complex projects

TU Delft

2022/23

COMPLEX PROJECTS
Bodies & Buildings studio

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THE REVIVAL OF NATURAL VENTILATION

Glossary:

Swimming Pool (n): A structure that has been built for people to swim in. [1]

Olympic Aquatic Centre (n): A swimming pool based on Olympic swimming pool size requirements and includes other aquatic sports besides swimming.

Air Quality (n): Refers to the condition of the air within our surroundings [2]

Natural Ventilation (v): The process of pulling fresh air into and out off a building, without the assistance of mechanical equipment

[1] Longman. (2010). Swimming Pool. In Active Study Dictionary (5th ed., Vol. 1, p. 907). Pearson Education.
[2] R. (2020, November 6). What is Air Quality, How it Gets Degraded and Ways to Improve it. Conserve Energy Future. Retrieved April 15, 2022, from https://www.conserve-energy-future.com/what-is-air-quality.php

INDEX

1. Preface & Facination

The 'Bodies and Buildings' graduation studio focuses on the following three topics: **Body, Building, and Berlin.** Together the exploration of these topics interlink with each other and form the answer to the studio's main research question: *How does one design a 'one off' building in the context of Berlin?*

The topic of the **building** focuses on certain building typologies that represent a 'one off' building typology within the context of Berlin. The term 'one of' describes a typology where there could only be one or a limited amount within a city parameter. Examples of such typologies are a parliament building, university building or hospital. A 'one off' building could also be described as a building that is functionally specific, making the building increasingly complex. This chosen building typology forms the final design project of the graduation studio and functions as the main topic of the studio. The chosen building typology for this research plan is an Olympic aquatic centre. An Olympic aquatic centre's function is derived from the typology of a swimming pool. However, it is explicitly built based on Olympic swimming pool size requirements and includes other aquatic sports. The research plan will refer to a swimming pool instead of an Olympic aquatic centre when mentioning the building. It is a more straightforward term to understand but still describes the primary function of an Olympic aquatic centre.

In order to support the design of the building, the topic of **Berlin** is introduced to provide an overview of Berlin's history and context. Specified to the chosen typology, a better understanding of the term 'one off' and what it means in the context of Berlin is created. Which will then help form design objectives further on in the design process. For example, Berlin has a rich history of swimming facilities both for recreational use and to facilitate exercise. Even though many swimming facilities are available to the inhabitants, there remains a high demand for outdoor and indoor swimming facilities within the city and its context. This high demand is primarily due to a growing social interest in the activity (Pereira, 2017). A deep dive into the role of the swimming pool within the context of Berlin could determine which role the Olympic aquatic centre could play in this discussion.

The topic of the **body** focuses on a particular building element that impacts or controls the way the body, in this case, the human body, experiences and functions within the building. These different building elements highlight the complexity of the chosen building typology. The implementation of these building elements into the design of a building is complex and involves a lot of discussion about their architectural performance within a building's design. This is where this research plan plays into the project's objective. The research described by the research plan aims to support the design process during the graduation studio by exploring one of these building elements and their relationship to the body. Within the interest of the chosen typology, this research focuses on the element of climate, particularly air quality, concerning the design of a swimming pool.

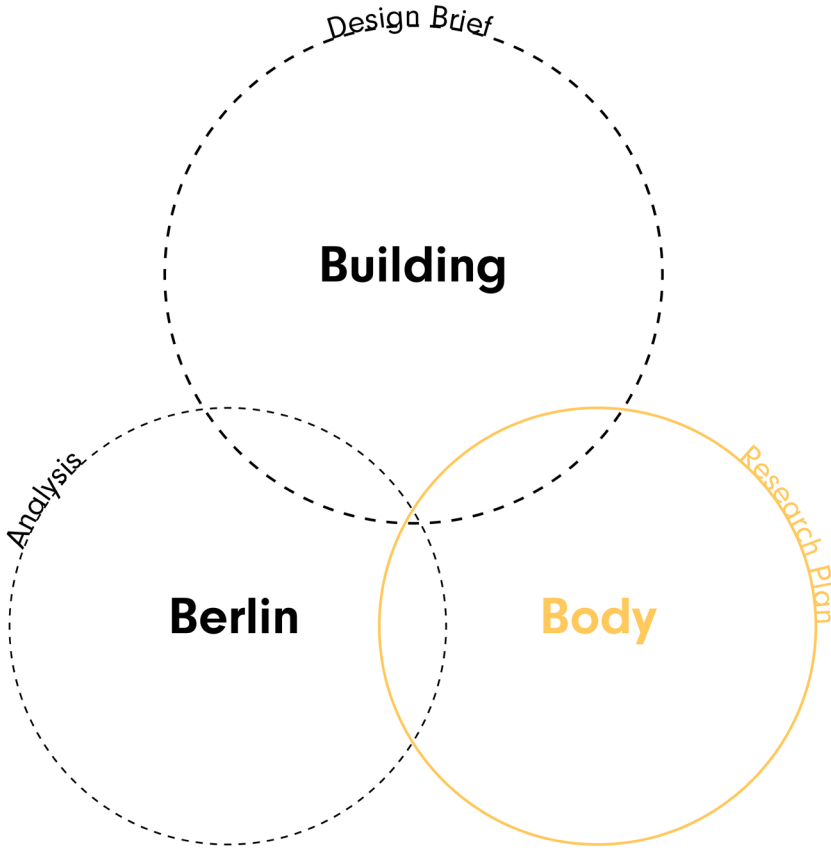


Figure 1: Visualisation 'Bodies and Buildings' graduation studio (Author, 2022)

2. Introduction

2.1. Early bath houses

The swimming pool can find its origins in the creation of bathhouses during the Iron Age. From around 1700 to 1400 B.C., many Greek cities started building bathing facilities to provide ways for inhabitants to keep clean, as the Greeks believed cleanliness was essential for a person's wellbeing (Basaran & Ilken, 1998). Many famous philosophers, such as Plato and Hippocrates, talked about the experience of bathing and the advantages it has for a person's health and wellbeing (Gianfaldoni et al. 2017). Hippocrates theorised that bathing helped solve specific liquid imbalances within the body that caused certain illnesses.

Later on, this theory was adopted into Greek medical practices. The ancient Greeks introduced the importance of bathing within society, but it was only during Roman times that bathing began playing a significant part in the entire society. It was one of the most common daily activities practised by many different social classes. As seen in figure 2, these bathing practices mostly took place in communal bathhouses as only the wealthiest members of society could afford private bathing facilities (Gianfaldoni et al., 2017). The bathing rituals were complex and extensive. When visiting a public bath, the visitor would visit different temperature baths, increasing humidity, forming a complex ritual (Ashenburg, 2010). These climate differences were created by specially designed natural ventilation techniques, with which they could control the air quality within different rooms. The Greek philosopher Vitruvius described this carefully designed process in his ten books on architecture (Pollio & Morgan, 2021).

2.2. The introduction of the swimming pool

Besides bathhouses, swimming pools were also part of Greek civilisation. They were used to train soldiers (McVicar, 1936). However, these pools did not include climatised differences for the visitors, such as in public baths at the time and therefore were seen as a different typology. With the rise of private bathing facilities during the 19th and 20th centuries, public bathhouses lost their original use primarily due to the growth of material prosperity (Twigg, 1997).

With this change in the use of public bathhouses, swimming pools started to have a more prominent role within society. Where bathhouses had the sole purpose of cleanliness, a swimming pool's primary focus was that of exercise. Where, in bathing houses, the influence of different indoor climates, determined by humidity and temperature levels, had a purposeful impact on the body as part of this cleansing experience, this was not the case for swimming pools. As the focus of the typology shifted from the bodily experience to the movement of the body, the inclusion of specialised humidity and temperature levels became unnecessary. It is assumed that the innovative technological advances regarding natural ventilation and heating systems that were made for Greek and Roman bathhouses to achieve different air qualities (humidity and temperature levels), such as the hypocaust system (figure 3) were eventually lost during this transition from bathhouses to modern-day swimming pools (Basaran & Ilken, 1998).

Figure 2: Illustration of a Roman Bath ([Illustration of a Roman Bath], n.d)

2.3. Experience of the air quality within swimming pools

However, there remains a somewhat unique experience regarding the air quality within today's swimming pools. When visiting a swimming pool, the visitor still experiences different indoor climates depending on the different uses of the pool. Air quality, in particular, humidity and temperature, play the most significant role during this experience. From the humid air the visitor inhales when visiting the warm recreational pool, to the stale cold air when swimming in the Olympic sized swimming pool which functions more like a high bodily performance environment. Once the visitor leaves the building and walks outside, there is a collective feeling of having visited a swimming pool. Additionally, air quality also plays an integral part in the movement of bodies within swimming pools, especially Olympic sized swimming pools. It has been proven that certain air quality levels, especially humidity and CO_2 levels, improve swimming abilities, whereas other air quality levels can negatively impact swimming abilities (Felgueiras et al. 2020). This direct correlation between humidity, temperature and CO_2 levels and the experience of the body, as well as the impact on the performance of the body, makes it an interesting topic to research. It is especially fascinating concerning the objective of the graduation studio, where the research supports the graduation project design of an Olympic aquatic centre, which is specifically focused on the movement of bodies.

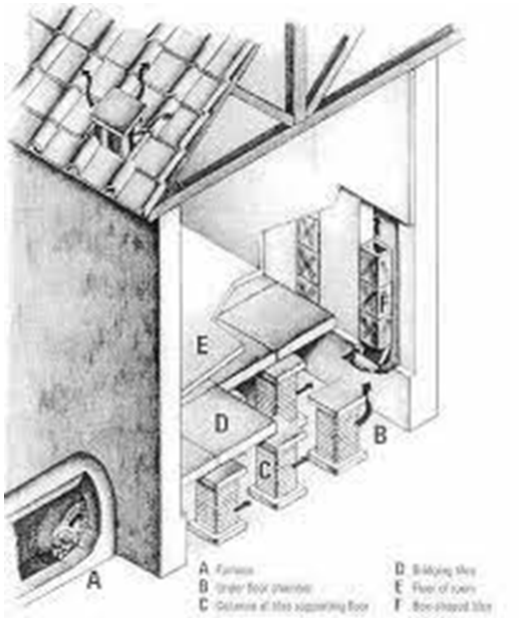


Figure 3: Cutaway diagram of a Roman hypocaust system (underground heating) (Dobson, n.d.)

2.4. Problem statement

The importance of air quality, especially humidity, temperature and CO_2 levels, makes for the implementation of primarily mechanical ventilation techniques in modern-day swimming pools. Because it is believed that mechanically ventilated buildings have more accessible climate control abilities (Lévesque, 2015). However, with today's climate change problems and an enhanced focus on energy sufficient building techniques, as well as the Covid pandemic, some claim that the inclusion of natural ventilation systems into our building systems could have significant advantages for designing environmental conscious buildings as well as safer and healthier buildings in regards to the spread of future airborne viruses (Allard, 1998; Zarandi, 2006; Bhagat, 2020). Therefore, this research aims to explore which natural ventilation techniques could be implemented into the design of modern-day swimming pools whilst still maintaining modern-day user comfort in regards to air quality levels (humidity, temperature and CO_2 levels).

3. Research Questions

Following this problem statement, **the main research question is**:

Which natural ventilation systems could be implemented into the design of modern-day swimming pools to achieve user comfort in regards to air quality, particularly humidity, temperature and CO_2 levels?

3.1. Phase 1: A deep dive into the swimming pool

In order to organize the research, it will be divided into different themes. Besides the fact that the different themes explore different aspects of the leading research question, they also provide the different phases of the research. The first phase explores the topic of the 'building': the swimming pool. It introduces the history of the swimming pools as a typology and lists the required air quality standards needed to answer the main research question. As seen in figure 4, **the sub-questions** which are addressed in this part of the research are:

How did the typology of swimming pools develop over time?

Which air quality requirements are needed to achieve standard user comfort levels in modern-day swimming pools, especially regarding humidity, temperature and CO_2 levels?

3.2. Phase 2: The revival of natural ventilation

The second phase introduces the topic of the 'body': natural ventilation systems. As with the first phase, the history of natural ventilation systems will be listed to form a complete overview of all natural ventilation systems. After this, the qualities and disadvantages of these different natural ventilation systems regarding air quality will be compared to the air quality requirements listed during the first phase. As seen in figure 4, **the sub-questions** which are addressed in this part of the research plan are:

What is the progression of natural ventilation systems throughout time?

What are the advantages and disadvantages of each natural ventilation type regarding the air quality within modern-day swimming pools?

3.3. The topic of Berlin

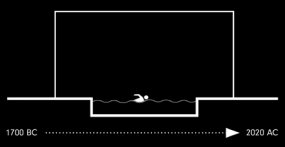
These topics describe either the 'body' as a research question or the 'building'. When answering each sub-question, the topic of 'Berlin' will be discussed by applying the found information to the context of Berlin. For example, when answering the sub-question: How did the typology of swimming pools develop over time? The developments found regarding the typology of swimming pools will be compared to certain Berlin case studies as well, as a further exploration of the topic.

For figure 4 look on the next page

RESEARCH QUESTION

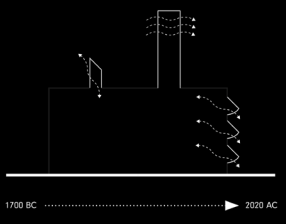
Phase 1: The Revival of Natural Ventilation Phase 2:

Which natural ventilation systems could be implemented into the design of modern-day swimming pools to achieve user comfort in regards to air quality, particularly humidity, temperature and CO2 levels?



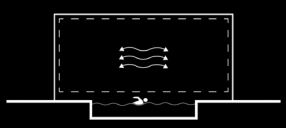
Part 1:

How did the typology of swimming pool develope over time?



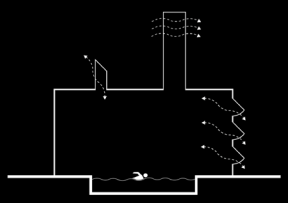
Part 1:

What is the progression of natural ventilation systems throughout time?



Part 2:

Which air quality requirements are needed to achieve standard user comfort levels in modern-day swimming pools, especially regarding humidity, temperature and CO2 levels?



Part 2:

What are the advantages and disadvantages of each natural ventilation type regarding the air quality within modern-day swimming pools?

'Body'
(hypothesis)

Figure 4: Visualisation Research Questions (Author, 2022)

4. Methods & Methodology

4.1. Phase 1: A deep dive into the swimming pool

Part 1: History of swimming pools

How did the typology of swimming pools develop over time?

Through the use of literature, an overview of the history of swimming is formed. This overview is created by forming a literature review that tracks the development of swimming both as a recreational activity as well as a sport through the social and technological changes which have occurred. Because these changes often directly correlate with changing requirements of swimming pools, they also influence the architectural requirements for swimming pools (Chaline, 2017). During the literary review, particular case studies will be highlighted through plan analysis to get a better understanding of the architectural implications of these developments on the typology. Certain Berlin case studies, such as the Schwimm- und Sprunghalle in the Europasportpark (SSE), will be highlighted as well (see figure 5). By using literary review to find certain case studies, there is the risk of missing out on specific case studies that could be interesting to the topic of the 'building'. As explained in figure 10, A visual timeline will be used to organize the information.

Figure 5: Schwimm- und Sprunghalle in the Europasportpark (SSE), Berlin ([Velodrome], n.d)

Part 2: Air quality requirements

Which air quality requirements are needed to achieve standard user comfort levels in modern-day swimming pools, especially regarding humidity, temperature and CO_2 levels?

Using literary research, and performing a literary review, a list of air quality requirements, focussing primarily on humidity, temperature, and CO_2 levels, will be formed (Figure 10). Because air quality requirements are partly dependent on local buildings laws, part of this research will focus on Berlin as an example. In case the literary review gives minimal results, the case studies found in Berlin during the first part of the research will be analysed according to the implemented air quality requirements within these buildings. This further exploration expands on the plan analysis from part one by looking further into the different building plans and sections by focusing on the ventilation systems within these buildings (figure 6 & 7).

4.2. Phase 2: The revival of natural ventilation

Part 1: History of natural ventilation systems

What is the progression of natural ventilation systems throughout time?

Through literary research, a list of natural ventilation techniques throughout history is formed. By performing a plan analysis of particular case studies of each natural ventilation system, using 3D modelling, the implementation of these natural ventilation techniques and the resulting air flows within the building will be further explored. Also, through the analysis of floorplans and sections, the architectural implications of these natural ventilation systems will be explored. Due to the broad scope of this part of the research, including all types of natural ventilation systems disregarding building typology and place in history, the focus will primarily be on case studies found within Europe. This specific focus is primarily due to the location of Berlin within this part of the world. As described in figure 10, a visual timeline will be formed, gathering all found natural ventilation systems. In order to organise the timeline, the timeline is divided into five different time periods (see figure 8): The Iron Age, Middle Ages, Early modern period, Long ninetieth century and the twenty-first century. The timeline forms a visual narrative from which certain conclusions could be drawn. For example, during the industrial revolution, mechanical ventilation, as opposed to natural ventilation, became more prevalent due to certain technological advances as well as a changing attitude regarding indoor air quality. During this period, innovations within the field of natural ventilation systems were limited. A good example of the sudden implementation of mechanical ventilation is the Metropolitan Opera House in New York City (see figure 9).

Part 2: Qualities of natural ventilation systems

What are the advantages and disadvantages of each natural ventilation type regarding the air quality within modern-day swimming pools?

By using the case studies and plan analysis used in part one of the research, the collected natural ventilation systems are organised according to their advantages and disadvantages regarding air quality. The advantages and disadvantages of each natural ventilation system are established through literary review work (figure 10). By cross-referencing this information with the conclusions drawn from the research into air quality requirements of swimming pools of phase one, it can be concluded which natural ventilation techniques can be applied to the typology of a swimming pool and which do not. Through this methodology, the different research approaches overlap, and the main research question will be answered.

For figure 10 look on page 18

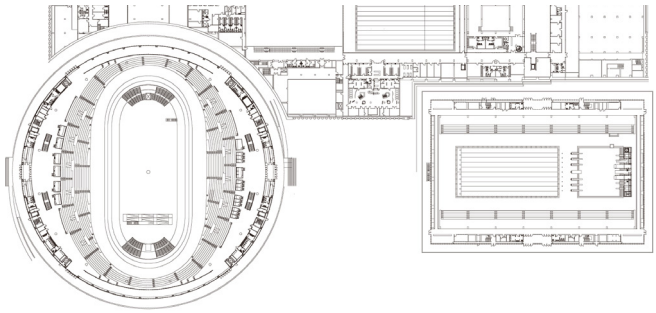


Figure 6: Floorplan +38.50, Schwimm- und Sprunghalle in the Europasportpark ([Floorplan +38.50], n.d.)

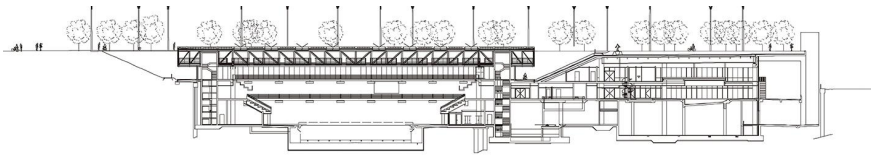


Figure 7: Section, Schwimm- und Sprunghalle in the Europasportpark ([Section], n.d.)

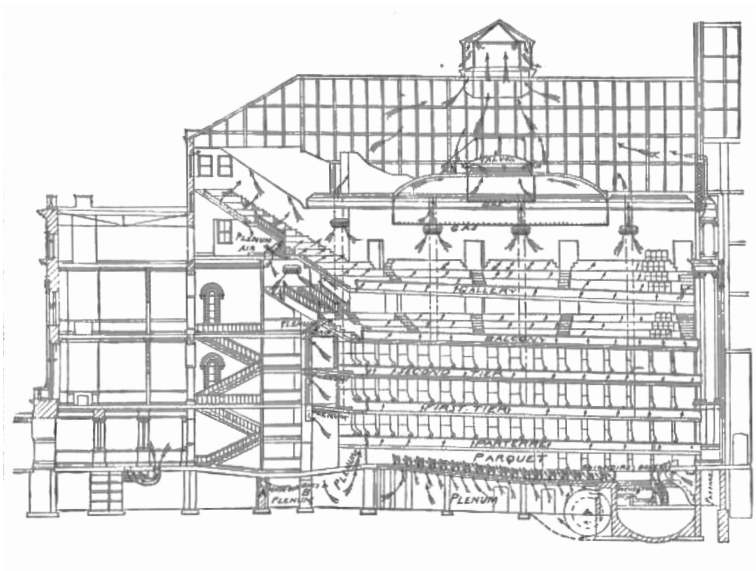


Figure 9: Metropolitan Opera House, New York City, longitudinal section ([Metropolitan Opera House]. n.d)

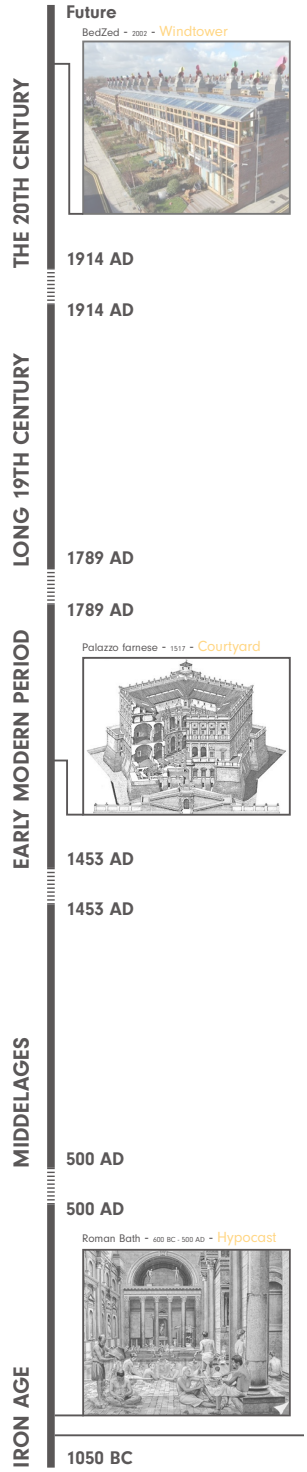
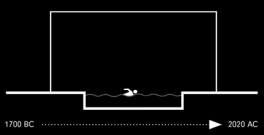


Figure 8: Visualisation possible start timeline (Author, 2022)

METHODS & METHODOLOGY

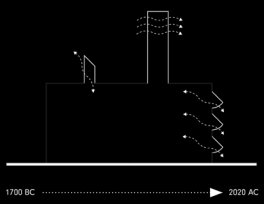
Phase 1: The Revival of Natural Ventilation Phase 2:

Which natural ventilation systems could be implemented into the design of modern-day swimming pools to achieve user comfort in regards to air quality, particularly humidity, temperature and CO2 levels?



Part 1:

How did the typology of swimming pool develope over time?

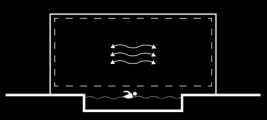


Part 1:

What is the progression of natural ventilation systems throughout time?

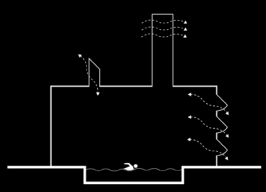
Literary Research & Case Studies
literary overview, Timeline

Literary Research & Case Studies
literary overview, Timeline



Part 2:

Which air quality requirements are needed to achieve standard user comfort levels in modern-day swimming pools, especially regarding humidity, temperature and CO2 levels?



Part 2:

What are the advantages and disadvantages of each natural ventilation type regarding the air quality within modern-day swimming pools?

Literary Research & Case Studies
Literary overview, list of requirements

Literary Research & Case Studies
Literary overview, list of requirements

'Body'
(hypothesis)

List of possible natural ventilation systems:

- .....
- .....
- .....
- .....

Figure 10: Visualisation methodology (Author, 2022)

5. Theoretical Framework

When forming the overview of natural ventilation systems, the research focuses on case studies found within Europe. However it is essential to look into sources such as Dehghani-sanij, Soltani, & Raahemifar (2015), which focuses on the wind towers of Meybodcity in Iran, as a natural ventilation technique (figure 11), as these non-European natural ventilation techniques are often the inspiration behind the development of natural ventilation techniques applied in Europe. Some examples of a wind tower implementation such as those in Meybodcity, are the wind towers of the BedZed community in London, England (figure 12).

There is already research that lists different natural ventilation techniques commonly used within specific typologies of buildings. An example of such research is Dahl (2010) who introduces different natural ventilation techniques widely used within typical vernacular architecture. This paper plans to collect these various researches and forms a collective overview of all natural ventilation systems. This collective overview is an attempt to develop an encyclopaedia of natural ventilation systems for practitioners within the field of architecture. It can form a base for further exploration on the topic of natural ventilation systems. Likewise, this theoretical approach, also applies to the exploration of the development of the swimming pool. Chaline (2017), Twigg (1997), and Lévesque (2015) all describe different parts of the development of the swimming pool. However, this research combines these other researches and uses various case studies to illustrate these developments.

Likewise, there is not yet research which forms a connection between natural ventilation systems and modern-day swimming pools. Most research regarding natural ventilation systems relating to specific typologies explores other typologies such as schools (Wachenfeldt, Mysen, & Schild., 2007), office buildings (Ismail & Rahman, 2012) and university buildings (Kleiven, 2003). By applying these different natural ventilation systems in swimming pools, this research gives a small insight into what role natural ventilation systems could play in today's design of complex buildings.

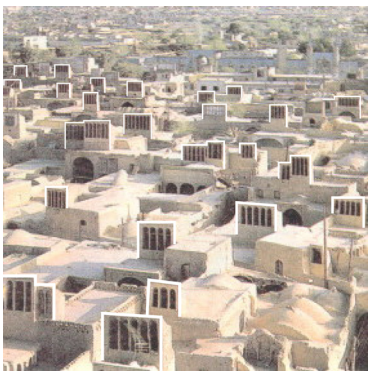


Figure 11: The one-sided wind towers of Meybod city, Yazd province, Iran (Bahadori & Dehghani-sanij, 2014)

Figure 12: Highlighted wind towers ([BedZed, London, England], 2002)

6. Synthesis & Outlook

This research aims to explore which natural ventilation techniques could be implemented into the design of modern-day swimming pools whilst still maintaining modern-day user comfort in regards to air quality levels (humidity, temperature and CO_2 levels). The research functions as an explorative tool for the design project. When specific natural ventilation techniques can apply to the typology of a swimming pool, these techniques will form the narrative regarding the design of the Olympic aquatic centre. Even when the outcome of the research contradicts what is implied by the research question, and no natural ventilation systems can provide the required air quality, the exploration of the history of swimming pools (timeline) should provide enough references that will help when further within the project. Likewise, the found humidity, temperature and CO_2 level requirements within the context of Berlin will get integrated into the design brief. As described in figure 13, all of this information can provide information for the development of the design brief and help during the design process, even if the main question is not successfully answered.

SYNTHESIS & OUTLOOK

MSC 3

RESEARCH (BODY)

Phase 1: **The Revival of Natural Ventilation** Phase 2:

'Building'

1700 BC — 2020 AC

Part 1:

How did the typology of swimming pool develope over time?

Literary Research & Case Studies
literary overview, Timeline

Part 2:

Which air quality requirements are needed to achieve standard user comfort levels in modern day swimming pools, especially in regards to humidity, temperature and CO2 levels?

Literary Research & Case Studies
Literary overview, list of requirements

1700 BC — 2020 AC

Part 1:

What is the progression of natural ventilation systems throughout time?

Literary Research & Case Studies
literary overview, Timeline

Part 2:

What are the advantages and disadvantages regarding each natural ventilation type regarding the air quality within modern day modern day swimming pools?

Literary Research & Case Studies
Literary overview, list of requirements

'Body'
(hypothesis)

List of possible natural ventilation systems:

- .....
- .....
- .....

DESIGN BRIEF (BUILDING)

'Building'

'Design Brief'

MSC 4

FINAL DESIGN (BUILDING)

'Building'

Figure 13: Visualisation synthesis & outlook research plan (Author, 2022)

7. A Deep Dive Into the Swimmingool

7.1. Early bath houses

The swimming pool can find its roots in the creation of bathhouses during the Roman and Greek ages. From around 1700 to 1400 B.C. (Figure 13), many Greek cities started building bathing facilities to provide ways for inhabitants to keep clean, as the Greeks believed cleanliness was essential for a person's wellbeing (Basaran & Ilken, 1998). Many famous philosophers, such as Plato and Hippocrates, talked about the experience of bathing and the advantages it has for a person's health and wellbeing (Gianfaldoni et al. 2017). Hippocrates theorised that bathing helped solve specific liquid imbalances within the body that caused certain illnesses.

Later on, this theory was adopted into Greek medical practices. The ancient Greeks introduced the importance of bathing within society, but it was only during Roman times that bathing began playing a significant part in the entire society. It was one of the most common daily activities practised by many different social classes. As seen in figure 2, these bathing practices mostly took place in communal bathhouses as only the wealthiest members of society could afford private bathing facilities (Gianfaldoni et al., 2017). The bathing rituals were complex and extensive. When visiting a public bath, the visitor would visit different temperature baths, increasing humidity, forming a complex ritual (Ashenburg, 2010).

7.2. The introduction of the swimming pool

Besides bathhouses, swimming pools were also part of Greek civilisation. They were used to train soldiers (McVicar, 1936) (Figure 14). With the rise of private bathing facilities during the 19th and 20th centuries, public bathhouses lost their original use primarily due to the growth of material prosperity (Twigg, 1997).

With this change in the use of public bathhouses, swimming pools started to have a more prominent role within society. Where bathhouses had the sole purpose of cleanliness, a swimming pool's primary focus was that of exercise. Where, in bathing houses, the influence of different indoor climates, determined by humidity and temperature levels, had a purposeful impact on the body as part of this cleansing experience, this was not the case for swimming pools. As the focus of the typology shifted from the bodily experience to the movement of the body, the inclusion of specialised humidity and temperature levels became unnecessary. It is assumed that the innovative technological advances regarding natural ventilation and heating systems that were made for Greek and Roman bathhouses to achieve different air qualities (humidity and temperature levels), such as the hypocaust system (figure 3) were eventually lost during this transition from bathhouses to modern-day swimming pools (Basaran & Ilken, 1998).

7.3 Modern day swimmingpools

As mentioned before the transistion of Bathing houses to swimming pools was done by creating outdoor swimming pools. A great example of this is the rise of ouside floating pools during the 19th century in europe which started to encurage the rise of swimming as a form of exercise. (Chaline, 2017) The encouragement of swimming as a sport was done by including the sport as part of the olympic games. Since then the sport started to develope itself through innovation and progress.

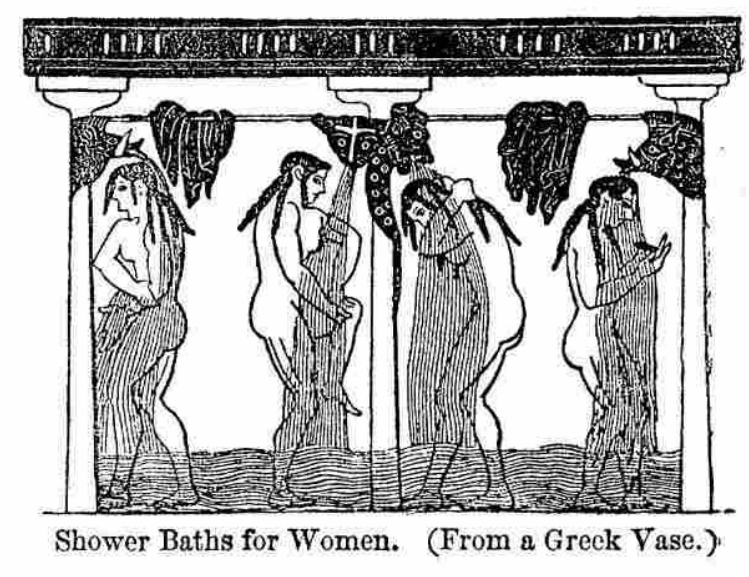


Figure 14: Illustration of Shower Baths ([Illustration of a Roman Bath], n.d)

Figure 15: View of greek baths (n.d)

Figure 16: View of roman baths (n.d)

For example the sport tranformed from outdoor swimming to indoorswimming. As well as innovations within the sport itsself. The poolsize and conditions changes of the years to create a better environments to preform as well as climate conditions changing. This cased a shift of focus. Where before the swimming pool was designed to be a high performance environment to support the Bodily Experience, to a high performance environment to support the Bodily Performance. With this also came certain climatised requirements.

7.4 Air Quality Requirements

These climatised requirements are changing every so often, however the main requirements are set. This also awnsers the subquestion: *Which air quality requirements are needed to achieve standard user comfort levels in modern-day swimming pools, especially regarding humidity, temperature and CO2 levels?.*

According to Fanger, 2000; Lévesque, 2015 and Felgueiras, 2020. The given air quality requirements are the following. The average CO2 levels should be between 500-750 ppm. The indoor temperature should be maximum 30 degrees and in combination with the temperature the air humidity should lay at around 60%. These requirement are not just to create a confortable indoor climate to deliver top performances. But also to prevent condensation to arise within the swimming pool. an exact overview is given in figure 17.

It is important when assesing wether or not natural ventilation systems are able to function within olympic aquatic centers that the outdoor climate within the buildings context is able to have the found air quality requirements.

Figure 17: Modern day swimming (Author, 2022)

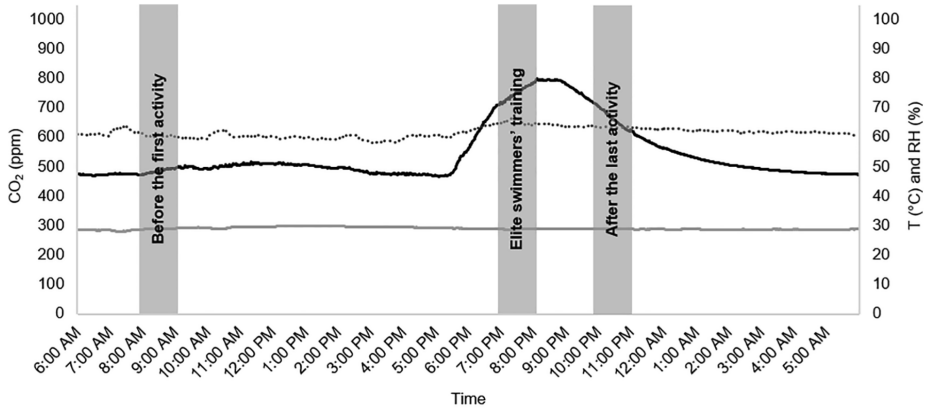


Figure 18: Indoor air requirements (Author, 2022)

8. The revival of natural ventilation

8.1. History of natural ventilation systems

These is very little information about the history of natural ventilation systems. The the exploration of the topic is best done by exploring different ventilation systems around the world.

Different parts of the world contain different climates. According to their location and climate zone different architectural concepts are created to include natural ventilation according to the context.

The found typologies are the following:

Thailand - House on stilts: A typology which places the building on stilts hereby increasing airflow underneed and through the building, causing humidity levels to drop.

Japan - traditional house: Having a very similar climate as thailand, however have lower levels of temprature. cross section ventilation is used as wel however screens are used as well to be able to regulate the indoor climate.

Turkey - Country house: this typology uses balconies to provide shade, whilest still including an open air facade for cross section ventilation.

Rome - Atrium house: Perhaps the most well known typology, the Roman atrium house, uses an inner courtyard to circulate cold air trough the building whilest minimising the surfacespace to heat up.

Egypt - Town house: This typology introduces the concept of rising air and a wind tower to create a natural flow of fresh air throught the building.

La Coruna - Townhouse: Uses this concpet as well. However addapted towards the incomming wind.

The other typologies visible in the figure, actually deter the wind and are limiting it's natural ventilation by the shape of the typology.

These are some of the main typology designs. These same principles are further repeated later in time. A great example of this being the BedZed project in Lodon england, which includes the same context as the Egygt Town house.

8.2. Qualities of natural ventilation systems

The functionality of these systems within an olympic aquatic centre are depended on the buildings climate. Within Berlin the main climate is a coastal climate (Figure 22). The CO2 values varry between 400 and 1000 ppm. The temperature varies between 14 and 24 degrees and the humidity averages around 60%.

Due to this varring climate the implementation of natural ventilation systems with an olympic aquatic center in the visinity and context of Berlin in not possible. A high performing pool needs a stable indoor climate and having the influence of an instanble outdoor climate due to natural ventilation negatively impacts the bodily experience of an indoor climate. Partly natural ventialtion however is possible. The moment when outdoor climate factors are stable the building could open up and implement natural ventiation.

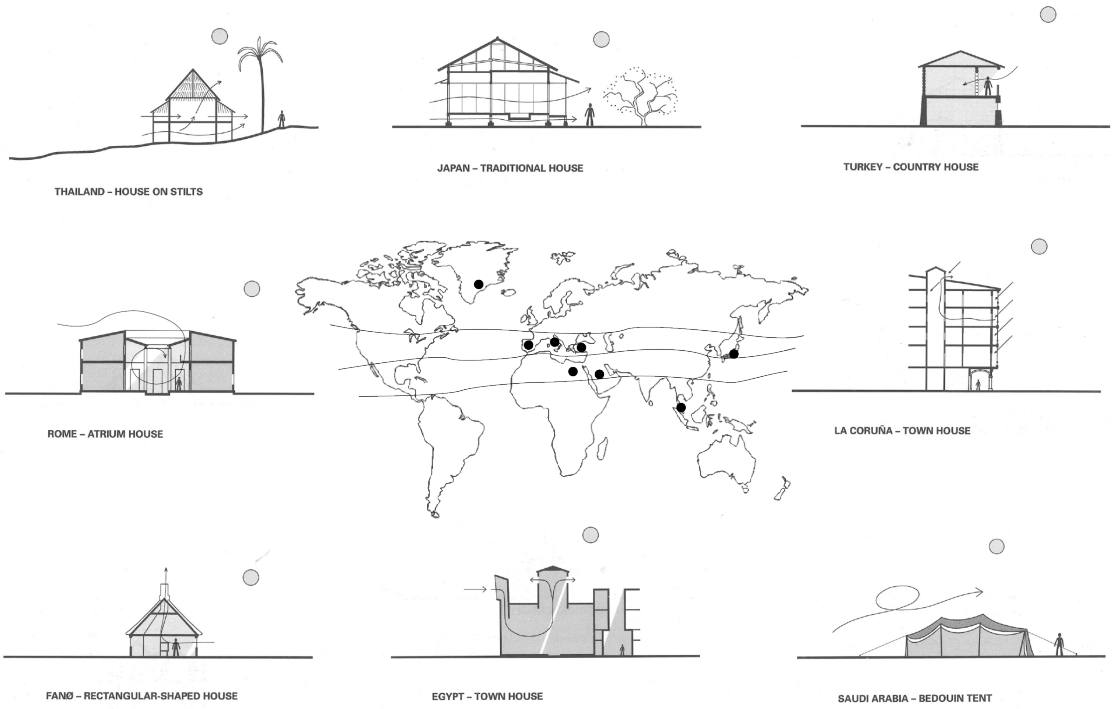


Figure 20: Highlighted wind towers ([BedZed, London, England], 2002)

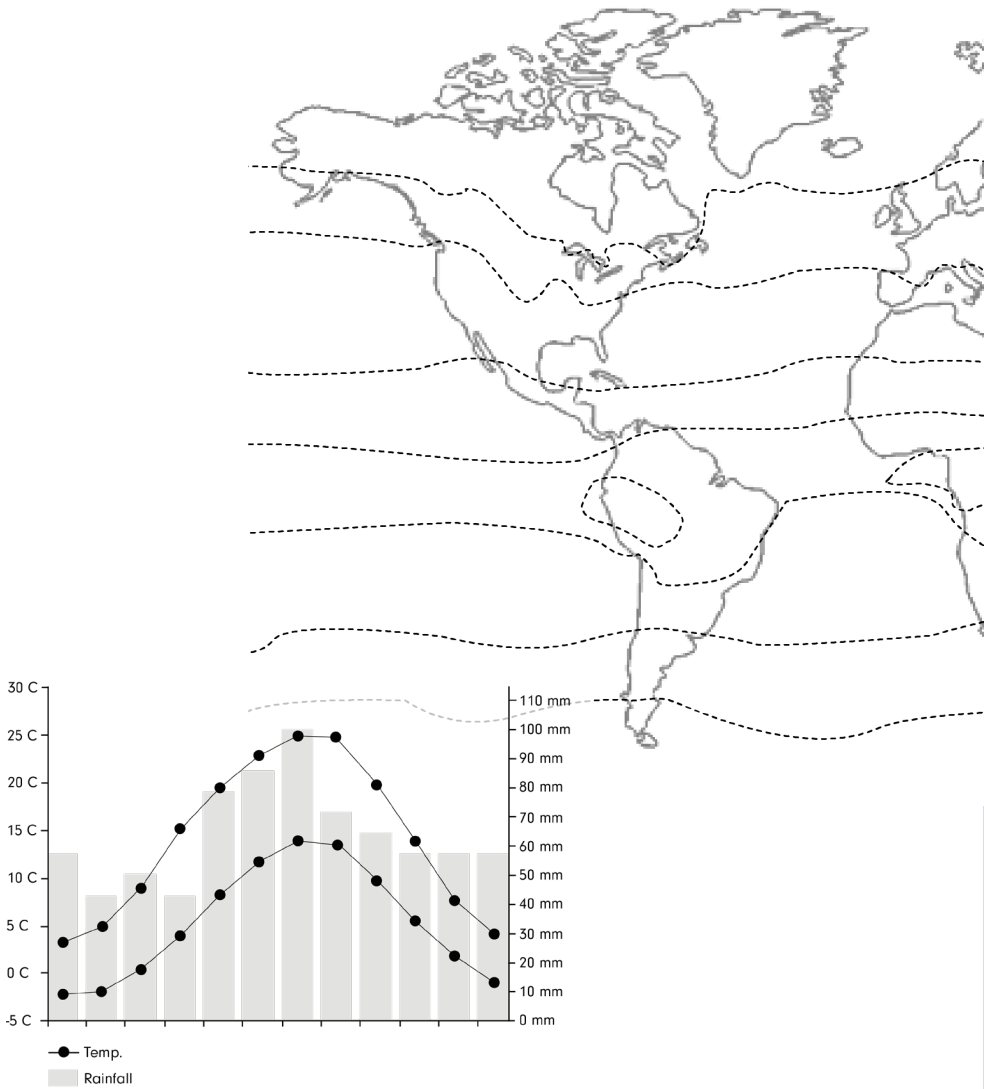
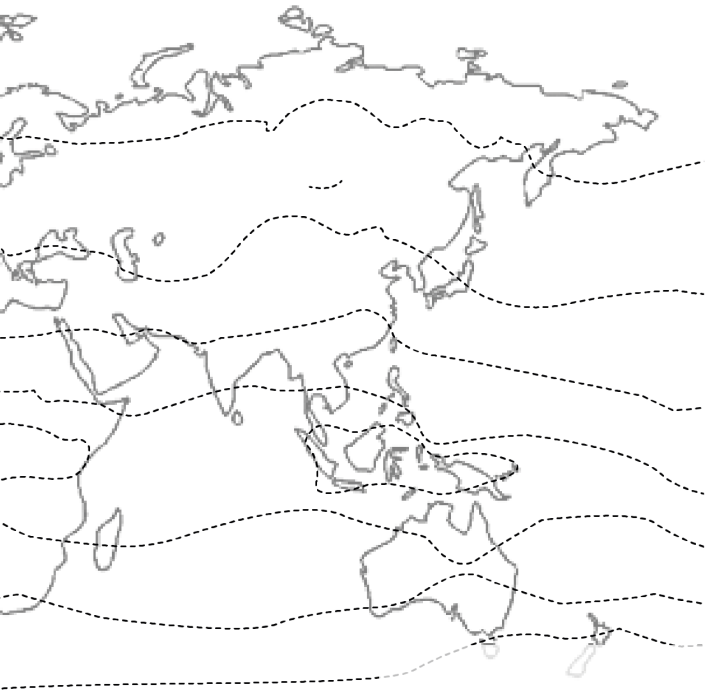
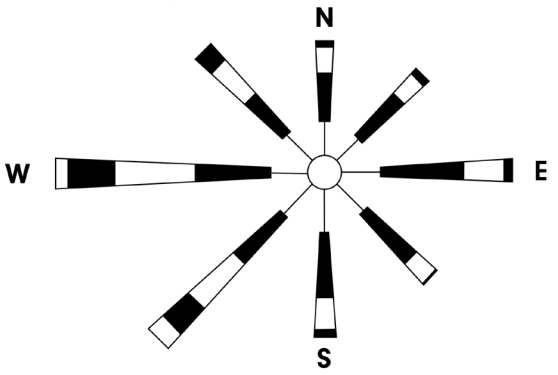


Figure 21: Berlin climate (author, 2022)

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Conclusion

The swimming pool has a very interesting history. With its start during the Greek and Roman times, as a communal bath. And ending up as high performance environmence in which athletes compete. The typology of the swimming pool has undergone an entire transformation.

Due to its compex indoor environment and therefore indoor requirements it was therefore concluded that the inplementation of a natural ventilation system is depended on the buildings outdoor climate.

With the casestudy of Berlin is was for example proven that the implementation of natural ventilationsystems is not possible due to its varring outdoor climate, making the indoor climate of the swimming pool therefore also instable.

Reflection

The relationship between research and design

The main approach to this design process was to constantly reflect back on the original design questions when taking further steps in the design. For this design, the project's main design questions included: How does an Olympic Aquatic centre become future-proof, How does one introduce grass root functions within the design and how does one minimise the impact of the building onto the surroundings? These questions and the research that was done to answer these questions helped guide the design process and gave a clear objective for the finished design. They also helped answer the main question within the design studio: How does one design a complex building within the city of Berlin?

However the research question regarding a building topic, in this case, air quality, was left to the last minute and in the end did not have a clear relation and significance to the studio anymore. Primarily because the research question did not match the other design questions and the studio's main objective. The topic of air quality was not interlinked enough with the design of the Olympic Aquatic Centre to give it the significance that it probably should have had. This approach of creating a completely separate research question, which was somewhat separate from the main design objective, was not very effective and hindered the design project. After further reflection, the research question somehow shifted from the original research question, to the earlier mentioned studio's main design question. The research question of: Can natural ventilation systems be implemented in an Olympic aquatic centre whilst still creating a comfortable indoor climate? Subconsciously became: How does one design a complex building within the city of Berlin?

The value of the feedback from the mentors

The primary feedback from the mentors throughout the course was to fall back on these earlier-mentioned design questions to help guide the process. This ended up being very effective in further developing the design process and answering the main design questions. However, as mentioned before, because this was the main feedback given by the teacher, the research question remained unanswered during the biggest part of the design process because the scope of the studio was pushed towards a different direction.

This approach by the mentors was also incredibly effective when managing the size of the project. The studio topic is that of complex projects, which are often projects that are big in scale and have complex social, economic and/or logistical characteristics. This makes for having to manage a very complex intricate project by yourself. Having these simple guiding design questions

helped manage this process, by giving the process more direction when the complexity of the project became overwhelming.

Within this design process, I have learned that sometimes the intended research approach and question might become irrelevant further on in the design when other or even new questions became more important in regards to furthering the design.

The relation between the graduation project topic, your master's track, and your master's programme

The main graduation project topic of designing a complex project within the city of Berlin relates to the master track of architecture as it teaches the student to help manage a large complex design project within a big metropolitan city, whilst using a research-based design approach. By using different research approaches within the design process such as case studies, and historic and literary research, the graduation project topic relates to the master's program and its emphasis on research-based education.

The influence of the research on the design and how the design influenced my research

As mentioned before the intended part of the studio which focussed on the specific research question did not help further the design process to the extent that that part of the studio remains unfinished and irrelevant. However, the focus of the research on the climate within the building did help with furthering the technical part of the design process as it made me more aware of the role of climate, especially air quality within the typology of an Olympic swimming pool. Because the research question remains partly unanswered the design influenced the research in a way that it became the research instead of the intended research.

Assessing the value of my way of working (approach, used methods and used methodology)

The use of case studies within the design process combined with a very analytical approach made the design process very organised and thorough. However some parts of the design process, therefore, were somewhat limited by this approach as it did not leave much room for experimentation with different design approaches, which was something my mentors made me aware of a couple of times. Finally, this also caused for some time constraints at the end of the design process when it came to finalising the process. All in all, this approach was very effective and offered a very concise way of working which helped when managing such a big project as this.

Assessing the graduation project's academic and societal value, scope and implication, including ethical aspects. And assessing the value of the transferability of your project results.

The project is relevant within the scope of current developments regarding the hosting of large sporting events. The current situation with large sporting complexes often causes a lot of problems in regard to legacy options. By exploring these options through location exploration and the building program makes the project socially valuable. It explores the extent of reusability of building elements and the context of the building. This exploration of a typology that already seems very defined within its characteristics (Olympic Aquatic Centre) by looking into these grass root functions and future possibilities, forms a study with high transferability in the future.

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Images:

Figure 1: Author. (2022). Visualisation 'Bodies and Buildings' graduation studio [illustration]

Figure 2: [Illustration of a Roman Bath]. (n.d). [illustration]. Scoop empire. https://scoopempire.com/roman-baths-of-the-middle-east-from-historic-palestine-to-the-shores-of-tunisia/

Figure 3: Dobson, D. (n.d.). Cutaway diagram of a Roman hypocaust system (underground heating). [illustration]. Retrieved May 11, 2022. Canterbury Archaeological Trust

Figure 4: Author. (2022). Visualisation research questions. [illustration]

Figure 5: [Velodrome]. (n.d). [picture]. Berlin.de. https://finals2019.berlin/sportstaetten/sse/

Figure 6: [Floorplan +38.50]. (n.d.). [Illustration]. Arquitectura Viva. https://arquitecturaviva.com/works/velodromo-y-piscina-olimpicos-2

Figure 7: [Section]. (n.d.). [Illustration]. Arquitectura Viva. https://arquitecturaviva.com/works/velodromo-y-piscina-olimpicos-2

Figure 8: Author. (2022). *Possible Timeline.* [illustration]

Figure 9: [Metropolitan Opera House]. (n.d). [illustration]

Figure 10: Author. (2022). *Visualisation methodology.* [illustration]

Figure 11: Bahadori, M. N., Dehghani-sanij, A.R. (2014), The view of one-sided wind towers in Meybod city, Yazd province, Iran [picture]. Climate and sustainability. Springer International Publishing; 2014.

Figure 12: [BedZed, London, England] (2002). [picture]. ResearchGate. https://www.researchgate.net/figure/BedZED-Community-with-a-concept-of-sustainable-lifestyle-and-life-work-integration-21_fig4_235339474

Illustrations