 million m^3
Electricity. 13,7 million kWh
Natural gas: 12,7 million kWh
Heating oil: 1,1 million kWh
District heating: 48,7 million kWh

In average, each bather consumed around 0.4 m^3 water/ waste water and 18,6 kWh energy.

To cover the operating resources in the year 2000, around 4,89 million Euros were spent for water/waste water and approximately 4,38 million Euros for energy. This makes a sum of around 9,27 million Euros. Thus, the operating costs lied in average around 2,26 Euros per bather. Due to the unfeasibility of covering the high costs through the entrance fees, the rising energy prices, a generally tight budget situation, the Maastricht criteria and the international obligations towards climate protection, the urge towards a reduction in resource consumption increased. The lack of budgetary resources to reach this goal led to the conclusion of working with energy saving contracting. To find the right contracting partner, a public competition has been opened in 2000. As a result, a contract between the municipal authority- baths, the MA 44, and the system and energy provider ENGIE (former AXIMA Building Technologies GmBh) was entered to modernize the indoor- & outdoor bath Simmering. The success of this pilot project led to further refurbishments of Vienna`s baths based on energy saving contracting. Subsequently, the MA 44 entered energy saving contracts with ENGIE, GWT and SIEMENS Building Automation, to implement the modernization of various public swimming halls in Vienna.

(Österreichischer Städtebund n.d)

The following table on page 47 (Table 2) displays the locations and dates between 2001 and 2017, in which the municipal authority- baths has implemented energy saving contracting projects. In several cases, the initial contracts were supplemented by additional contracts within the subsequent years. All the following listed modernization projects were mainly based on technical renovations. Only the Theresienbad and the Amalienbad were complemented by some structural measures as well. Currently, almost all the district indoor- & combination baths in Vienna have been modernized with the help of this concept. Currently no further projects are in process. (Dipl.-Ing. Jandak J. 23.05.2018)

Table 2: Overview of the implemented energy saving contracting projects by the MA 44 (source: MA 44, 2018)

Bath	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Contractor
Brigittenau*			X		X		X											SIEMENS
Döbling*			X		X		X											SIEMENS
Donaustadt*								X	X		X				X			GWT
Floridsdorf*					X			X										ENGIE
Großfeldsied.*		X					X								X		X	ENGIE
Hietzing*			X						X	X						X	X	ENGIE
Hütteldorf									X									GWT
Ottakring*																	X	GWT
Schafbergbad																	X	GWT
Laaerberg						X							X		X			ENGIE
Simmering*	X			X		X		X		X			X				X	ENGIE
Theresienbad									X							X		SIEMENS
Jörgerbad						X												SIEMENS
Amalienbad												X				X		ENGIE

* Designed by F.F. Grünberger

According to the European Energy Service Initiative, the contracting period should lie around 6 to 15 years. In most renovations of Vienna`s district baths, a contracting period within this frame has been met. (Ernst 2010; Hermann n.d)

In order to implement the energy- & water saving measures of the above listed baths, requirements towards the following boundary conditions were given to the according contractor:

- Constructional requirements (building envelope, space for housing technology, etc.)
- Technical conditions (filtration technology, ventilation systems, piping etc.)
- Pool water temperatures (variety of user interests)
- Air temperature & humidity (user comfort and building physics are decisive)
- Requirements towards water flow in shower areas
- Requirements regarding the sanitation laws in baths (chlorine, circulation, fresh water etc.)

Based on the consideration of these boundary conditions, a variety of measures have been implemented to modernize public swimming halls in Vienna. In the following, a list of the measures, which have been realized within several or all of the contracting projects, is given:

- Central control technology
- Construction of solar energy systems, partially in combination with heat pumps
- Optimization of district heating stations or heating boilers, heating circuits, ventilation systems, night setbacks, pool heating, water treatment, lighting, sauna heaters, water preheating
- Blind current compensation
- Installation of frequency converters
- Replacement of ventilation units
- New, modernized filter systems
- Individual drinking water pipeline
- Return of sample water into the compensation reservoir
- Installation of heat recovery systems
- Usage of filter water as lawn irrigation
- Installation of contact water meters
- Lawn irrigation wells
- Installation of water-saving fittings

(Österreichischer Städtebund n.d)

Especially the measures regarding the water sector were quite innovative. Installations such as modernized filter technologies and heat recovery systems eminently contributed to the reduction of water (~50%) and heat consumption. The new installed central control technology enables inspection of operating parameters, such as water temperature, indoor air quality, operation of the solar energy panels etc. at any time. Furthermore, the optimization of the ventilation system depending on the open or closed state of exterior doors and the CO2 concentration of the indoor air were quite new in the field of baths. The implementation of antifreeze agents within the solar panels in combination with heat recovery systems allowed Vienna`s baths for the first time a year-round usage of solar energy. Overall, there are 14.000 m² installed solar panels (state 2008) in Vienna, which makes the MA 44 the biggest operator of solar panels in Vienna. (Magistrat der Stadt Wien 2008; Österreichischer Städtebund n.d)

The project sum of all the implemented energy saving projects by the MA 44 between 2000 and 2014 accounts for approximately 41 million euros, while the guaranteed savings lied around 4,7 million euros per year (without sales tax). The calculated operating life of the installed components lies around 20 years and the payback period at approximately 10,5 years. Through the implemented modernizations, it was possible to save around 24.600 MWh district heating, 486.000 m³ natural gas and 908.000 m³ water/ waste water. Overall the energy savings led to a reduction of CO2 emissions of approximately 4.600 tons per year. (Redaktion wien.at 2014)

Besides achieving the guaranteed energy savings, it was crucial to implement the necessary measures without expense of user comfort, but rather improve it. In this sense, it was possible to extensively reduce the amount of physically irritating chlorine with the help of new filter technologies. (Österreichischer Städtebund n.d)

The following chapter focuses on one of the implemented modernization projects of the MA 44, the Floridsdorfer indoor bath. By decreasing financial savings by approximately 45% through technical renovation, this bath constitutes a showcase for the successful modernization of one of F.F. Grünberger`s deprecated swimming halls.

6 FLORIDSDORFER INDOOR BATH

The construction of Friedrich Florian Grünberger`s district indoor bath in Floridsdorf began on an 8.100 m² plot in the Franklinstraße 22, 1210 Vienna, on the 9st of May in 1964. The inauguration of the swimming hall took place on the 6th of October in 1967. Overall, the construction costs lied around 1.832 Austrian schilling per m³. It was the first public bath erected after WWII and was constructed as a focus bath (de. Schwerpunktbad). The goal of this focus bath was to supply the catchment area with various utilization options such as recreational swimming, swim training, sports events, steam baths and saunas. Additionally, since most of the homes were lacking sanitary facilities, additional tubs and shower installations were added. The Floridsdorfer indoor bath was the last focus bath of its kind before F.F. Grünberger further developed the concept the Europe bath. (Bednarik et al. 1994/95; Redaktion wien.at 2017)

6.1 Location and amenities

The building can be entered at the Franklinstraße, a pedestrian area which directly connects the bath with the Floridsdorfer train station within a short walking distance. Furthermore, a well-connected bike path, as well as a parking lot right in front of the building, are given for private transportation.

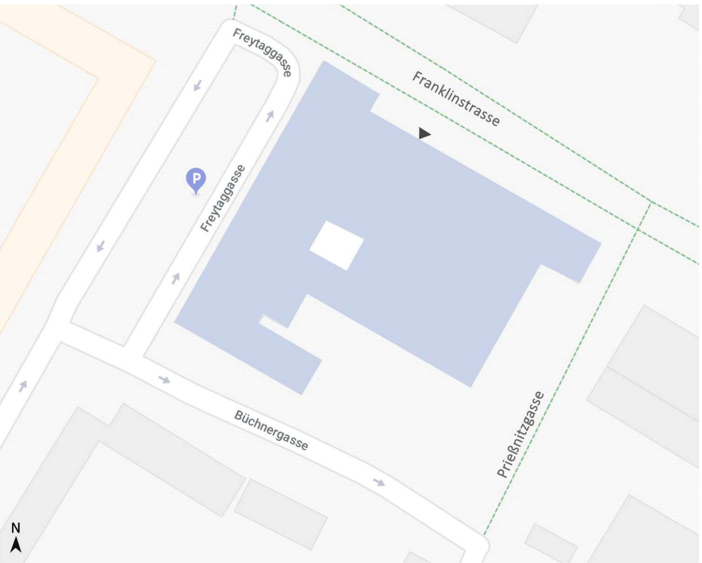


Figure 11: Site map Floridsdorfer indoor bath (source: Google)

The bath contains various swimming pools, a high diving tower, as well as stands for the audience in case of sports competition events. Besides steam baths and saunas, the bath also includes an outside area, which offers the possibility of enjoying outside air during summer months. Due to the excellent condition of today`s sanitary facilities in Vienna, the originally available tubs have been removed. Overall, the bath offers a great variety of services, which have been developed over the years. (Bednarik et al. 1994/95)

In the following, an overview of the currently offered amenities of the Floridsdorfer bath is given:

- Swimming hall
    - Sports pool (25 m x 16.6 m, 1.37 – 3.8 m)
    - Multi-functional pool (7.5 m x 16.6 m, 0.96 – 1.37 m)
    - Children`s pool (7.3 m 6.25 m, 0.6 m)
    - Baby pool (5.5 m x 2.2 m, 0.3 m)
    - Diving tower (1 m, 3 m, 5 m)
    - Sunbathing lawn (summer)
- Teaching pool (12 m long, 7 m wide, 0.6- 1.2 m deep)
- Sauna
    - Finnish sauna
    - Organic sauna
    - Steam bath
    - Herb- & eucalyptus chamber
    - Whirlpool
    - Sun deck (summer)
- Shower area
- Additional facilities
    - Fitness centre
    - Restaurant
    - Pedicure area
    - Cosmetic area
    - Massage area

(Bednarik et al. 1994/95; Redaktion wien.at n.d; Wien-konkret)

Overall, the Floridsdorfer indoor bath offers an effective area of 18.440 m² and a pool surface area of 770 m². The Visitor frequency of the bath lies up to 600 visitors per day on peak days. (MA 44- Bäder 2005b; Wien-konkret)

6.2 Architecture and housing technology

Figure 12: Floridsdorfer indoor bath (source: Kotinsky 2017)

The building itself can be divided into three main tracts. The 4-storey construction on the right in Figure 12 incorporates the dressing areas, saunas facilities, as well as the listed additional facilities on page 51. The swimming hall, which displays the heart of the building, is circumvented by a single-story passageway and can be seen on the left side of Figure 12. The passageway offers an outside view into three directions and connects the swimming hall with the sunbathing lawn. The intermediate part of the construction connects the two previously mentioned tracts. It includes the entrance of the building, which can be seen on the bottom of the picture, a yard, and a teaching pool. A fourth tract, the gym, has been added in 1992 by the architecture office Durst to offer additional space for sports. It lies behind the tall tree at the bottom of Figure 12.

The building has been constructed as a reinforced concrete skeleton construction including cast concrete infill. Due to the poor load-bearing capacity of the building site, oscillating support has been used as foundation along the swimming hall. Grünberger`s goal was to reduce the operating costs by saving as much construction volume as possible. Based on this concept, the room height has been constructed as low as possible. To keep the cubature in the swimming hall, which required a certain height due to the diving towers, as low as possible as well, a circumferential corridor with lower ceiling height has been created around it.

Another aspect which was quite important for the construction of this bath was to provide good room acoustics. Consequently, acoustic-bricks have been used on the inside walls of the swimming hall. Additionally, a suspended ceiling out of aluminum lamella with an insulation layer have been installed. The surface constructions of the pools were created including 4 x 4 cm white tiles with a smooth surface. The tiles on the floor required a rough, slip-resistant surface. The architect also incorporated a variety of artistic designs such as mosaic pictures on the walls by artists like Maria Szeni and Anton Krejcar, as well as a sculpture by Prof. Leinfelnder in the central yard of the building. The initial external surfaces were cladded with milk-white glass mosaic and included safety glass within the area of glass facades. The windows were decorated with blue glass, with the intention of unifying the windows of various sizes. Due to increased temperature differences in swimming halls, movement within the skeleton construction led to shrinkage cracks in the façade, which further led to the installation of a mounted façade in 1992.

The bathers themselves perceive the bath in the following way: When entering the bath at the main entrance (see Figure 13- Figure 17 on the following pages), an inviting view straight into the teaching pool is given through a glass wall. Guests can choose between directly entering the restaurant, which offers view and access in and from the swimming area, and taking the staircase to the public gallery on the upper . The public gallery offers space for 424 people to oversee the swimming hall in case of sports events.

The male swimmers can access the locker and changing area right from the ground floor, after they have passed the cash desk. Subsequently, the guests can enter the shower area, from which they have the possibility to directly continue towards the swimming hall.

Women need to rise to the first floor to enter the female dressing area. After passing through the shower area, a staircase leads them back into the ground floor, from where they can reach the swimming hall.

The first floor also offers a fitness area, as well as the pedicure area, which both male and female guests can enter from the staircase. Furthermore, a gym is given in both, the ground floor and the 1st floor which can be accessed from a separate entrance on the ground floor, as well as the swimming hall and both dressing areas. The upper floors include all the above-mentioned sauna amenities, warm- & cold- water pools, as well as the additional facilities. The 2nd floor, which is assigned for the male bathing guests, offers almost the same layout as for the female guests on the 3rd floor. Though the women area additionally includes a cosmetic and massage area, as well as the organic sauna, which cannot be found in the 2nd floor. The sun deck on the 4th floor provides access to two gender separated sunbathing areas including toilet facilities and shower areas.

(Bednarik et al. 1994/95)

In the basement area of the bath (Figure 18), the technical installations for water and air preparation can be found along with some offices, a workshop, a sewing room, laundry facilities and additional spaces for personnel. The original housing technology included radiators and copper heating coils within the floor and seats in the swimming hall area for heating. The initial boiler plant and a transformer station have later been replaced by a district heating system. The saunas were supplied by steam generators with a natural gas connection. In case of power failure, the bath was supplied by emergency power through a Diesel generator. The swimming hall further included a mechanical ventilation system with an environmental friendly oil filter system to clean the air. The water of the bath was heated by plate heat exchangers, purified with sand filters and disinfected with the help of chloride dioxide. Additionally, a well system has initially been provided, which is nowadays decommissioned. (Bednarik et al. 1994/95; Redaktion Fachzeitschrift Schwimmbad & Therme)

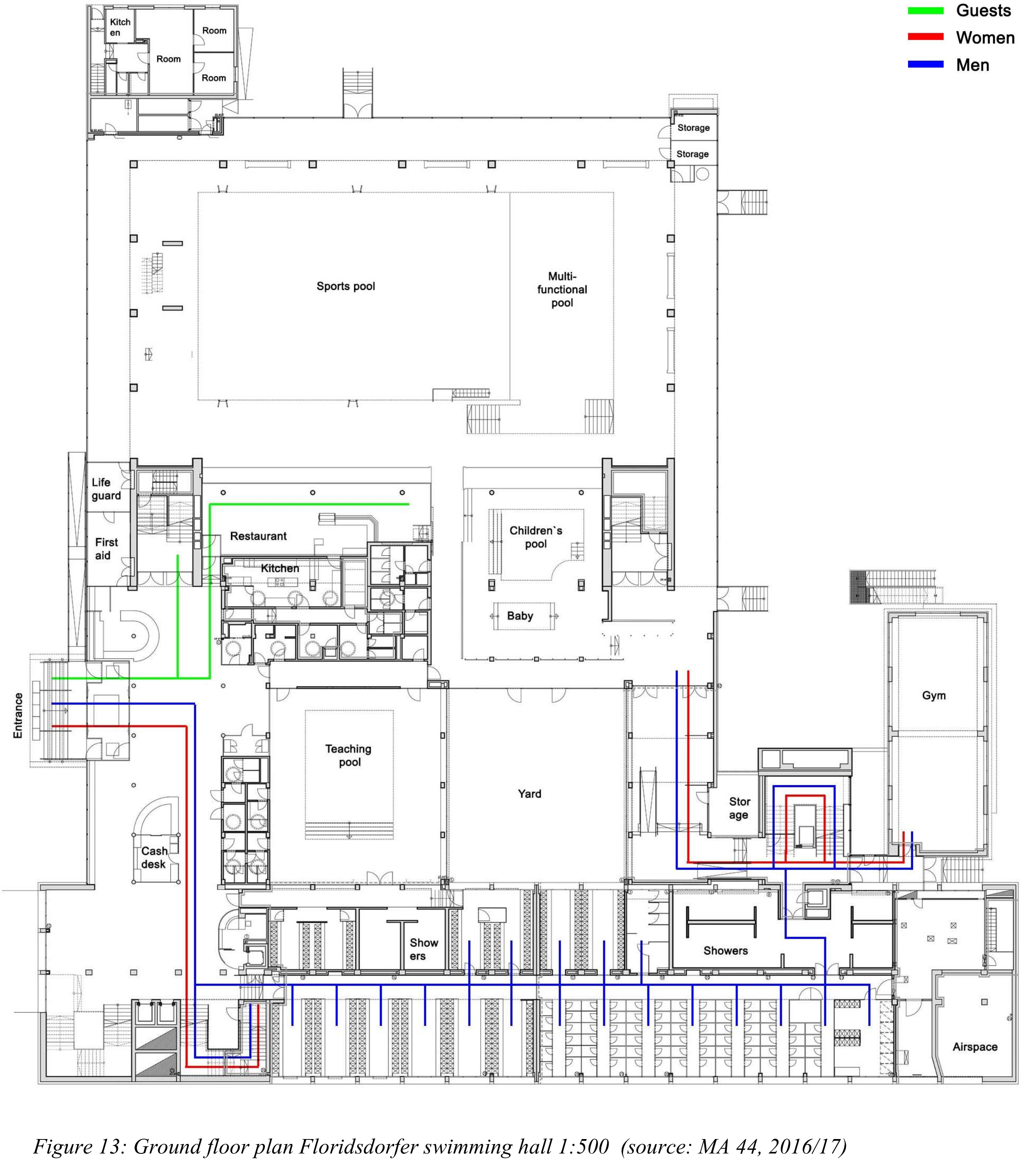


Figure 13: Ground floor plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

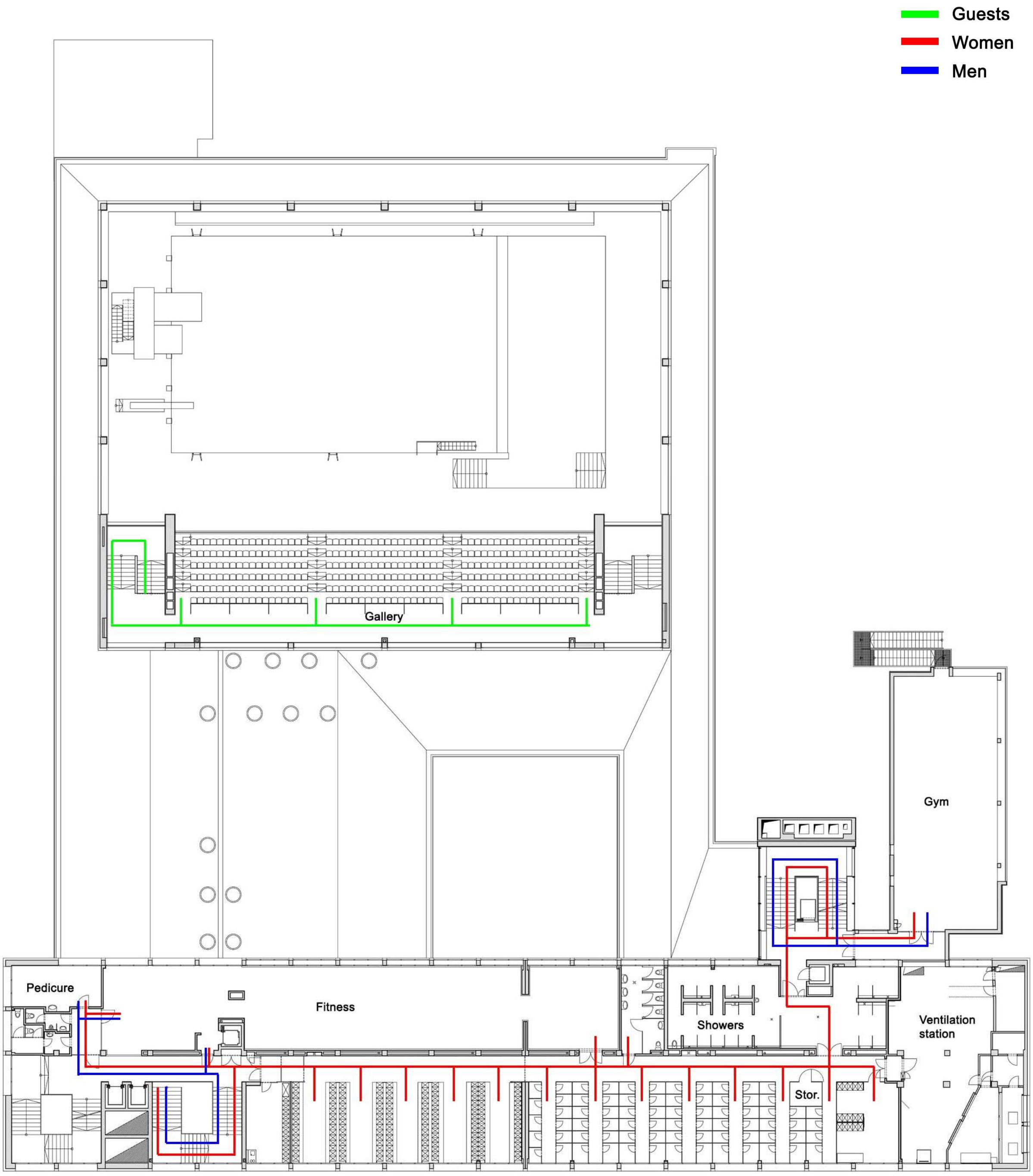


Figure 14: 1st floor plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

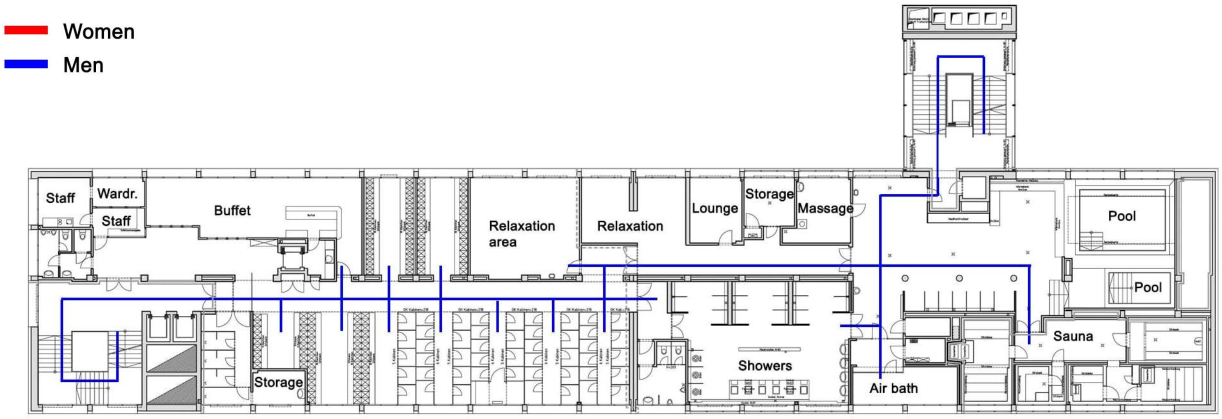


Figure 15: 2nd floor plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

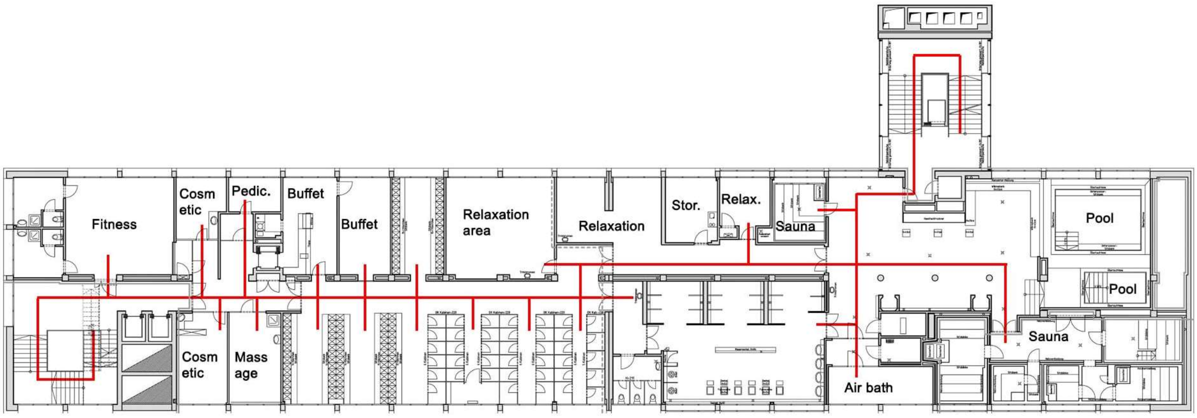


Figure 16: 3rd floor plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

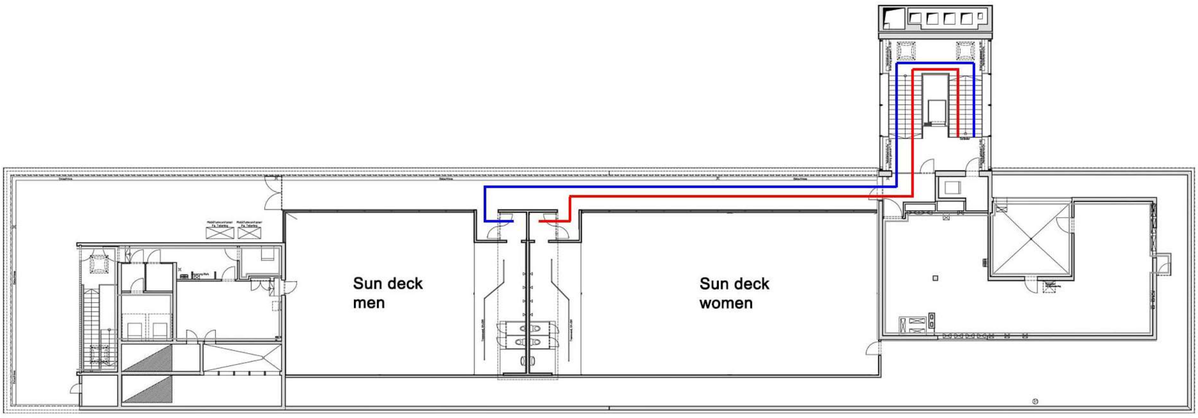


Figure 17: 4th floor plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

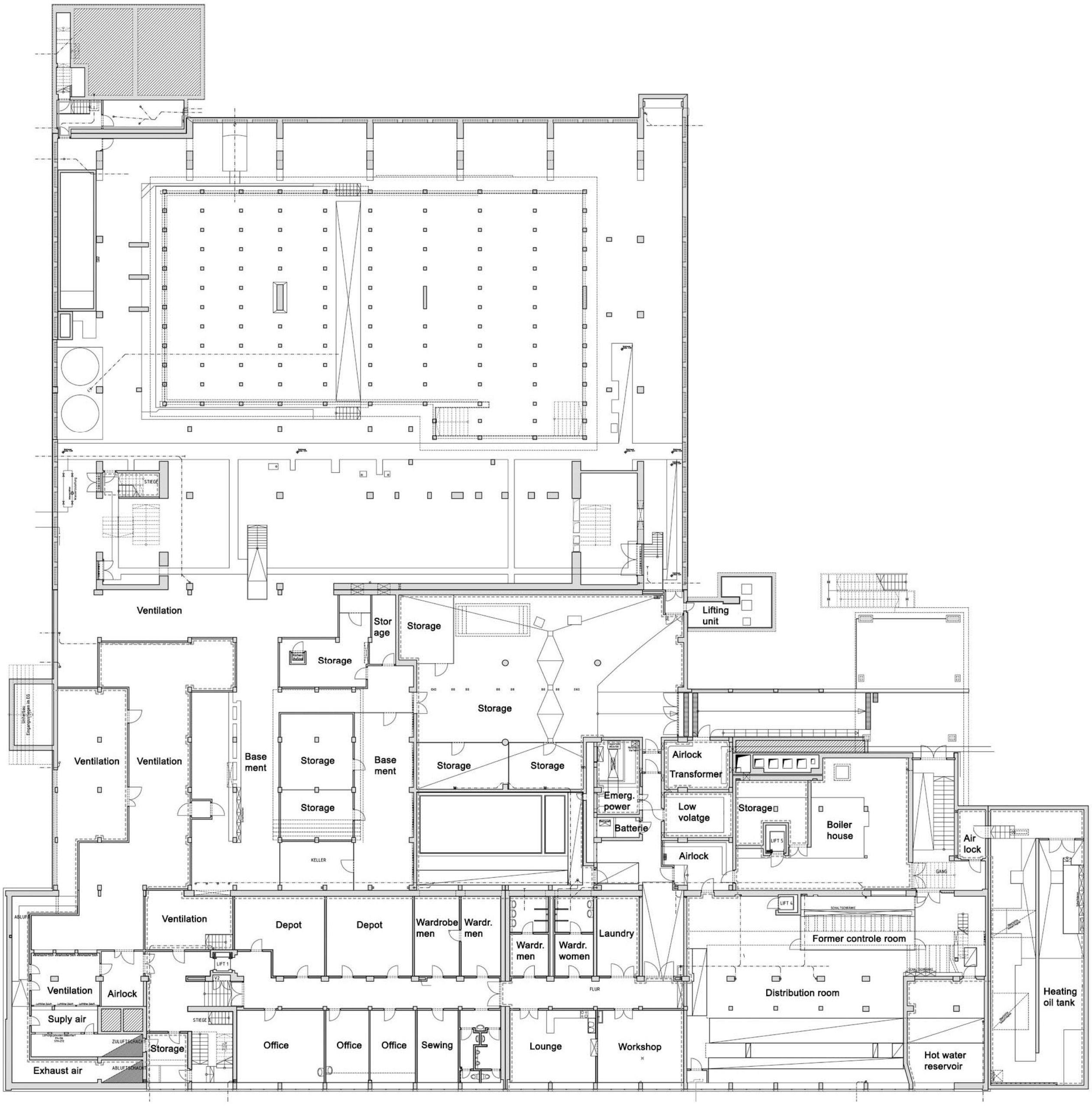


Figure 18: Basement plan Floridsdorfer swimming hall 1:500 (source: MA 44, 2016/17)

Although, as previously mentioned, the technical equipment seemed quite modern and technologically advanced during their time of installation, the nowadays outdated technology required great amounts of energy. Especially, due to the nonexistence of heat recovery systems, the heating demand was extremely high in this bath. The one-layered sand filters, without efficient backwashing, further increased the water usage. Moreover, the ventilation technology, which consisted of 70 single fans, resulted in an especially high energy consumption. High operating costs and deprecated technology consequently led to the decision of rehabilitating the bath. With help of the previously discussed energy saving contracting, an energy optimization, including a general renovation of the housing technology, was facilitated. (MA 44- Bäder 2005a)

6.3 Energetic optimization

The energy saving contracting project of the Floridsdorfer indoor bath involved a cooperation between a contracting authority, the municipal authority MA 44- baths of Vienna, and an executing contractor, the AXIMA Building Technologies GmBh (nowadays ENGIE). Furthermore, a variety of general contractors for heating- & air installations were integrated in this contract. The agreement, which was based on a tendering and award procedure, mainly focused on energy- & water savings. The objectives of this contract were to reach these energy- & water savings through plant optimization, as well as prolonging the lifespan of the construction by renovating the housing technology based on the above-mentioned financing model. Additionally, the operational comfort was intended to be increased and the room conditions, the air quality and the water quality to be improved. (MA 44- Bäder 2005a)

In the following, the various measures which have been implemented to modernize the Floridsdorfer indoor baths are listed:

Structural measures

The water heating system has been switched from district heating to a thermal solar system. This solar system includes 1.050 m² of absorbing mats which heat up a 30 m³ buffer storage directly, or with the help of a heat pump, depending on the weather conditions. The buffer storage was originally utilized as a hot water tank and has been converted for this purpose. Furthermore, the heat pump helps regain heat from the swimming hall ventilation exhaust air. The recovered heat is further used for heating up the pool water, preheating inlet outside air, hot water and floor heating. Although, these measures overall result in an increase of electricity, the sanctions result in a much more efficient operation due to the significant amount of heat savings.

Additional structural measures implemented within this refurbishment included the reconstruction of the ventilation station, as well as the improvement of precautionary fire protection. The ventilation stations have been designed as fire safety compartments according to the current standards and requirements. All fire protection flaps have been exchanged, encased fire-resistant and indicated in the building control system.

<ins>Energetic measures</ins>

The renewal of the ventilation system involved a combination of the supply- & exhaust air systems. Forty-eight of the ventilation system`s original 70 single fans have been merged into eight pressure controlled central units including zoning and variable volume flow rates. The remaining systems are now only used for secondary purposes due to their low output. With this modernization, not only heating of the interior spaces can be decreased, but the pool water as well.

Furthermore, the pneumatic controls and control cabinets have been replaced, and the sauna facilities equipped with a heat recovery system.

The energetic measures further included the inclusion of the whole building construction into a building control system which is connected to a control station in the bath itself, the MA 44 and ENGIE. This system is incorporated in the intranet of the city of Vienna and fulfills the purpose of detecting setpoint deviations, plant malfunction etc. at an early stage, and to consequently react to them accordingly. This way, not only water, but energy can be saved as well.

Additional optimizations which have been conducted within this area are:

- Exchange of the blind current compensation
- Open ventilation above motorized fanlights and door contacts
- Improved sauna control
- Condensate return at the high-speed steam generator
- General optimization of the measuring and control technology including night-setback and peak-load management

- CO_2- and dew-point controlled air recirculation
- Optimization of the lighting

All in all, the relation between structural and energetic measures accounted for 1:13.

Water-saving measures

The water-saving measures mainly focused on the reutilization of used water. Within this sense, the water filters have been refurbished or exchanged, filter rinses optimized with new pumps and single-layer filters were exchanged by multi-layered filters. The installation of a reverse osmosis system, which decreases the amount of chlorides in the water, further contributed to the reduction in water consumption. Due to the increased amount of reusable cleared water, the quantity of additional fresh water decreases. Additionally, a $60m^3$ reservoir for stocking the water for rinsing has been installed and leaky gas pipes have been exchanged by plastic pipes.

The existing water pumps have been equipped with frequency converters in order to adapt the power of circulation to the corresponding needs. In addition, the measuring technology and the installations for chemical dosage have been exchanged or renewed. The measuring- and control engineering for the pool water technology, which is also integrated in the building control system, was replaced as well. With the help of new membrane filters, 70% of waste water from the backwashing of the filters can now be regained. This technology is also displayed in the central building control system and has not been implemented in any other baths in Austria before.

Overall, the above-mentioned measures led to great amounts of water and energy savings.

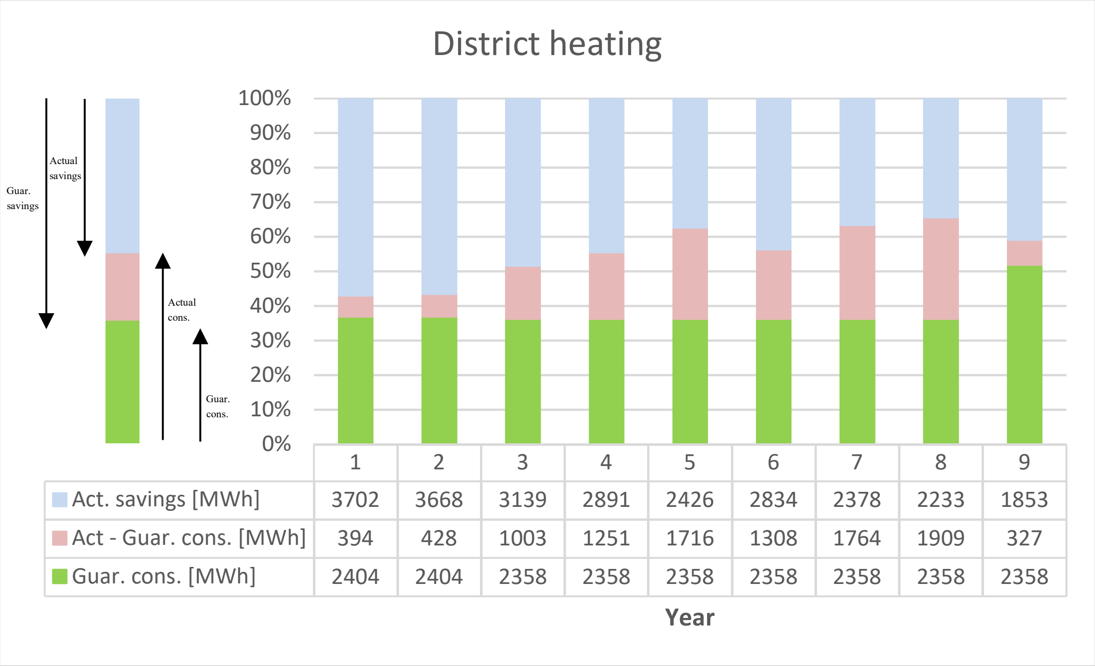
The implementation of all the measures required an operational interruption of the bath. The length of this interruption was considered within the award criteria as well. All in all, the construction period required 10 months and the interruption has been kept down to 5 weeks, in which all the necessary modifications were able to be conducted.

During the contracting period, the effectiveness of the measures was recorded by energy statistics. Furthermore, daily operations were discussed within regular meetings. The central building control system visualizes the energy statistics of all the contracting projects by the MA 44 and provides information for the operating personnel. Through a remote access, the contractor has the possibility of monitoring the condition and operation of the systems. This, in addition with regular on-site maintenance, facilitates regular quality control of the bath operation.

(Ernst 2010; MA 44- Bäder 2005a; Redaktion Fachzeitschrift Schwimmbad & Therme)

The subsequent pages provide a more detailed insight into the above-mentioned energy statistics based on information given by ENGIE. Within the following graphs, the actual savings in comparison to the guaranteed ones and the reference values of the various energy sources are visualized over the course of the contracting period of 9 years (5th of Dec 2005 – 5th of Aug. 2014).

Within the first graph (Figure 19) the district heating consumption is displayed. The 100% line in this graph marks the so called "baseline". The "baseline" displays the current energy consumption, on which the targeted savings are being guaranteed. It is visible in figure 19, that the guaranteed energy savings of approximately 2/3rd were nearly reached within the first two contracting years. However, within the following years, the actual savings turned out to be much lower than expected. According to Michael Sturm, the project manager of ENGIE, one of the reasons for these unexpected results was lead back to loss of glycol of the solar matts due to bird picking. However, precise cause evaluation requires more detailed investigation.

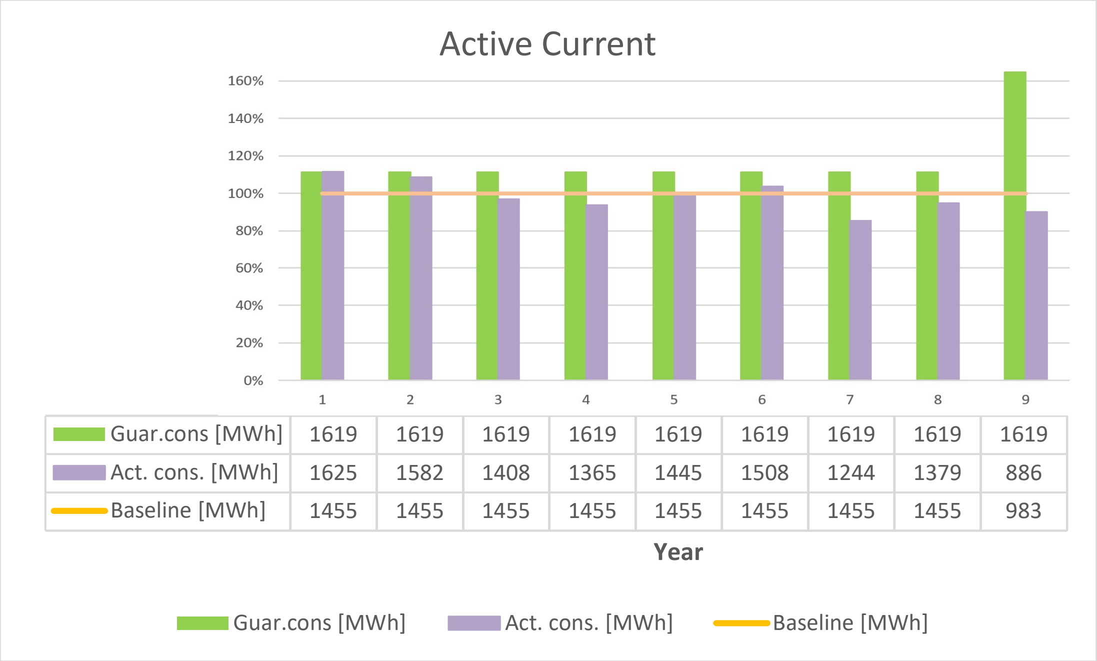


	1	2	3	4	5	6	7	8	9
🟦 Act. savings [MWh]	3702	3668	3139	2891	2426	2834	2378	2233	1853
🟥 Act - Guar. cons. [MWh]	394	428	1003	1251	1716	1308	1764	1909	327
🟩 Guar. cons. [MWh]	2404	2404	2358	2358	2358	2358	2358	2358	2358

Figure 19: District heating evaluation over contracting period (source: ENGIE Austria, 2014)

Furthermore, it needs to be mentioned that since the last contracting year does not include 12 whole months, the reference values have consequently been adapted to the baseline from December- July. Although, since the guaranteed savings have maintained the same as in the previous years, the percentage share of the actual/guaranteed consumption to the baseline display values differing from the average in figure 19-23.

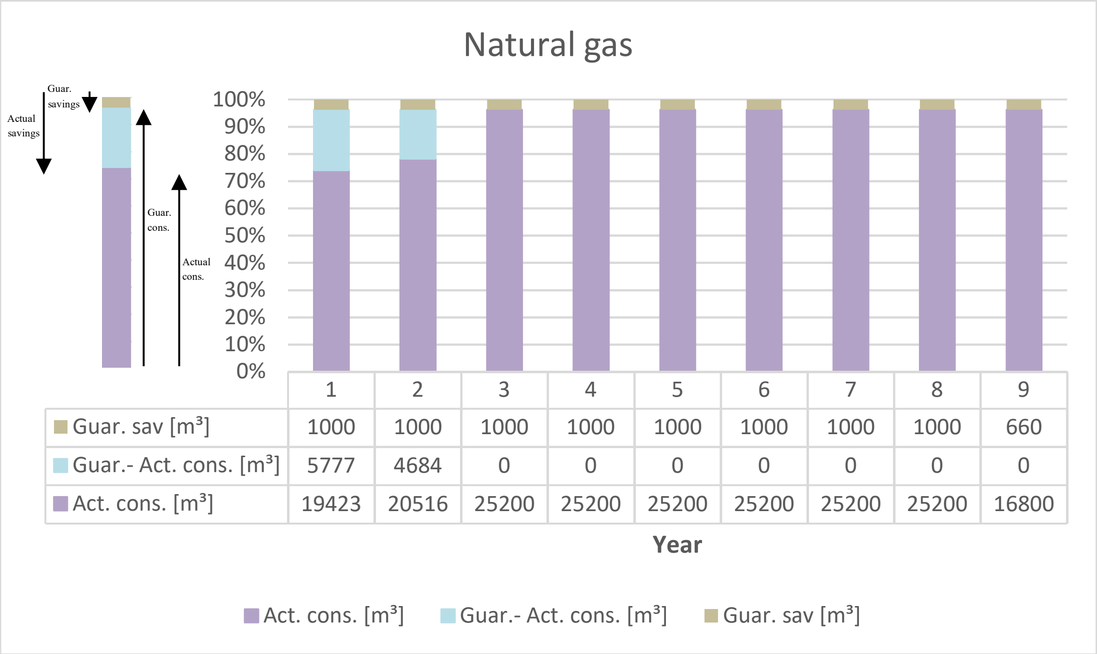
The next graph (Figure 20) displays the consumption of active current. Since the actual and guaranteed consumption fluctuate above and underneath the baseline, a different form of visualization has been chosen in this case. The increase of active current consumption above the baseline is led back to the elimination of reactive current from an original baseline value of 293 MVArh to zero. Although, as visible in the figure 20, the guaranteed consumption for active current predicted values above the baseline, the actual consumption has decreased underneath the line in most years. At this point it needs to be mentioned, that savings above the guaranteed savings will benefit the contractor 100%. The anomaly in year 9, as previously mentioned, is caused by the consistency of the guaranteed costs in regard to the shortened annual balance.



	1	2	3	4	5	6	7	8	9
Guar.cons [MWh]	1619	1619	1619	1619	1619	1619	1619	1619	1619
Act. cons. [MWh]	1625	1582	1408	1365	1445	1508	1244	1379	886
Baseline [MWh]	1455	1455	1455	1455	1455	1455	1455	1455	983

Figure 20: Active current evaluation over contracting period (source: (ENGIE Austria 2014)

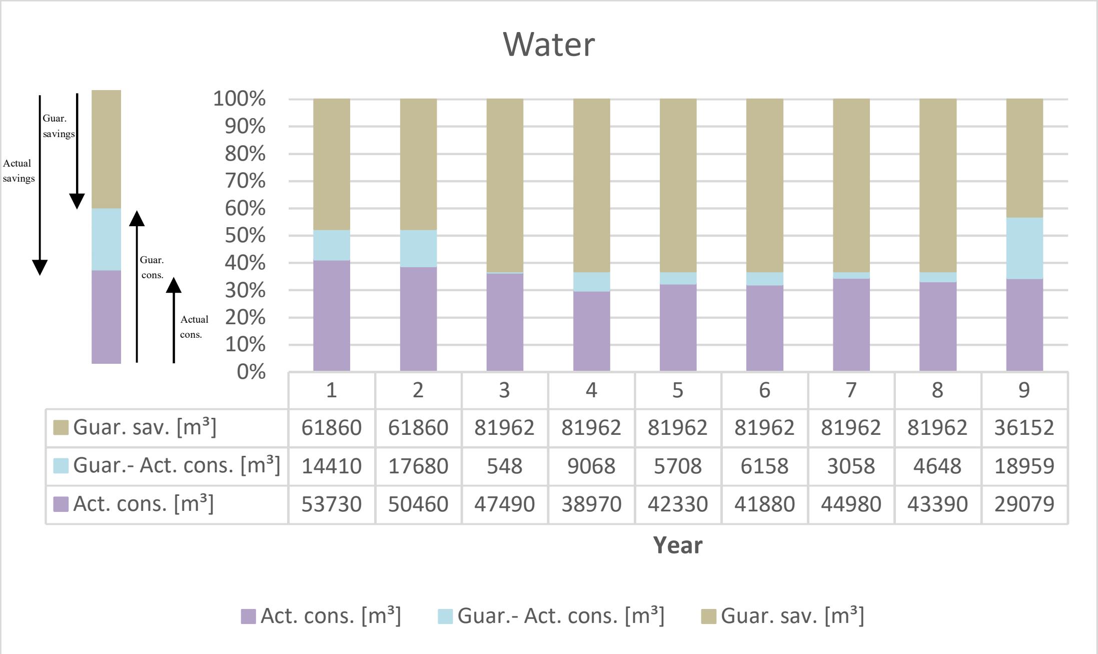
The predicted savings referring natural gas consumption have proved to be quite successful with this refurbishment. It is visible in the following graph (Figure 21), that from the 3rd year onwards until the end of the contracting period, the actual savings reached the guaranteed amount by the exact value. Within the first two years, the actual savings have even surpassed the guaranteed savings by approximately 20% of the reference values, which further leads to additional savings.



	1	2	3	4	5	6	7	8	9
Guar. sav [m³]	1000	1000	1000	1000	1000	1000	1000	1000	660
Guar.- Act. cons. [m³]	5777	4684	0	0	0	0	0	0	0
Act. cons. [m³]	19423	20516	25200	25200	25200	25200	25200	25200	16800

Figure 21: Natural gas evaluation over contracting period (source: ENGIE Austria, 2014)

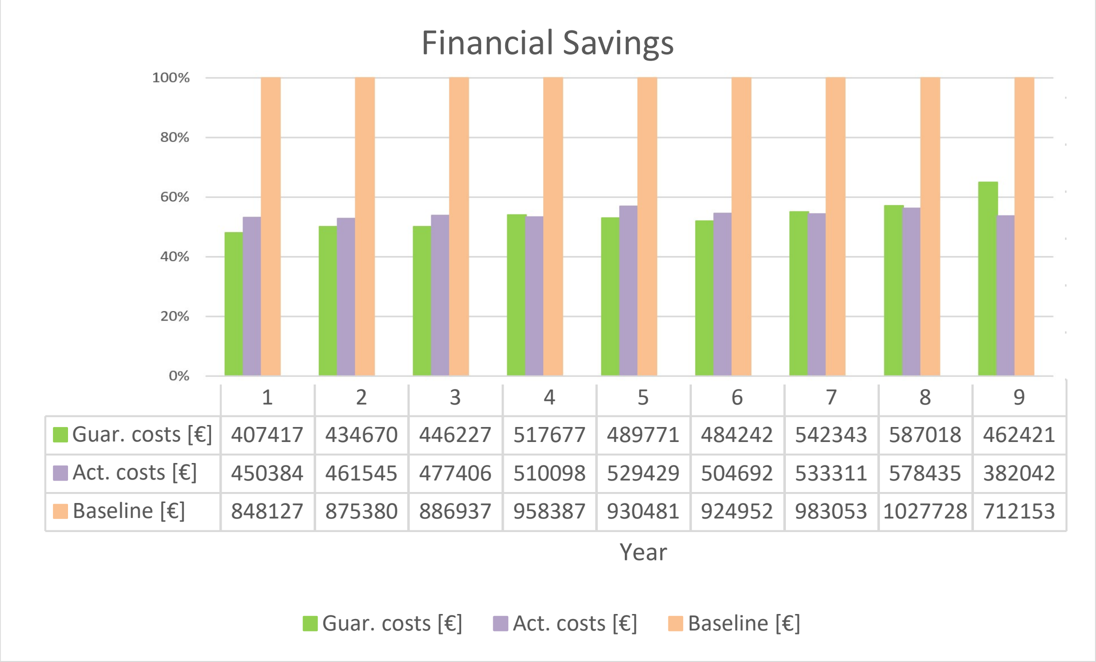
The amount of water which was reduced through this optimization turned out much higher than expected. As visible in Figure 22, the actual savings have succeeded the guaranteed savings each year. Overall, the amount of water consumption was reduced approximately down to 1/3rd.



	1	2	3	4	5	6	7	8	9
Guar. sav. [m³]	61860	61860	81962	81962	81962	81962	81962	81962	36152
Guar.- Act. cons. [m³]	14410	17680	548	9068	5708	6158	3058	4648	18959
Act. cons. [m³]	53730	50460	47490	38970	42330	41880	44980	43390	29079

Figure 22: Water evaluation over contracting period (source: ENGIE Austria, 2014)

The final graph (Figure 23) displays the overall financial savings in comparison to the baseline. The following values are based on the respective energy prices of each year. Constant fluctuation of these energy prices however, complicate direct comparison. All in all, the modernization has led to savings of approximately 55%.



	1	2	3	4	5	6	7	8	9
🟩 Guar. costs [€]	407417	434670	446227	517677	489771	484242	542343	587018	462421
🟪 Act. costs [€]	450384	461545	477406	510098	529429	504692	533311	578435	382042
🟧 Baseline [€]	848127	875380	886937	958387	930481	924952	983053	1027728	712153

Figure 23: Financial savings over contracting period (source: (ENGIE Austria 2014)

The AXIMA Building Technologies GmBh invested in total 3,128.491 € into the renovation of this bath. The yearly savings, which also constitute the contracting rate, lied at 366.000 € and included a payback period of 8.5 years.

(MA 44- Bäder 2005a)

To further point out the effect of the refurbishment, a comparison between the energy consumption before the optimization, which is defined through the baseline, and at the end phase of the contracting period is given in the following. Since the last contracting year, year 9, does not include one full year, year 8 has been chosen in order to make a full comparison.

Consumption before optimization:		Consumption contracting year 8:		
District heating:	6 500 MWh	District heating:	4 267 MWh	(-34%)
Natural gas:	26 200 m^3	Natural gas:	25 200 m^3	(-4%)
Electricity:	1 748 MWh	Electricity:	1 379 MWh	(-21%)
Water:	130 000 m^3	Water:	43 390 m^3	(-67%)

(ENGIE Austria 2014)

Overall, the measures implemented within this renovation led to great amounts of water and energy savings. Even though some of the guaranteed values were not achieved, the optimization shows great results, especially in case of water reduction. It is however necessary to point out that the targeted results always need to be observed over a sufficient period to discover their full effects. For example, in case of district heating, the initial savings, which came close to the guaranteed 63% within the first two years, could not be sustained at the same level within the following years.

Another essential aspect, which turned out to be of high importance during this research, is that the graphs only display the overall energy and water savings. Due to the complex relationship between the different assets of the respective systems (housing technology, pool technology, building envelope). Encompassing highly complex building service systems and operational schemes, it is a challenge to identify a detailed list of measured values for evaluation of the success of retrofit. (Ernst 2010)

Besides technical installations, the construction itself plays an important role regarding the building performance of swimming halls as well. The following subchapter focuses on an energy evaluation of the building envelope of the Floridsdorfer swimming hall. It contains the bath`s constructions and geometry and shall serve as a rough indicator of the building`s thermal performance.

6.4 Energy evaluation

Architect:

Friedrich Florian Grünberger

Date of construction:

9th of May 1964

Calculation progam:

ArchiPHYSIK 15.0

Applied calculation methods:

Building components:	EN ISO 6946: 2003-10 (2003)
Windows:	EN ISO 10077- 1:2006-12 (2006)

Unconditioned building components:	simplified, ON B 8110-6:2014-11-15
Reaching Building components:	simplified, ON B 8110-6:2014-11-15
Thermal bridges:	generalized, ON B 8110-6:2014-11-15
Shading coefficient:	simplified, ON B 8110-6:2014-11-15

The wall constructions and geometry of the building were taken from various plans of the Floridsdorfer indoor bath, which have been viewed at the municipal authorities for buildings, the MA 37, in Vienna. In case of insufficient or incomplete documentation within the existing plans, especially in case of wall constructions, assumptions, which were based on the author’s personal expertise, have been made. This energy evaluation, therefore only serves as a rough assessment of the current condition of the swimming hall`s building envelope. A detailed list of the corresponding building components and wall constructions, including their thermal properties, which have been used for this calculation can be found in chapter 6.4.2 and 6.4.3.

6.4.1 Results

Gross- area:	10 306, 95 m^2	Characteristic length:	2,25 m
Reference surface:	8 245, 56 m^2	Heating days:	216 d
Gross- volume:	49 761, 95 m^3	Heating degree days:	3460 Kd
Building surface envelope:	22 079, 88 m^2	Norm- outdoor temp.	-12,9 °C
Compactness (A/V):	0,44 1.m^{-1}	Target- Indoor temp.:	28°C
Average U-value:	0,716 W.m^{-2}.K^{-1}	Construction:	heavy

Reference heating demand (HWB$_{Ref,SK}$):	129,01 kWh.m^{-2}a^{-1}
Heating demand (HWB$_{SK}$):	357,30 kWh.m^{-2}a^{-1}
Primary energy demand (PEB$_{SK}$):	727,66 kWh.m^{-2}a^{-1}
Carbon dioxide emissions (CO2$_{SK}$):	137,20 kWh.m^{-2}a^{-1}

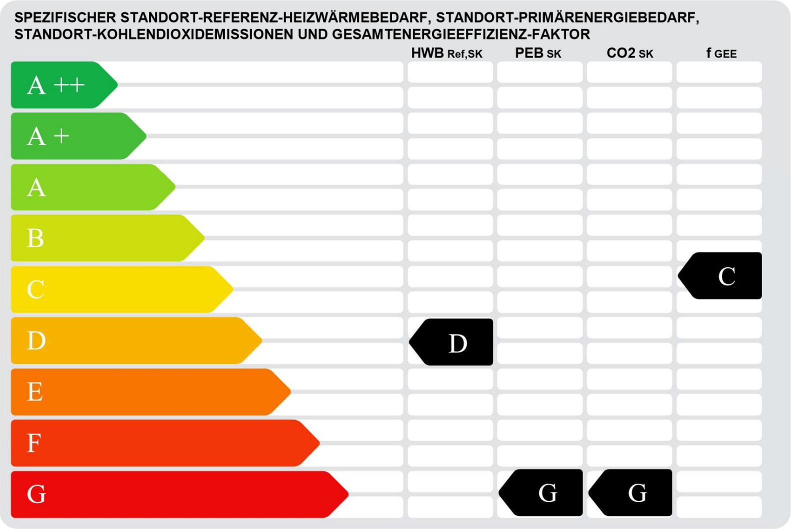


Figure 24: Energy certificate chart (source: Archiphysik)

As expected, the energy loss through the building surface of the Floridsdorfer swimming hall is quite high, since the building`s envelope has not been subjected to any major structural renovations since its construction.

6.4.2 Building Components

Nr.	Unit m²/m³	Sum	U-value
	Heated Gross Area	10306.95 m²	-
	Heated Gross Volume (with Pool)	49770.6375 m³	-
	Heated Gross Volume (without Pool)	20989.894 m³	-
1	Floor to unheated (Gym above garbage room)	5012 m²	0.163 (W.m^{-2}K^{-1})
2	Floor to unheated basement (1.BM-2.BM)	548.65 m²	2.155 (W.m^{-2}K^{-1})
3	Floor to unheated basement (Gym above basement)	108.51 m²	0.291 (W.m^{-2}K^{-1})
4	Floor to unheated basement (Swimming hall)	1808.2 m²	2 (W.m^{-2}K^{-1})
5	Floor to unheated basement (Entrance)	452.22 m²	2.012 (W.m^{-2}K^{-1})
6	Floor to unheated basement (attendant's hut)	92.96 m²	0.83 (W.m^{-2}K^{-1})
7	Floor to unheated basement (Pool 30 cm)	63.47 m²	1.969 (W.m^{-2}K^{-1})
8	Floor to unheated basement (Pool 40 cm)	716.52 m²	1.812 (W.m^{-2}K^{-1})
9	Floor to unheated basement (Dressing area)	255.58 m²	0.794 (W.m^{-2}K^{-1})
10	Floor to unheated basement (Staircase)	274.36 m²	2.141 (W.m^{-2}K^{-1})
11	Floor to unheated (3.FL - Rooftop)	68.31 m²	2.141 (W.m^{-2}K^{-1})
12	Roof A	1085.09 m²	1.033 (W.m^{-2}K^{-1})
13	Roof B	613.06 m²	0.878 (W.m^{-2}K^{-1})
14	Roof C	1523.59 m²	0.027 (W.m^{-2}K^{-1})
15	Roof (Rooftop)	868.28 m²	0.024 (W.m^{-2}K^{-1})
16	Floor to unheated (Rooftop)	375.15 m²	0.601 (W.m^{-2}K^{-1})
17	Exterior Wall net (ZMW 0.4)	2,136 m²	0.26 (W.m^{-2}K^{-1})
17.1	- Windows nord-west	239.397 m²	1.6 (W.m^{-2}K^{-1})
17.2	- Glass south- east (Staircase)	128.567 m²	1.6 (W.m^{-2}K^{-1})
17.3	- Window facade south-east (swimming hall)	140 m²	1.6 (W.m^{-2}K^{-1})
17.4	- Windows south-west	190.512 m²	1.6 (W.m^{-2}K^{-1})

17.5	- Window facade south-west	125.79 m^2	1.6 ($W.m^{-2}K^{-1}$)
17.6	- Glass south-west (staircase)	24.153 m^2	1.6 ($W.m^{-2}K^{-1}$)
17.7	- Windows north-east	69.0795 m^2	1.6 ($W.m^{-2}K^{-1}$)
17.8	- Glass north-east (staircase)	76.028 m^2	1.6 ($W.m^{-2}K^{-1}$)
17.9	- Window facade north-east	209.51 m^2	1.6 ($W.m^{-2}K^{-1}$)
17.1O	- Glass brick	4.02 m^2	3.58 ($W.m^{-2}K^{-1}$)
18	Exterior Wall Gross (ZMW 0.51)	509.344 m^2	0.247 ($W.m^{-2}K^{-1}$)
18.1	- Windows north-west	37.065 m^2	1.61 ($W.m^{-2}K^{-1}$)
18.2	- Windows south-east	22.47 m^2	1.61 ($W.m^{-2}K^{-1}$)
18.3	- Windows south-west	41.895 m^2	1.61 ($W.m^{-2}K^{-1}$)
18.4	- Windows north-east	22.47 m^2	1.61 ($W.m^{-2}K^{-1}$)
19	Exterior Wall Gross (ZMW 0.25)	145.882 m^2	0.273 ($W.m^{-2}K^{-1}$)
20	Exterior Wall Gross (STB 0.51)	1616.595 m^2	0.295 ($W.m^{-2}K^{-1}$)
21	Exterior Wall Gross (STB 0.4)	104.806 m^2	0.3 ($W.m^{-2}K^{-1}$)
22	Exterior Wall Gross (SB 0.5)	88.209 m^2	0.288 ($W.m^{-2}K^{-1}$)
23	Exterior Wall Gross (Ground)	48.642 m^2	2.086 ($W.m^{-2}K^{-1}$)
24	Wall to unheated (ZMW 0.12)	260.5728 m^2	0.313 ($W.m^{-2}K^{-1}$)
25	Wall to unheated (ZMW 0.5)	153.326 m^2	0.944 ($W.m^{-2}K^{-1}$)
26	Wall to unheated (ZMW 0.25)	73.72 m^2	1.252 ($W.m^{-2}K^{-1}$)
27	Wall to unheated (STB 0.2)	78.702 m^2	2.597 ($W.m^{-2}K^{-1}$)
28	Wall to unheated (STB 0.3)	292.4928 m^2	2.336 ($W.m^{-2}K^{-1}$)
29	Wall to unheated (STB 0.38)	124.65 m^2	2.105 ($W.m^{-2}K^{-1}$)
30	Wall to unheated (Pool 40 cm)	335.27 m^2	2.119 ($W.m^{-2}K^{-1}$)
31	Wall to unheated (Pool 30 cm)	335.27 m^2	2.336 ($W.m^{-2}K^{-1}$)
32	Exterior Wall net (yard)	57.483 m^2	0.425 ($W.m^{-2}K^{-1}$)
32.1	- Windows north-west	41.035 m^2	1.61 ($W.m^{-2}K^{-1}$)
32.2	- Windows south- east	44.486 m^2	1.61 ($W.m^{-2}K^{-1}$)

32.3	- Windows north-east	44.486 m^2	1.61 (W.m^{-2}K^{-1})
33	Exterior Wall net (Gym 0.3)	170.584 m^2	0.431 (W.m^{-2}K^{-1})
33.1	- Glass south- east	32.06 m^2	1.61 (W.m^{-2}K^{-1})
33.2	- Windows south-west	7.38 m^2	1.64 (W.m^{-2}K^{-1})
33.3	- Windows north-east	3.136 m^2	1.7 (W.m^{-2}K^{-1})
34	Exterior Wall net (Gym 0.27)	193.712 m^2	0.433 (W.m^{-2}K^{-1})
34.1	- Windows south-east	11.88 m^2	1.63 (W.m^{-2}K^{-1})
34.2	- Windows south-west	3.24 m^2	1.7 (W.m^{-2}K^{-1})
34.3	- Windows north-east	7.29 m^2	1.64 (W.m^{-2}K^{-1})

6.4.3 Wall Constructions

01. Floor to unheated (Gym above garbage room)

		d [m]	λ [W/mK]	R [m2K/W]
1	Mineralfaserschicht	0,2000	0,040	5,000
2	Stahlbeton-Decke	0,2500	2,300	0,109
3	Estrich (Zement-)	0,0400	1,400	0,029
4	Holzwerkstoff	0,1000	0,150	0,667
	Wärmeübergangswiderstände			0,340
		0,5900	RT =	6,145
			U =	**0,163**

02. Floor to unheated basement (1.BM- 2.BM)

		d [m]	λ [W/mK]	R [m2K/W]
1	Betonplatten	0,2000	2,100	0,095
2	Estrich (Beton-)	0,0400	1,400	0,029
	Wärmeübergangswiderstände			0,340
		0,2400	RT =	0,464
			U =	**2,155**

03. Floor to unheated basement (Gym above basement)

		d [m]	λ [W/mK]	R [m2K/W]
1	Mineralfaserschicht	0,0800	0,040	2,000
2	Stahlbeton-Decke	0,2500	2,300	0,109
3	Schüttung	0,2000	0,700	0,286
4	Estrich (Zement-)	0,0400	1,400	0,029
5	Holzwerkstoff	0,1000	0,150	0,667
	Wärmeübergangswiderstände			0,340
		0,6700	RT =	3,431
			U =	**0,291**

04. Floor to unheated basement (Swimming hall)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,1000	2,300	0,043
2	• Dampfbremse (PE)	0,0001	0,500	0,000
3	Schutzbeton	0,0300	1,300	0,023
4	Gefällebeton	0,0900	1,300	0,069
5	Glasmosaik	0,0300	1,200	0,025
	Wärmeübergangswiderstände			0,340
		0,2500	RT =	0,500
			U =	**2,000**

05. Floor to unheated basement (Entrance)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,1000	2,300	0,043
2	• Ausgleichsmörtel	0,1000	1,000	0,100
3	Terrazzo	0,0500	3,500	0,014
	Wärmeübergangswiderstände			0,340
		0,2500	RT =	0,497
			U =	**2,012**

06. Floor to unheated basement (Attendant`s hut)

		d [m]	λ [W/mK]	R [m2K/W]
1	Betonplatten	0,1000	2,100	0,048
2	• PE-Dampfbremsfolie	0,0001	0,500	0,000
3	Schutzbeton	0,0500	1,300	0,038
4	Mineralfaserschicht	0,0300	0,040	0,750
5	Estrich (Zement-)	0,0300	1,400	0,021
6	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,340
		0,2200	RT =	1,205
			U =	**0,830**

07. Floor to unheated basement (Pool 30 cm)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,3000	2,300	0,130
2	Zementputz	0,0300	1,000	0,030
3	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,340
		0,3400	RT =	0,508
			U =	**1,969**

08. Floor to unheated basement (Pool 40 cm)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,4000	2,300	0,174
2	Zementputz	0,0300	1,000	0,030
3	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,340
		0,4400	RT =	0,552
			U =	**1,812**

09. Floor to unheated basement Dressing area)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,1200	2,300	0,052
2	Mineralfaserschicht	0,0300	0,040	0,750
3	• Dampfbremse (PE)	0,0001	0,500	0,000
4	Schutzbeton	0,0300	1,300	0,023
5	Gefällebeton	0,0900	1,300	0,069
6	Mörtelbett	0,0400	2,300	0,017
7	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,340
		0,3200	RT =	1,259
			U =	**0,794**

10. Floor to unheated basement (Staircase)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,2500	2,300	0,109
2	Mörtelbett	0,0200	2,300	0,009
3	Terrazzo	0,0300	3,500	0,009
	Wärmeübergangswiderstände			0,340
		0,3000	RT =	0,467
			U =	**2,141**

11. Floor to unheated (3. FL - Rooftop)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,2500	2,300	0,109
2	Mörtelbett	0,0200	2,300	0,009
3	Terrazzo	0,0300	3,500	0,009
	Wärmeübergangswiderstände			0,340
		0,3000	RT =	0,467
			U =	**2,141**

12. Roof A

		d [m]	λ [W/mK]	R [m2K/W]
1	Dachpappe (2,4mm)	0,0024	0,170	0,014
2	Estrich (Zement-)	0,0300	1,400	0,021
3	Mineralfaserschicht	0,0300	0,040	0,750
4	Aluminium Dampfsperre	0,0010	221,000	0,000
5	Stahlbeton-Decke	0,1000	2,300	0,043
	Wärmeübergangswiderstände			0,140
		0,1630	RT =	0,968
			U =	**1,033**

13. Roof B

		d [m]	λ [W/mK]	R [m2K/W]
1	Dachpappe (2,4mm)	0,0024	0,170	0,014
2	Holzschalung	0,0250	0,130	0,192
3	Mineralfaserschicht	0,0300	0,040	0,750
4	Aluminium Dampfsperre	0,0010	221,000	0,000
5	Stahlbeton-Decke	0,1000	2,300	0,043
	Wärmeübergangswiderstände			0,140
		0,1580	RT =	1,139
			U =	**0,878**

14. Roof C

	Lage		d [m]	λ [W/mK]	R [m2K/W]
1	•	Rhepanol fk	0,0025	0,200	0,013
2	•	Glasvlies-Bitumendachbahn	0,0007	0,170	0,004
3	•	Korkplatten	0,0300	0,045	0,667
4	•	Polystyrol	0,0300	0,160	0,188
5	•	Aluminium Dampfsperre	0,0001	221,000	0,000
6	•	Villas Polymerbitumenbahnen Flachdach	0,0020	0,170	0,012
7		Sigma Siloxan Haftgrund	0,0010	0,000	0,000
8	•	Betonplatten	0,3000	2,100	0,143
9.0	| •	Beton	2,2701	1,580	1,437
		Breite: 0,20 m Achsenabstand: 7,20 m			
9.1	•	Luft	2,0000	0,025	80,000
9.2	•	Aluminium Dampfsperre	0,0001	221,000	0,000
9.3	•	Betonplatten	0,2700	2,100	0,129
		Wärmeübergangswiderstände			0,140
		RTo=44,196 m2K/W; RTu=30,623 m2K/W;	**2,6360**	RT =	37,409
				U =	**0,027**

Roof (Rooftop)

		d [m]	λ [W/mK]	R [m2K/W]
1	Dachpappe (2,4mm)	0,0024	0,170	0,014
2	Holzschalung	0,0250	0,130	0,192
3	Mineralfaserschicht	0,0300	0,040	0,750
4	Aluminium Dampfsperre	0,0010	221,000	0,000
5	Betonplatten	0,1200	2,100	0,057
6	Luft	1,0000	0,025	40,000
7	Vollholzsparren	0,1000	0,170	0,588
	Wärmeübergangswiderstände			0,140
		1,2780	RT =	41,741
			U =	**0,024**

15. Floor to unheated (Rooftop)

		d [m]	λ [W/mK]	R [m2K/W]
1	Fliesen	0,0100	1,300	0,008
2	Mörtelbett	0,0400	2,300	0,017
3	Dachpappe (2,4mm)	0,0024	0,170	0,014
4	Mörtelbett	0,0200	2,300	0,009
5	Gefällebeton	0,1400	1,300	0,108
6	Baupapier	0,0009	0,170	0,005
7	Mineralfaserschicht	0,0500	0,040	1,250
8	• Dampfbremse (PE)	0,0001	0,500	0,000
9	Stahlbeton-Decke	0,1200	2,300	0,052
	Wärmeübergangswiderstände			0,200
		0,3830	RT =	1,663
			U =	**0,601**

16. Exterior wall net (ZMW 0,4)

Lage		d [m]	λ [W/mK]	R [m2K/W]
1	• Keramikverkleidung	0,0030	1,200	0,003
2	Luft	0,0300	0,025	1,200
3	• Polypropylen	0,0004	0,220	0,002
4	• Mineralfaserschicht	0,0700	0,040	1,750
5.0	• Stahlbeton Breite: 0,30 m Achsenabstand: 3,60 m	0,4000	2,300	0,174
5.1	• Hochlochziegelmauerwerk	0,4000	0,500	0,800
6	• Innenputz	0,0300	0,800	0,038
	Wärmeübergangswiderstände			0,170
	RTo=3,902 m2K/W; RTu=3,777 m2K/W;	**0,5330**	RT =	3,839
			U =	**0,260**

16.1 Windows north-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	167,58	70,00	1,60
Rahmen				71,82	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	239,40		**1,60**

16.2 Windows north-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	115,71	90,00	1,60
Rahmen				12,86	10,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	128,57		**1,60**

16.3 Windows façade south-east (swimming hall)

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	123,20	88,00	1,60
Rahmen				16,80	12,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	140,00		**1,60**

16.4 Windows south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	133,36	70,00	1,60
Rahmen				57,15	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	190,51		**1,60**

16.5 Windows façade south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	100,63	80,00	1,60
Rahmen				25,16	20,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	125,79		**1,60**

16.6 Glass south-west (Staircase)

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	21,74	90,00	1,60
Rahmen				2,42	10,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	24,15		**1,61**

16.7 Windows north-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	48,36	70,00	1,60
Rahmen				20,72	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	69,08		**1,60**

16.8 Glass north-east (Staircase)

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	68,43	90,00	1,60
Rahmen				7,60	10,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	76,03		**1,60**

16.9 Windows facade north-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	167,61	80,00	1,60
Rahmen				41,90	20,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	209,51		**1,60**

16.10 Glass brick south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	4,02	100,00	3,50
Glasrandverbund	5,46	0,060				
			vorh.	4,02		**3,58**

17. Exterior wall net (ZMW 0,51)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1	•	Keramikverkleidung	0,0030	1,200	0,003
2		Luft	0,0300	0,025	1,200
3	•	Polypropylen	0,0004	0,220	0,002
4	•	Mineralfaserschicht	0,0700	0,040	1,750
5.0	•	Stahlbeton Breite: 0,51 m Achsenabstand: 7,20 m	0,5100	2,300	0,222
5.1	•	Hochlochziegelmauerwerk	0,5100	0,500	1,020
6	•	Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,170
		RTo=4,114 m2K/W; RTu=3,975 m2K/W;	**0,6430**	RT =	4,044
				U =	**0,247**

17.1 Windows north-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	25,95	70,00	1,60
Rahmen				11,12	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	37,07		**1,61**

17.2 Windows south-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	15,73	70,00	1,60
Rahmen				6,74	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	22,47		**1,61**

17.3 Windows south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	15,73	70,00	1,60
Rahmen				6,74	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	22,47		**1,61**

18.3 Windows south-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	15,73	70,00	1,60
Rahmen				6,74	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	22,47		**1,61**

18.4 Windows north-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	15,73	70,00	1,60
Rahmen				6,74	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	22,47		**1,61**

18. Exterior wall (ZMW 0.25)

			d [m]	λ [W/mK]	R [m2K/W]
1	•	Keramikverkleidung	0,0030	1,200	0,003
2		Luft	0,0300	0,025	1,200
3	•	Polypropylen	0,0004	0,220	0,002
4	•	Mineralfaserschicht	0,0700	0,040	1,750
5		Hochlochziegelmauerwerk	0,2500	0,500	0,500
6	•	Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,170
			0,3830	RT =	3,663
				U =	**0,273**

19. Exterior wall (STB 0.51)

			d [m]	λ [W/mK]	R [m2K/W]
1	•	Keramikverkleidung	0,0030	1,200	0,003
2		Luft	0,0300	0,025	1,200
3	•	Polypropylen	0,0004	0,220	0,002
4	•	Mineralfaserschicht	0,0700	0,040	1,750
5	•	Stahlbeton	0,5100	2,300	0,222
6	•	Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,170
			0,6430	RT =	3,385
				U =	**0,295**

20. Exterior wall (STB 0.4)

			d [m]	λ [W/mK]	R [m2K/W]
1		• Keramikverkleidung	0,0030	1,200	0,003
2		Luft	0,0300	0,025	1,200
3		• Polypropylen	0,0004	0,220	0,002
4		• Mineralfaserschicht	0,0700	0,040	1,750
5		• Stahlbeton	0,4000	2,300	0,174
6		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,170
			0,5330	RT =	3,337
				U =	**0,300**

21. Exterior wall (SB 0.5)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1		• Keramikverkleidung	0,0030	1,200	0,003
2		Luft	0,0300	0,025	1,200
3		• Polypropylen	0,0004	0,220	0,002
4		• Mineralfaserschicht	0,0700	0,040	1,750
5.0	ǀ	• Stahlbeton Breite: 0,50 m Achsenabstand: 3,60 m	0,5000	2,300	0,217
5.1		• Beton	0,5000	1,500	0,333
6		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,170
		RTo=3,479 m2K/W; RTu=3,472 m2K/W;	**0,6330**	RT =	3,475
				U =	**0,288**

22. Exterior wall (Ground)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1.0	ǀ	• Stahlbeton Breite: 0,50 m Achsenabstand: 3,60 m	0,5000	2,300	0,217
1.1		• Beton	0,5000	1,500	0,333
2		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,130
		RTo=0,481 m2K/W; RTu=0,478 m2K/W;	**0,5300**	RT =	0,479
				U =	**2,086**

23. Wall to unheated (ZMW 0.12)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1		• Putz	0,0200	0,800	0,025
2.0	ǀ	• Stahlbeton Breite: 0,50 m Achsenabstand: 5,30 m	0,5000	2,300	0,217
2.1		• Hochlochziegelmauerwerk	0,1200	0,500	0,240
2.2		Luft	0,3800	0,025	15,200
3		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,260
		RTo=4,307 m2K/W; RTu=2,087 m2K/W;	**0,5500**	RT =	3,197
				U =	**0,313**

24. Wall to unheated (ZMW 0.5)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1		• Putz	0,0300	0,800	0,038
2.0	|	• Stahlbeton Breite: 0,50 m Achsenabstand: 3,60 m	0,5000	2,300	0,217
2.1		• Hochlochziegelmauerwerk	0,5000	0,500	1,000
3		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,260
		RTo=1,116 m2K/W; RTu=1,002 m2K/W;	**0,5600**	RT =	1,059
				U =	**0,944**

25. Wall to unheated (ZMW 0.25)

Lage			d [m]	λ [W/mK]	R [m2K/W]
1		• Putz	0,0300	0,800	0,038
2.0	|	• Stahlbeton Breite: 0,25 m Achsenabstand: 8,00 m	0,2500	2,300	0,109
2.1		• Hochlochziegelmauerwerk	0,2500	0,500	0,500
3		• Innenputz	0,0300	0,800	0,038
		Wärmeübergangswiderstände			0,260
		RTo=0,814 m2K/W; RTu=0,784 m2K/W;	**0,3100**	RT =	0,799
				U =	**1,252**

26. Wall to unheated (STB 0.2)

		d [m]	λ [W/mK]	R [m2K/W]
1	• Stahlbeton	0,2000	2,300	0,087
2	• Putz	0,0300	0,800	0,038
	Wärmeübergangswiderstände			0,260
		0,2300	RT =	0,385
			U =	**2,597**

27. Wall to unheated (STB 0.3)

		d [m]	λ [W/mK]	R [m2K/W]
1	• Stahlbeton	0,3000	2,300	0,130
2	• Putz	0,0300	0,800	0,038
	Wärmeübergangswiderstände			0,260
		0,3300	RT =	0,428
			U =	**2,336**

28. Wall to unheated (STB 0.38)

		d [m]	λ [W/mK]	R [m2K/W]
1	• Stahlbeton	0,3800	2,300	0,165
2	• Putz	0,0400	0,800	0,050
	Wärmeübergangswiderstände			0,260
		0,4200	RT =	0,475
			U =	**2,105**

29. Wall to unheated (Pool 40 cm)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,4000	2,300	0,174
2	Zementputz	0,0300	1,000	0,030
3	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,260
		0,4400	RT =	0,472
			U =	**2,119**

30. Wall to unheated (Pool 30 cm)

		d [m]	λ [W/mK]	R [m2K/W]
1	Stahlbeton-Decke	0,3000	2,300	0,130
2	Zementputz	0,0300	1,000	0,030
3	Fliesen	0,0100	1,300	0,008
	Wärmeübergangswiderstände			0,260
		0,3400	RT =	0,428
			U =	**2,336**

31. Exterior wall net (yard)

	Lage	d [m]	λ [W/mK]	R [m2K/W]
1	• Mineralfaserschicht	0,0700	0,040	1,750
2.0	• Stahlbeton	0,2500	2,300	0,109
	Breite: 0,25 m Achsenabstand: 3,60 m			
2.1	• Hochlochziegelmauerwerk	0,2500	0,500	0,500
	Wärmeübergangswiderstände			0,170
	RTo=2,388 m2K/W; RTu=2,320 m2K/W;	**0,3200**	RT =	2,354
			U =	**0,425**

31.1 Windows north-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	34,88	85,00	1,60
Rahmen				6,16	15,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	41,04		**1,61**

31.2 Windows south-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	37,81	85,00	1,60
Rahmen				6,67	15,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	44,49		**1,61**

31.3 Windows south-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	37,81	85,00	1,60
Rahmen				6,67	15,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	44,49		**1,61**

32. Exterior wall net (Gym 0.3)

			d [m]	λ [W/mK]	R [m2K/W]
1	•	Mineralfaserschicht	0,0800	0,040	2,000
2	•	Stahlbeton	0,3000	2,300	0,130
3		Gipsputz	0,0150	0,700	0,021
		Wärmeübergangswiderstände			0,170
			0,3950	RT =	2,321
				U =	**0,431**

32.1 Windows north-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	37,81	85,00	1,60
Rahmen				6,67	15,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	44,49		**1,61**

32.2 Windows south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	5,17	70,00	1,60
Rahmen				2,21	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	7,38		**1,64**

32.3 Windows south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	2,20	70,00	1,60
Rahmen				0,94	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	3,14		**1,70**

33. Exterior wall net (Gym 0.27)

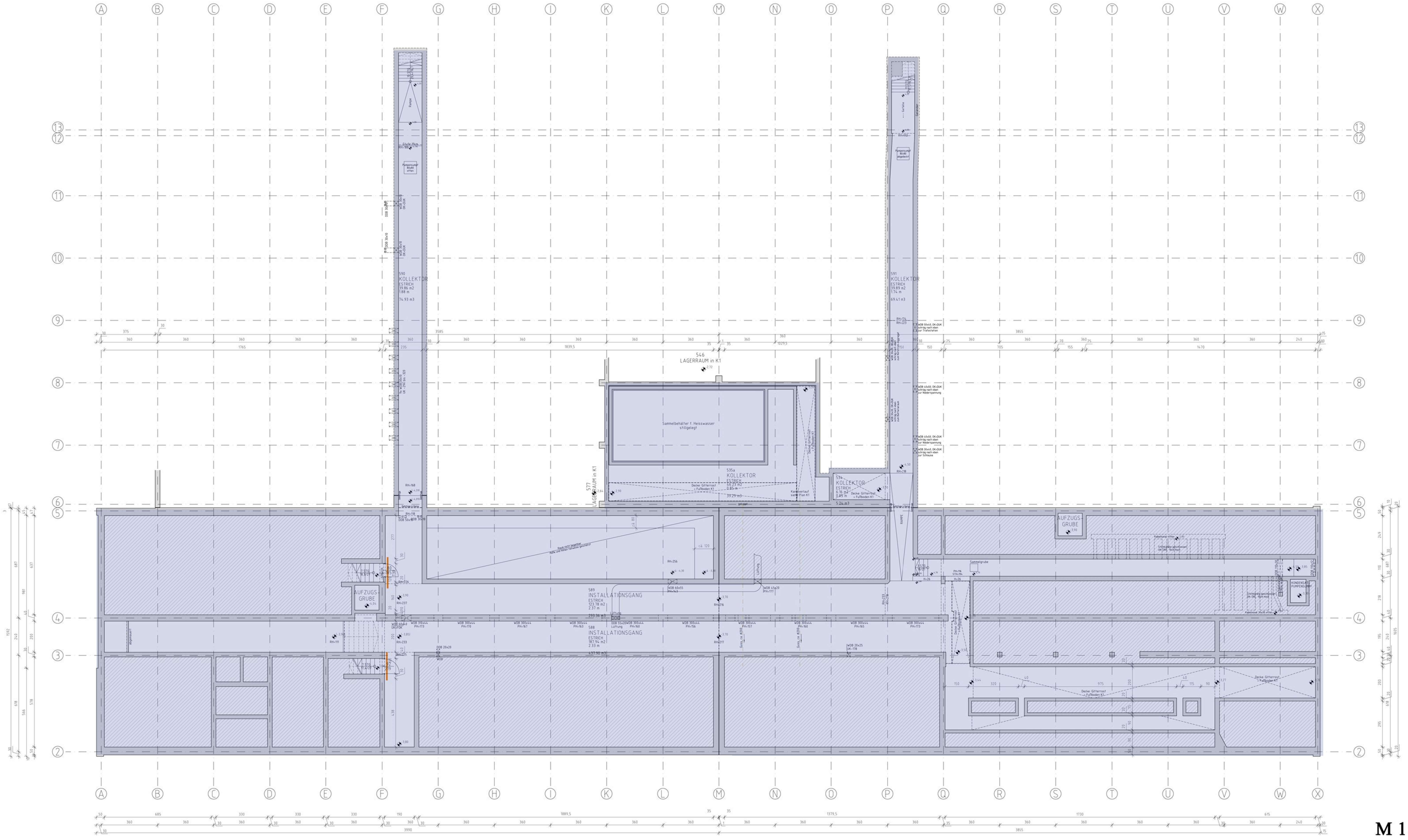
			d [m]	λ [W/mK]	R [m2K/W]
1	•	Mineralfaserschicht	0,0800	0,040	2,000
2	•	Stahlbeton	0,2700	2,300	0,117
3		Gipsputz	0,0150	0,700	0,021
		Wärmeübergangswiderstände			0,170
			0,3650	RT =	2,308
				U =	**0,433**

33.1 Windows south-east

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	8,32	70,00	1,60
Rahmen				3,56	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	11,88		**1,63**

33.2 Windows south-west

	Länge	ψ	g	Fläche	%	U
	m	W/mK	-	m²		W/m²K
Verglasung			0,590	2,27	70,00	1,60
Rahmen				0,97	30,00	1,60
Glasrandverbund	5,46	0,060				
			vorh.	3,24		**1,70**



M 1:300

2. Basement

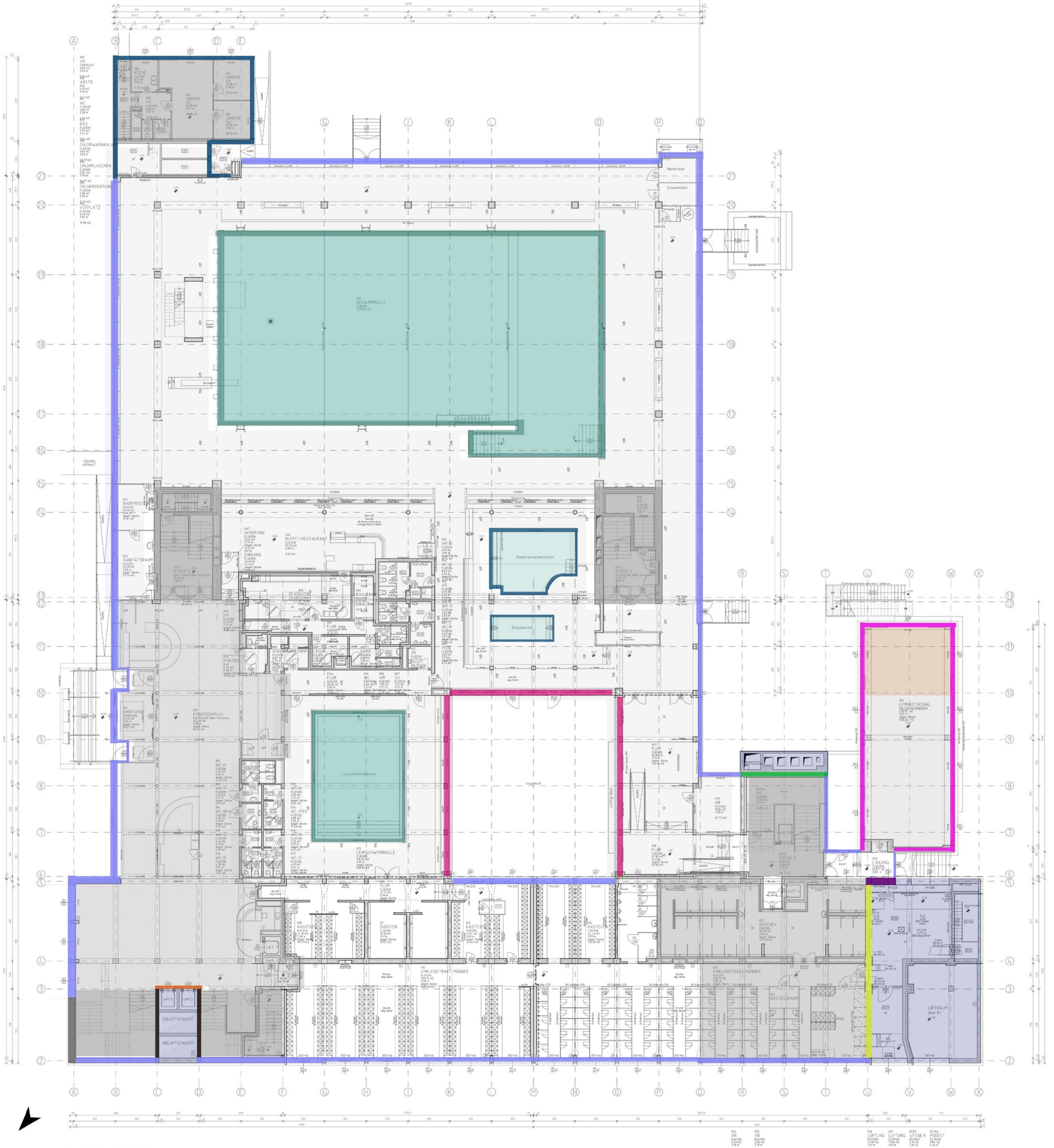
■ Unheated basement 1486.81 m²

1. Basement

Heated gross area 555.8 m^2
Heated gross volume 1056.11 m^3
Windows north- west 30.78 m^2

▨ Unheated basement 4574.03 m^2
⬜ Floor to unheated basement 555.8 m^2
🟦 Exterior wall gross (SB 0.5) 88.21 m^2 &
🟦 Exterior wall gross (Ground) 48.64 m^2
🟨 Wall to unheated (ZMW 0.12) 16.68 m^2
🟩 Wall to unheated (ZMW 0.25) 73.72 m^2
🟪 Wall to unheated (ZMW 0.5) 126.88 m^2
🟥 Wall to unheated (STB 0.3) 43.07 m^2

M 1:500

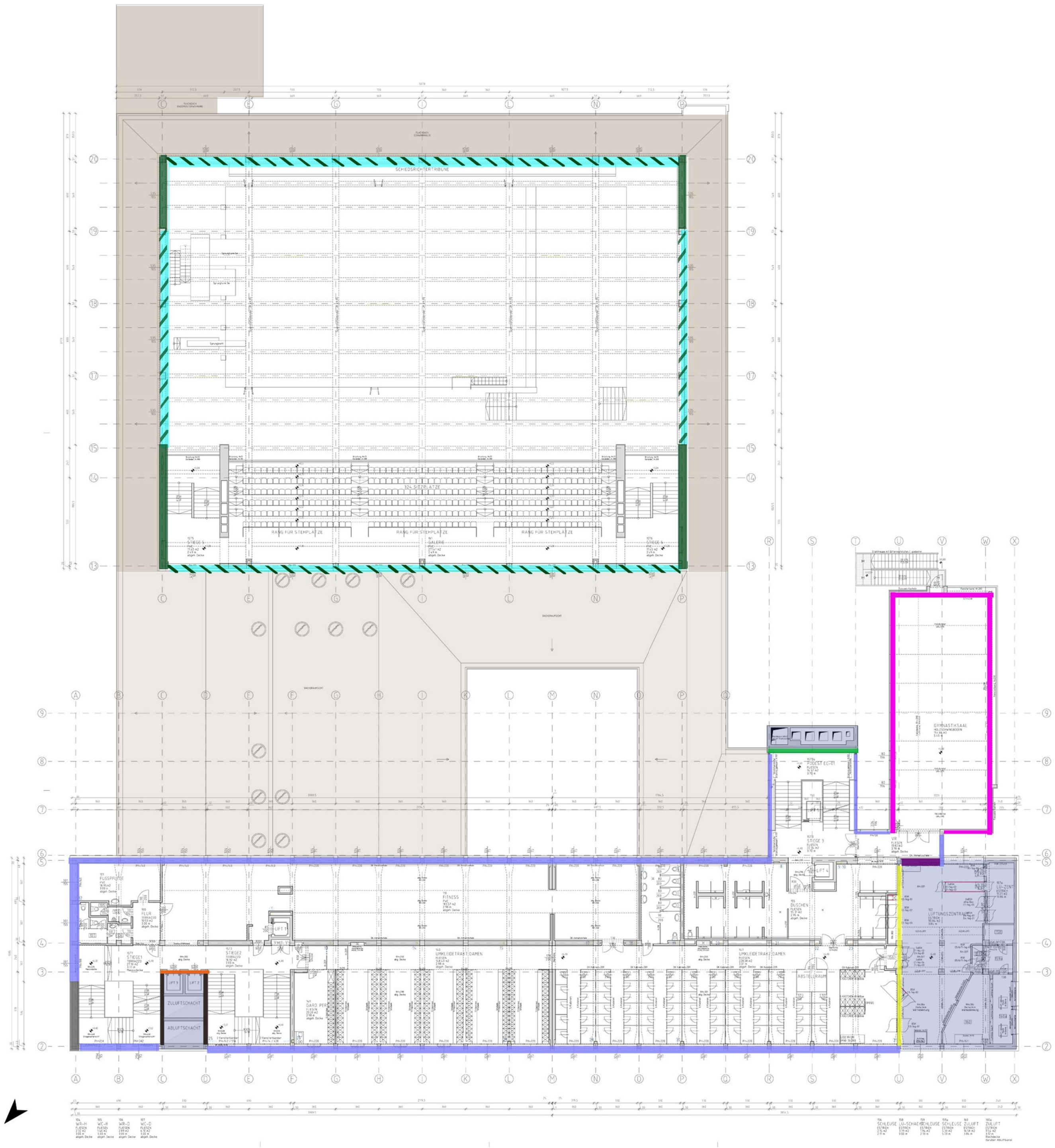


M 1: 500

Ground floor

Heated gross area 4403.7 m²
Heated gross volume 19933.79 m³
Windows & Glass facades 700.1 m²

- ⬜ Floor to unheated basement (Staircase) 274.36 m²
- ⬜ Floor to unheated basement (Swimming hall) 1808.2 m²
- ⬜ Floor to unheated basement (Attendant's hut) 92.96 m²
- 🟩 Floor to unheated basement (Pool 40cm) 716.52 m²
- 🟩 Floor to unheated basement (Pool 30cm) 63.47 m²
- ⬜ Floor to unheated basement (Entrance) 452.22 m²
- 🟫 Floor to unheated (Gym above garbage room) 50.12 m²
- ⬜ Floor to unheated basement (Gym above basement) 108.51 m²
- ⬜ Floor to unheated basement (Dressing area) 255.58 m²
- 🟪 Unbeheizt area 194.13 m²
- 🟦 Exterior wall gross (ZMW 0.4) 1052.91 m²
- 🟥 Exterior Wall gross (Yard) 187.49 m²
- 🟦 Exterior Wall gross (ZMW 0.25) 145.88 m²
- ⬛ Exterior Wall gross (STB 0.4) 32.97 m²
- 🟪 Exterior Wall gross (Gym 0.27) 216.13 m²
- 🟨 Wall to unheated (ZMW 0.12) 70,61 m²
- 🟧 Wall to unheated (0.2 STB) 23,17 m²
- 🟩 Wall to unheated (STB 0.38) 31.13 m²
- ⬛ Wall to unheated (STB 0.3) 73.29 m²
- 🟪 Wall to unheated (0.5 ZMW) 10.58 m²
- 🟩 Wall to unheated (Pool 40 cm) 335.27 m²
- 🟦 Wall to unheated (Pool 30 cm) 51.41 m²



M 1: 500

1. Floor

Heated gross area 2833.91 m²
Heated gross volume 18349.55 m³
Windows & Glass facades 263.28 m²

🟪	Unbeheizt area 194.13 m²
🟫	Roof B 613.06 m²
⬜	Roof A 913.41 m²
🟦	Exterior wall gross (ZMW 0.4) 711.57 m²
🟪	Exterior Wall gross (Gym 0.3) 213.16 m²
🟦	Exterior wall gross (ZMW 0.51) 633.24 m²
🟩	Exterior wall gross (STB 0.51) 1616.6 m²
⬜	Exterior wall gross (STB 0.4) 25.58 m²
🟨	Wall to unheated (ZMW 0.12) 70.61 m²
🟪	Wall to unheated (ZMW 0.5) 15.87 m²
🟧	Wall to unheated (STB 0.2) 23.13 m²
⬛	Wall to unheated (STB 0.3) 73.29m²
🟩	Wall to unheated (STB 0.38) 31.13m²

M 1: 300

2. Floor

Heated gross area 1256.77 m²
Heated gross volume 5215.6 m³
Windows & Glass facades 226.95m²
Roof C (swimming hall) 1523.59 m²
Roof A (gym) 171.68 m²

🟦 Exterior Wall gross (ZMW 0.4) 756,704 m²
▨ Exterior Wall gross (STB 0.4) 32.13 m²
⬛ Wall to unheated (STB 0.3) 51.42 m²

🟩 Wall to unheated (STB 0.38) 31.2 m²
🟨 Wall to unheated (ZMW 0.12) 51.33 m²
🟧 Wall to unheated (STB 0.2) 16.22 m²
⬜ Unheated area 63,58 m²

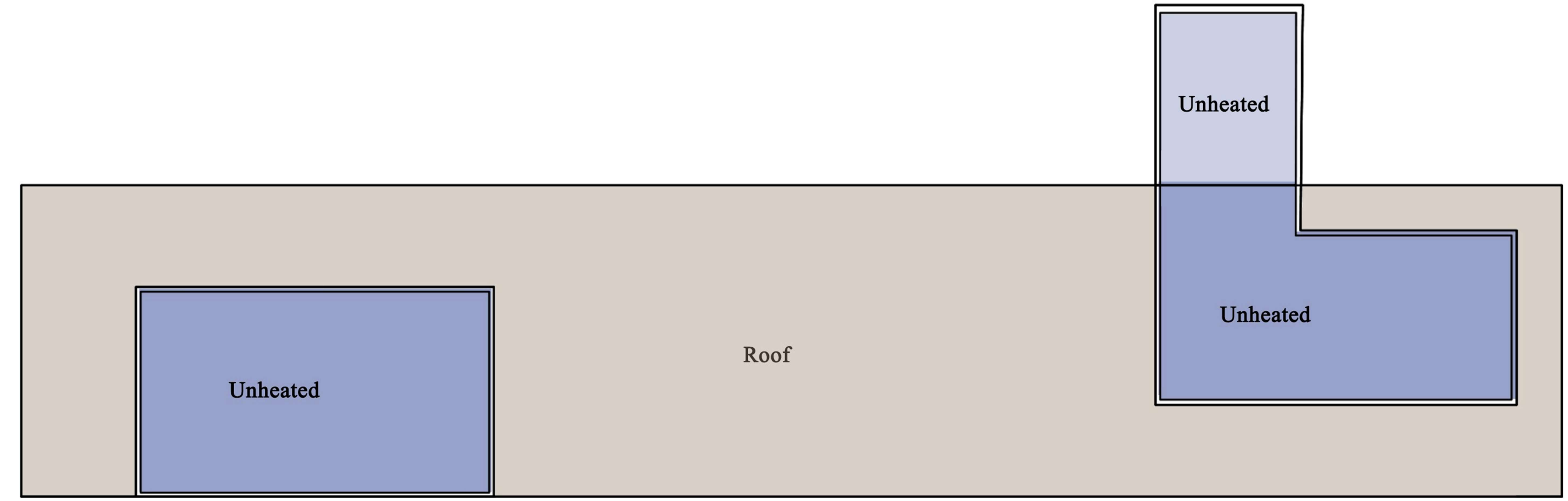
Note: Due to lack of information of the gymnasium`s roof, the construction has been set to the same as Roof A

M 1: 300

3. Floor

Heated gross area 1256.77 m²
Heated gross volume 5215.6 m³
Windows & Glass facades 226.95m²

🟦	Exterior Wall gross (ZMW 0.4) 756,704 m²
⬜	Exterior Wall gross (STB 0.4) 32.13 m²
⬛	Wall to unheated (STB 0.3) 51.42 m²
🟩	Wall to unheated (STB 0.38) 31.2 m²
🟨	Wall to unheated (ZMW 0.12) 51.33 m²
🟧	Wall to unheated (STB 0.2) 16.22 m²



M 1: 300

Rooftop

🟦 Floor to unheated (Rooftop) 375.15 m²

🟪 Floor to unheated (3.FL - Rooftop) 68.31 m²

🟫 Roof (Rooftop) 868.21 m²

7 CONCLUDING REFLECTIONS

Between the year 2015 and 1990, the overall energy consumption in Europe has decreased by - 2.5%. While countries, such as the Baltic states have contributed to this outcome by reaching an energy reduction of up to -57%, other countries, including Austria, have increased their usage by more than a third. (Figure 25) (Austria Presse Agentur eG 2017)

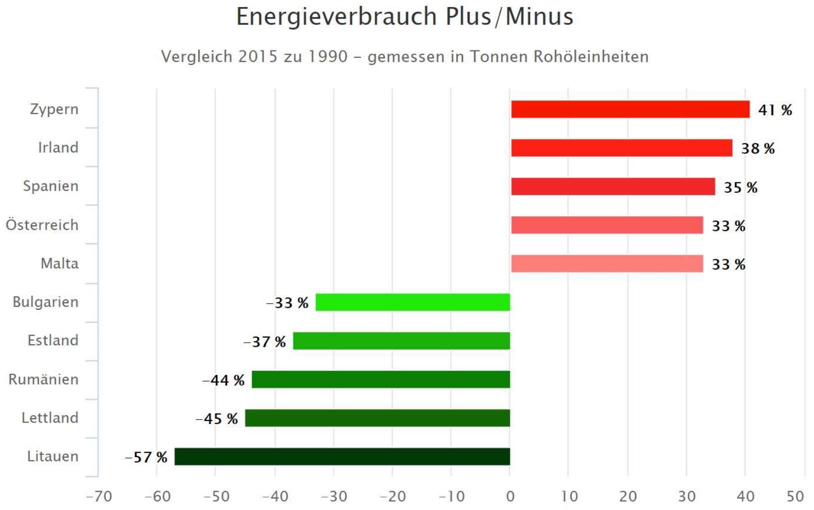


Figure 25: Energy consumption plus/minus- Comparisson 2015 to 1990, measured in tons oil equivalent (source: Austria Presse Agentur eG, 2017)

Given Austria's self-definition as lighthouse state in sustainable development, this development can be considered to be very disillusioning. Moreover, it can be understood as a call for change. Today, it is even more than necessary to take actions in creating a more sustainable environment and impel the public to create a greater environmental and energy awareness in Austria. Especially projects such as renovating deprecated swimming halls, strongly contribute to a more energy efficient and healthy environment due to their role as public buildings and lighthouse projects. Given the extreme indoor conditions in such buildings, which is connected with extreme water and energy consumption, modern and efficient technology are decisive for a sustainable future operation.

Via conducting projects such as the renovation of the Floridsdorfer swimming hall, the MA 44 has set an important cornerstone towards a more conscientious future and has proved itself as an environmental role model operator. Reducing the energy consumption in such a great extent with a financial support model such as the energy contracting, has not only shown the feasibility and effectiveness of such renovations, but could further promote environmental awareness in general.

Besides the meaningfulness for sustainability, Vienna’s swimming pools are an active contribution to a vivid and liveable social environment in Vienna and have thus a big socio-cultural impact. As such, the swimming pool halls by F.F. Grünberger contribute to Vienna’s building heritage, even if the buildings are from a period that is widely underestimated by the architectural perception of the general public. The baths designed by Grünberger can be considered as well-working in terms of building typology and flexibility. Moreover, they form a backbone of Vienna’s public bathing buildings. Thus, the general analysis of Grünberger’s work is more than working on a specific architect’s oeuvre, but rather contributing to the state of knowledge regarding this specific building typology.

Even though the city of Vienna has already made quite a progress in modernizing its baths, there is still much more to do in order to target a decline in energy consumption in Austria. It is however important to use projects, such as the renovation of the Floridsdorfer indoor bath, as role models and keep studying their building physical behavior to extend our knowledge in this area.

This contribution constitutes a starting point for further investigations of Vienna`s district indoor pools. Researching the effectiveness of Vienna`s contracting projects more deeply and comparing the targeted results to the actual outcomes, helps create a clearer picture of this process. By studying the details of these renovations and investigating the building envelope, acoustical behavior, lighting, energy usage and occupancy behavior, the buildings overall behavior can be understood, and predictive assumptions can be made more clearly. This not only helps create a more accurate estimation of the effectiveness of the refurbishments, but also helps optimize the implemented measures towards the individual constructions.

8 INDEX

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9 REFERENCES

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10 APPENDIX

10.1 Catalogue of Significant Works

Legend:

E = Europe-bath

The given years denote the beginning of the planning phase.

Recreational Facilities

with indoor swimming pool

- Braunschweig/ Lower Saxony- Nordbad (1968) – E
- Braunschweig/ Lower Saxony- Am Sackring (1972) – E
- Braunschweig/ Lower Saxony- Heidbergbad (1972) – E
- Braunschweig/ Lower Saxony- Gliesmarode (1974) – E
- Daun/Eifel/Rheinland-Pfalz (1968) – E
- Düsseldorf-Gerresheim (1960)
- Düsseldorf- Oberkassel (1966)
- Düsseldorf- Unterrath (1965)
- Düsseldorf- central bath with wave pool
- Kassel- Baunatal/Hessen – E
- Kufstein/Tyrol- private bath (1967)
- Kufstein/Tyrol- private bath (1968)
- Langen bei Frankfurt/Main (1969) – E
- Marburg-Marbach/ Hessen (1970) – E
- Münster/Nordrhein-Westfahlen (1973) – E
- Nienhagen/Lower Saxony (1970) – E
- Schneverdingen/ Lower Saxony (1970) – E
- Schwalmstadt/ Hessen (1969) – E
- Selm bei Dortmund (1972) – E
- Semmering/Lower Austria- Austrian mineral oil administration plc (1974)
- Sprendlingen bei Frankfurt/ Main (1971) – E
- St. Moritz/Engadin- private bath with movie theatre and bowling alley (1959)
- Voerde/ Nordrhein-Westfahlen (1973)

- Wien- Dianabad - with Prof. Lippert (1966)
- Wien- Floridsdorf (1962)
- Wien- private bath (1969)
- Wien- Kaltenleutgeben- private bath (1967)
- Wien- Schmelz- federal school for physical education and university institution- indoor pool- with Prof. Purr (1969)

with outdoor swimming pool

- Bludenz/Vorarlberg (1956)
- Berndorf/ Lower Austria (1960)
- Brunn am Gebirge/ Lower Austria- natural beach (1962)
- Dürnkrut/ Lower Austria (1974)
- Düsseldorf- Lörick- natural beach (1960)
- Düsseldorf- Unterbacher lake- natural beach (1960)
- Gloggnitz/ Lower Austria (1953)
- Gumpoldskirchen/ Lower Austria (1961)
- Jenbach/ Tyrol (1960)
- Leverkusen- Bayern plants (1957)
- Lustenau/ Vorarlberg (1960)
- St. Johann/ Tyrol (1960)
- Salzburg- Leopoldskron- park bath (1960)
- Steyr/ Upper Austria (1956)
- Traiskirchen/Lower Austria (1950)
- Waidhofen/Ybbs/ Lower Austria (1961)
- Wattens/ Tyrol (1953)
- Wien- palace Laudon
- Zistersdorf/ Lower Austria (1960)

with indoor- & outdoor swimming pool

- Auersthal/ Lower Austria (1966)
    - indoor pool – E
    - outdoor pool
- Eschborn/ Hessen (1971)
    - indoor pool – E
    - outdoor pool
- Hannover- stadium pool (1964)
    - indoor pool
    - outdoor pool
- Köln- Brück (1974) – E
- Korneuburg/ Bisamberg/ Lower Austria (1973) – E
- Neunkirchen/ Lower Austria
    - indoor pool
    - outdoor pool – E
- Nürnberg (1973)
- Steinbach/ Taunus/ Hessen (1968)
    - indoor pool with medical baths– E
    - outdoor pool
- Stockerau/ Lower Austria
    - indoor pool (1973)
    - outdoor pool (1963) – E
- Tulln /Lower Austria (1972)
    - indoor pool – E
    - outdoor pool
- Wien Ottakring (1968) – E
- Wildeshausen/ Lower Saxony
    - indoor pool (1969) – E
    - outdoor pool

Sports Facilities

- Maria Enzersdorf- Südstadt/ Lower Austria- Austrian federal sports centre – with Prof. Hubatsch (1970)
- Großraum Frankfurt- local recreational- & sports centre (1972)
- Perchtoldsdorf/ Lower Austria- sports centre (1971)
- Vöcklabruck/ Upper Austria- athletic sports facility (1962)
- Wattens/ Tyrol- football stadium, athletic sports facility (1953)

Sanatoriums & Clinics

- Daun/ Eifel/ Rheinland-Pfalz – sanatorium with indoor pool (1968)
- Düsseldorf- sanatorium in the central bath (1955)
- Düsseldorf- diabetes research centre (1963)
- Düsseldorf- DRK Krankenhaus (1963)
- St. Radegund/ Styria – cardiovascular sanatorium (1968)
- Sylt/ Westerland- sanatorium with apartment building- with Arch. Scheide (1969)
- Wien- sanatorium in the Dianabad (1966)
- Wien Floridsdorf- sanatorium in the indoor bath (1962)
- Wien Oberlaa- curative spring spa (1970)

Buildings of Various Kinds

- Hessen- model swimming- and sports hall for comprehensive schools (1972)
- Kassel- Baunatal/ Hessen- artificial ice rink ((1974)
- Perchtoldsdorf/ Lower Austria- artificial ice rink (1973)
- Sauna facilities in indoor- & outdoor baths
- Schottwien/ Lower Austria- city hall (1958)
- Stockerau/ Lower Austria- motorway maintenance agency (1950)
- Traiskirchen/ Lower Austria- city hall cellar (1950)
- Tulln/ Lower Austria- federal school centre- with Arch. Neckam, A. Obermann & Dr. W. Obermann (1973)
- Tulln/ Lower Austria- city hall & gas station (1959)
- Weißenbach/ Lower Austria- city hall (1948)
- Wiener Prater- messerestaurant (1969)
- Wien Stadlau- post- & administrative building- with Arch. Scheide (1970)
- Wildeshausen/ Lower Saxony- artificial ice rink (1974)

- Housing complexes in: Gänserndorf/ Lower Austria
  Gloggnitz/ Lower Austria
  Purkersdorf/ Lower Austria
  Pyrawarth/ Lower Austria
  Reisenberg/ Lower Austria
  Retz/ Lower Austria
  Scheibbs/ Lower Austria
  Schottwien/ Lower Austria
  Semmering/ Lower Austria
  Wels/ Upper Austria
  Wien III., XIII., XVIII & XII
- Sauna facilities in indoor- & outdoor swimming baths
- Restaurant- & buffet operations within the recreational facilities
- Premises

futher

- Several single-family houses, exhibitions, urban development projects & assessments at home and abroad

(Grünberger 1974)

10.2 Prizewinning Competitions & Lectures

Prizewinning Competitions

1950	Traiskirchen/ Lower Austria- city hall cellar	1st Prize
1955	Steyr/ Upper Austria- outdoor swimming pool	1st Prize
1955	Bludenz/Vorarlberg- outdoor swimming pool	1st Prize
1958	Salzburg-Leopoldskron- outdoor swimming pool	1st Prize
1960	Sauerbrunn/ Burgenland- sanatorium	2nd Prize
1967	Innsbruck- university intensive training centre	2nd Prize
1967	St. Radegund/ Styria- cardiovascular sanatorium	1st Prize
1970	Wien-Oberlaa- curative spring spa	3rd Prize

1971	Bad Hall/ Upper Austria- sanatorium	3rd Prize
1973	Kassel- Baunatal/ Hessen- indoor pool	1st Prize
1973	Nürnberg- indoor- & outdoor pool	1st Prize
1973	Tulln/ Lower Austria- federal school centre - with Arch. Neckam, A. Obermann & Dr. W. Obermann	1st Prize

Lectures

1955	Congress of the German society for the baths industry in Düsseldorf: “Development of the baths industry in Austria”
1958	Baths conference in Baden bei Wien: „Baths construction today and tomorrow”
1960	International congress for leisure in Straßburg: “Problems of leisure in Austria today and tomorrow”
1962	Baths conference in Baden bei Wien: „Development of the baths construction in relation to the recreation centre”
1963	Tourist conference in Linz/ Upper Austria: “Modern baths construction”
1963	Congress of the German society for the bathing industry in Kiel: “Modern baths construction in the recreation centre- yes or no?”
1965	International symposium of the International Academy for baths studies & baths technology in Hannover: “Planning, construction and operation of large swimming pools”
1965	Conference of the Austrian Institute for the construction of school- & sports facilities ÖISS in Raach/ Lower Austria. “The individual baths construction in Austria”
1965	At the exhibition of the German society for baths industry in Berlin: “Heating of pool water in outdoor pools”
1965	Congress of the German society for the bathing industry in Baden- Baden: “Forms and possibilities of international collaborations within the scientific and organizational field of the baths industry”
1966	4th International sauna congress in Munich. “Planning & design of sauna facilities”

1966	1. International congress for the bathing industry (INTERBAD) in Düsseldorf: “Typification of prefabricated construction methods in the baths construction”
1967	Seminar of the Council of Europe in Cologne: “low-cost sports facilities-construction and operation of swimming pools” Submission of the EUOPE-BATH concept
1968	Day seminar for the German City day in Nürnberg: “Development in the outdoor- & indoor baths construction” “Calculation in the outdoor- & indoor baths construction” “Operating costs in the outdoor- & indoor baths construction”
1968	Information conference for the county of Hessen in Gladenbach: “Construction, operation and development in the indoor baths construction”
1969	Guest lecture at the University of Vienna: “Outdoor baths” “Indoor baths” “Combination baths”
1969	Information conference for the county Niedersachsen in Bückeburg: “indoor baths, outdoor baths- Further development of the Europe- bath”
1969	Hotel construction seminar in Bad Homburg: “The development of the hotel indoor pools in Europe”
1969	Baths conference of the Swedish city- & municipality day in Stockholm: “The bathing facilities of the future”
1969	Guest lecture at the Technical University in Braunschweig: “Baths construction of the future for sports & leisure”
1969	International congress of the international task force sport facility construction IAKS in Cologne: “Sports facilities & bathing facilities” “New methods in the construction of indoor swimming baths & swimming pools”
1969	Information conference of the German Architects in Hannover: “Indoor- & outdoor baths – planning- & development tendencies”
1969	Conference of the German Society for construction in Bückeburg: “Economic indoor baths construction in district towns and centre communities”

1970	International congress for the baths industry (INTERBAD) in Munich: “New findings in the construction of baths”
1972	Information conference for the baths journal in Salzburg, Schloss Fuschl: “Problems in construction & operation of baths”
1973	Guest lecture at the institute of science & art in Vienna: “Venue- & sports facility construction in architecture”
1973	Congress of the German Society for the baths industry in Reichenhall & Salzburg: “Experience & development of the baths construction in Austria”
1973	Hungarian baths day in Budapest: “International tendencies in the baths construction”
1974	2nd International colloquium within the scope of the SPORTEXPO in Bordeaux: “Sports- & leisure facilities”
1974	Guest lectures at the Technical University in Vienna. “Problems of the baths construction & operation in practice”
1974	10 years Austrian institute for for school-& sports facility construction ÖISS, conference in Baden: Indoor baths construction “the construction & requirements concerning the indoor baths construction Submission of the indoor baths guidelines

(Grünberger 1974)

10.3 Publications

by Professor F.F. Grünberger

6/1965	Sports- & baths constructions “Planning, construction and operation of large swimming pools”
7/1965	Archive of the baths industry “ Fresh wind from Austria in the baths construction” “ Forms & possibilities of international collaboration in the scientific & organizational field in the baths industry”

1966 Special print Austrian construction chronicle
    “Individual construction in the baths industry”
    “ Recreation centre Lustenau, Vorarlberg”
    “Lido Lörick, Düsseldorf, West Germany”
    “ Recreation centre St. Johann, Tyrol”
    “ Recreation centre Stockerau, Lower Austria”
    “ Recreational centre Unterbacher See, in the area Düsseldorf, West Germany”
    “ Ice stadium St. Moritz, Switzerland”
    “ The sauna”
    “ The small bath complex”, private bath St. Moritz, hotel bath Schloss Laudon, Vienna
    “ District indoor baths” (garden indoor baths, indoor- & outdoor bath)
    “ District indoor bath Düsseldorf-Gerresheim”
    “District indoor bath Düsseldorf- Unterrath”
    “Planning, construction and operation of large swimming pools”
    “Indoor bath Floridsdorf, Vienna”
    “Central bath Düsseldorf, West Germany”
    “Stadium indoor bath Hannover, West Germany”
    “Information about the activity of the office Arch. Prof. Ing. F.F. Grünberger, Vienna- Düsseldorf”

9/1966 Special print of the ARCHIVE OF THE BATHS INUSTRY
    “Düsseldorf`s baths”
    “New central bath Düsseldorf”
    “Exercise swimming pools with flexible pool bottom”
        “Wave swimming bath with sports equitable 50-m pool”

1/1967 ARCHIVE OF THE BATHS INDUSTRY
    “Typification & prefabricated construction in the baths construction”

6/1967 Special print sports facility construction & bath facilities
    “Indoor baths, inexpensive sports facilities- construction and operation of swimming baths”

1/1968 School- & sports facility construction ÖISS
    “Indoor swimming baths, inexpensive sports facilities – construction and operation of swimming baths”

1970	Official publication of the lecture by Prof. Arch. F.F. Grünberger on occasion of the Council of Europe seminar “The indoor baths, inexpensive sports facilities- construction & operation of swimming baths” (Europe-bath)
13/1970	Review of the Council for Cultural Co-operation of the Council of Europe Education and Culture “Recreational activities in the year 2000” “The establishment of culture”
1970	Information of the administration union area Ziegenhain about the construction of the first Europe-bath including three pools in the federal republic
1/1970	City forum- urban development, architecture, economy “Stadium bath Hannover”
2/1971	Sports- & baths construction “Centre- Garden indoor bath district Ziegenhain” “Europe- bath Ziegenhain/Treysa”
8/1973	The development “International tendencies in the bath construction“
1/1974	Baths Journal “The future of the Europe-bath”
1974	Austrian Institute for School- & Sports facility construction ÖISS “Indoor baths- guidelines”

about Professor F.F. Grünberger

12/1965	Archive of the baths industry “Model exhibition in Berlin”
1966	Austrian construction chronicle Special episode baths construction “We present- Prof. Arch. Ing. F.F. Grünberger”
1966	Special publication of the journal construction- construction planning, construction technology, construction operation “Central bath in Düsseldorf” “Lido in Düsseldorf- Lörick”

“People`s recreation centre Unterbacher See in Düsseldorf”
“District indoor bath in Düsseldorf- Gerresheim”
“District indoor bath in Düsseldorf- Unterrath”
“District indoor bath in Düsseldorf- Oberkassel”

1966 Special print Austrian construction chronicle
Curriculum Vitae of Prof. Arch. Ing. F.F. Grünberger
“The outdoor bath”
“Recreation centre (Centrelax)”
“Recreation centre Lustenau, Vorarlberg”
“Lido Lörick, Düsseldorf, West Germany”
“Recreation centre St. Johann, Tyrol”
“Recreation centre Stockerau, Lower Austria”
“Recreation centre Unterbacher See, in the area of Düsseldorf, West Germany”
“Ice stadium St. Moritz, Switzerland”
“The sauna”
“The small bath facility”
“Private bath St. Moritz”
“Hotel bath Schloss Laudon, Vienna”
“District indoor baths” (Garden indoor baths, indoor- & outdoor baths)
“District indoor bath Düsseldorf- Gerresheim”
“District indoor bath Düsseldorf- Unterrath”
“Planning, construction and operation of large swimming pools”
“Indoor bath Floridsdorf, Vienna”
“Central bath Düsseldorf, West Germany”
“Stadum indoor bath Hannover, West Germany”
“Information about the activity of the office Arch. Prof. Ing. F.F. Grünberger, Vienna- Düsseldorf”

9/1966 Special print of the ARCHIVE OF THE BATHS INDUSTRY
“Düsseldorf`s baths”
“New central bath Düsseldorf”
“Exercise pools with flexible pool bottom”
“Wave swimming bath with sports equitable 50-m pool”
“Therapeutic bath organization in the new central bath Düsseldorf”
“Suspension roof, an economical solution for large swimming halls with 50-m pools”

10/1966	International construction journal construction- construction planning, construction technology, construction operation “Central bath Düsseldorf”
2/1967	Architecture current “Centrelax Stockerau” “Indoor bath Vienna- Floridsdorf” Idea concept of modern bath construction
5/1967	Sports facility construction & baths facilities “Recreation centre Stockerau, Austria”
5/1967	Special print sports facility construction & baths facilities, indoor- & outdoor baths “Recreation centre Stockerau, Austria”
12/1967	ARCHIVE OF THE BATHS INDUSTRY “A section of modern baths facilities/ Salzburg baths exhibition
1/1968	Sports- & baths constructions “Urban indoor baths in the culture centre Floridsdorf”
3/1968	Sports facility construction & baths facilities “Recreation centre Lustenau, Vorarlberg”
8/9/1968	The development “Reconstruction & expansion of the summer bath Ottakring, Vienna” “The indoor bath Floridsdorf, Vienna” “Studies for a new Dianabad Vienna” “Recreation centre Stockerau, Lower Austria” “Recreation centre Auersthal, Lower Austria” “Recreation centre Brunn am Gebirge, Lower Austria” “District indoor bath Oberkassel- Düsseldorf” “Nordbad Braunschweig Bienroderweg”
3/1969	Sports facility construction & baths facilities “Private bath Zöhrer”
5/1969	Sports facility construction & baths facilities “Hotel bath Schloss Laudon, Vienna”
6/1969	Sports facility construction & baths facilities “Private bath Niarchos with bowling alley, Villa Marguns, St. Moritz”

1970	Information of the administration union area Ziegenhain about the construction of the first Europe-bath including three pools in the federal republic
1/1970	City forum- urban development, architecture, economy “Stadium bath Hannover”
2/1970	Sports- & baths construction “Centre- garden indoor bath area Ziegenhain/Treysa”
4/1971	Documentation, information “Europe bath in Treysa, area Ziegenhain/Hessen” “The first Europe-bath with three pools in the federal republic”
6/1971	Sports facility construction & baths facilities “Stadium bath Hannover”
1/1972	Baths journal “Competition Hohe Warte, Vienna, PRO & CONTRA” “Indoor bath Ottakring”
2/1972	Sports facility construction & baths facilities “Recreation centre St. Johann in Tyrol- design: Prof. Ing. F.F. Grünberger, Vienna”
3/1972	Baths journal “The indoor bath in Auersthal, Lower Austria”
5/1972	Sports- & baths constructions “Indoor bath Hannover”
6/1972	Baths journal “The new stadium bath in Hannover”
7/1972	ARCHIVE OF THE BATHS INDUSTRY “Largest indoor bath of the federal republic opens- Hannover”
8/1972	The building authority “First Europe-bath in the federal republic with three pools”
1973	CITY FORUM “Europe baths in Braunschweig” “Nordbad“ „Characteristics of the Europe- baths am Sackring & Heidbergbad”

		"Bath am Sackring"
		"Heidbergbath"
1/1973	German construction magazine DBZ	"Architecture design detail stadium bath Hannover"
3/1973	Baths journal	"Federal sports centre Südstadt"
4/1973	Baths journal	"The indoor bath Steinach am Taunus"
		"Indoor bath & culture centre Daun"
8/1973	The development	"Ottarkinger bath, Vienna 16, Johann- Staud- Straße"
11/1973	ARCHIVE OF THE BATHS INDUSTRY	"Three Europe-baths in Braunschweig completed"
1/1974	Baths journal	"25 years architect Friedrich Florian Grünberger"
		"The origin of the Europe- bath"
		"Short characteristic of the built Europe- baths"
		"The new treatment centre in Oberlaa"
2/1974	Baths journal	"For the cure to Oberlaa"
		"Europe bath Auersthal"
2/1974	Sports baths recreation constructions	"Niedersachsen stadium in Hannover"
3/1974	ARCHIVE OF THE BATHS INDUSTRY	"The new indoor bath in the health centre of the city Daun/Eifel"
1974	Labours magazine	"The new health centre in Oberlaa opened"
15/1974	Austrian construction magazine	"A health centre for Vienna"
5/6/1974	The development	"Curative spring Vienna- Oberlaa, Kurmittelhaus"

(Grünberger 1974)