The contribution of albedo-enhanced houses in the Netherlands to reducing the urban heat island effect

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Abstract

This thesis investigates the potential contribution albedo-enhanced houses could have in the Netherlands to mitigate the urban heat island (UHI) effect. Albedo-enhanced houses are characterized by aspects such as white paint, thick walls, dome roofs, and narrow streets to maintain ambient temperatures and reflect solar radiation. These aspects are inspired by the successful practices in Santorini. The central research question focused on the potential impact and feasibility of integrating these architectural elements into the Dutch context.

The study made use of a qualitative research design, it involved interviews with professionals from different sectors, including spatial planners, architects, and project developers. These interviews gathered expert insights on the effectiveness and implementation of albedo-enhancing techniques to reduce UHI effects in urban settings.

The main findings indicate that the reflective properties of white paint and the thermal mass of thick walls can significantly lower ambient temperatures and reduce heat absorption. However, the widespread implementation of these features faces aesthetic, cultural, and practical challenges in the Netherlands. Dome roofs, even though beneficial for heat dispersion and air circulation, are not typically suited for the Dutch architectural style because it is predominantly vertical. Similarly, the narrow, tree-lined streets that cool the environment and reduce direct sunlight are limited because of regulatory and logistical constraints in urban Dutch settings.

In conclusion, while the albedo-enhanced houses offer an optimistic approach to mitigate UHI effects, their adoption in the Dutch context requires innovative adaptations and solutions to overcome existing barriers. The study suggests integrating these features with urban planning norms and Dutch architectural styles for further research. Moreover, it recommends that policymakers provide incentives to raise awareness for the adoption of albedo-enhancing technologies.

This research contributes to the broader conversation about sustainable urban development and lays the groundwork for policy initiatives, and future studies aimed at mitigating the UHI phenomenon in densely populated regions.

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1. Introduction

1.1 Background:

In the context of modern urban development, cities around the globe are experiencing growth in infrastructure and population, this is due to rapid urbanization and industrialization (United Nations, 2017). This growth, while bringing economic progress, comes with its profound alterations in land use and land cover (LULC). This in turn affects local climatic conditions, especially increasing the urban heat island (UHI) effect (Khan et al., 2020). The UHI effect, characterized by higher temperatures in urban areas compared to their rural counterparts, contributes to heightened physical discomfort, more energy consumption for cooling, and in extreme cases even increased mortality rates (Tong et al., 2021). This phenomenon is especially relevant as it is estimated that by 2030, 60% of the world's population will live in cities (United Nations Human Settlements Programme, 2020).

With these challenges in mind, it becomes critical to explore sustainable construction and urban planning methods that can mitigate these adverse effects. The design and layout of Albedo houses in the Netherlands presents significant potential for UHI mitigation. These houses, characterized by their white walls, thick structural compositions, dome-shaped roofs, and the strategic layout of narrow streets, are not just architectural features but also function as responses to the demands of climate adaptability in urban areas.

The Albedo effect, fundamentally, comes down to the reflection of solar radiation away from the earth's surface. This principle is utilized by these houses to keep indoor and surrounding temperatures lower compared to standard buildings (Liu & Morawska, 2020). The white walls of these structures reflect a larger amount of solar radiation, thereby reducing heat absorption, which is a critical factor in the formation of the UHI effect (Bansal et al., 1992). The dome roofs function as high ceilings where the hot air can be stored and eventually ventilated to keep the living space cooler (Zhu et al., 2021). Additionally, the thick walls provide substantial thermal mass, this naturally regulates the indoor climate and therefore reduces the need for artificial cooling (Goufri et al., 2022). Furthermore, the narrow streets create shaded walkways that not only enhance comfort for pedestrians but also contribute to lowering local ambient temperatures (Nasrollahi et al., 2020).

There are many ways to reduce the urban heat effect, cooling strategies like evapotranspiration from vegetation or the development of cooling parks with leverage shade are examples covered in the literature (Simpkins, 2023) & (Irfeey et al., 2023). However, the opportunities presented by the building style of Albedo houses is an undiscovered subject when it comes to reducing the urban heat island effect (Using Green Roofs to Reduce Heat Islands | US EPA, 2024). Therefore, this thesis investigates how attributes such as white paint, thick walls, dome roofs, and narrow streets can be utilized in the Dutch context to contribute to reducing the UHI. This is done by taking a closer look at the template city Santorini where these features have been used for many years. Hereby trying to fill the gap in the literature about this topic and delve into the possible options for sustainable urban development in the Dutch landscape. In the end, serving as a blueprint for future urban planning initiatives to reduce the UHI phenomenon.

1.2 Research problem:

In the literature, there is a gap regarding the applicability of albedo measures, particularly the ones used in Santorini, to reduce the UHI effect in other parts of the world. Santorini is well known for its approach to mitigate the UHI effect due to its architectural features. However, it is unclear if these features can successfully be translated to other urban environments, like the Dutch. This research will address this gap by examining the barriers, feasibility, adaptability, and potential impact of these measures in the Netherlands.

Therefore, the central research question guiding this study is: "What could be the contribution of albedo houses aspects to reducing the urban heat island effect in the Netherlands?"

This question will be answered using case studies, comparative analysis, and other literature. Moreover, interviewing different people with knowledge on the subject such as architects, spatial planners, and project developers will provide many insights into the barriers, feasibility, and implementation of these measures. By systematically addressing these aspects of the measures the research will contribute valuable knowledge to the field of sustainability and urban planning.

1.3 Structure of the research:

This research is structured to provide a clear understanding and comprehensive analysis of the study's objectives, methodologies, findings, and implications.

The theoretical framework lays the foundation by discussing relevant concepts and theories. It includes theoretical references, reviews existing literature, and formulates the hypotheses that guide the research.

The methodology section shows the data collection processes and research methods employed in the study. It describes the ethical considerations considered, the specific example used, and the overall research design. This ensures the study's validity and reliability.

The results section presents the findings and addresses the main question by using the findings from the research. To provide a well-rounded view of the data, the results are analyzed from multiple perspectives.

The conclusion summarizes the findings of the research and highlights the main insights and their implications. Furthermore, it reflects on the strengths and weaknesses of the study, this way providing a balanced view of the research outcomes.

The discussion critically evaluates the research, it discusses potential areas for improvement and future research options. It reflects on which parts of the research were effective and what could be improved in subsequent studies.

Lastly, the references section provides a clear overview of all the sources used throughout the research. This ensures proper attribution and allows readers to explore more literature on the topic.

This coherent structure makes sure that the research is accessible and well-organized. It helps to guide the reader through each stage of the study.

2. Theoretical framework:

2.1 Concepts:

Climate change refers to alterations in weather and temperature, primarily caused by human activities such as deforestation and burning fossil fuels in the long term. These activities lead to increased concentration of greenhouse gasses in the atmosphere which leads to global warming. The concept of climate change confines a range of impacts, including rising sea levels, more frequent and severe weather events, and disruptions to biodiversity and ecosystems (Climate Change 2021: The Physical Science Basis). The changing climate is a crucial reason for the research, since the climate is changing the Dutch infrastructure needs to change as well. To help future-proof the landscape in the Netherlands solutions need to be found (Climate Change 2021: The Physical Science Basis).

Simultaneously, urbanization is transforming the landscape as well and adds to the pressure of futureproofing the Dutch landscape. This refers to the process by which more percent of the population lives in urban areas instead of rural areas. This phenomenon is driven by many factors including better living standards, economic opportunities, and improved access to services such as education and healthcare. Urbanization leads to changes in land use patterns and the expansion of cities. Examples are increasing the height and density of buildings, which can reduce airflow circulation and trap heat (Mushmore et al., 2022). Also, it impacts housing, transportation systems, and infrastructure, and can lead to the urban heat island (UHI) effect and increased pollution (Piracha & Chaudhary, 2022).

The urban heat island (UHI) effect is defined as the temperature increase in urban areas compared to their rural counterparts, mostly due to land surface alterations and human activities. This phenomenon affects energy use, human health, and climate. A baseline is provided for understanding how urban structures impact local climates in studies. As cities expand the natural landscape gets replaced by roads, buildings, and other infrastructure. This leads to more absorption and retention of heat in urban areas. This phenomenon is mainly due to the increase of low albedo surfaces in cities, such as concrete and asphalt. Moreover, the concentration of human activities, such as industrial processes and transportation, contributes to more heat emissions in urban areas (Mushmore et al., 2022).

Albedo is a critical concept to understand when it comes to mitigating the urban heat island effect. The measure is used to determine the reflectiveness of surfaces, especially how much solar radiation it reflects into the atmosphere. If a surface has a higher albedo, it reflects more solar energy, thus absorbing less heat and contributing to reducing the temperature. In studies, the potential of high-albedo materials in urban areas to mitigate the UHI is explored. In the study by Liu and Morawska, the effectiveness of reflective surfaces like cool roofs and white paint is highlighted. These features have been shown to lower surface temperatures due to their reflectiveness. It is crucial to understand how reflective surfaces and white paint can cool urban areas. By incorporating these high albedo materials in the construction of pavements, buildings, and other urban infrastructure, cities can become more resilient to heat (Liu & Morawska, 2020).

2.2 Literature

2.2.1 White paint

The first aspect to delve deeper into is the white paint. Lighter colors have a higher albedo factor, which means that the lighter the color the more solar radiation is being reflected. For an experiment two enclosures were created, one painted black and the other one painted white on four walls and the roof. During observations, the temperatures were measured and at the peak hours, the black enclosure reached approximately 7 degrees higher temperature than the white enclosure. However, in the nighttime, the two were nearly identical when it came to temperature. The temperatures inside the enclosures were measured by thermohygrographs and the ambient temperature was measured by a copper constantan thermocouple (Bansal et al., 1992).

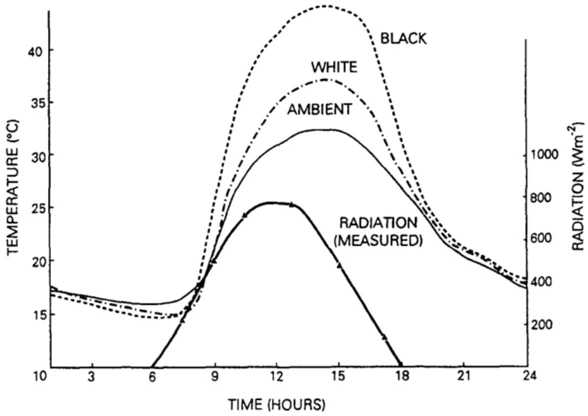

Figure 3. Temperature difference in enclosures (Bansal et al., 1992)

2.2.2 Thick walls

The second aspect to further examine is the thick walls. In arid climates, such as Morocco, traditional building techniques mostly include thicker walls which are made from materials with high thermal mass. This causes slow heat transfer from the exterior to the interior, as a result stabilizing indoor temperatures in the heat of the day, whilst maintaining warmth during cool nights. This principle is in line with the usage of building materials that help regulate temperature by absorbing heat during the day and in the night releasing it slowly. Materials with high heat capacity, solar reflectance, and thermal emissivity are pivotal in the construction of urban areas that can combat the UHI effect (Goufri et al., 2022).

2.2.3 Dome roofs

Thirdly, dome roofs can effectively trap warm air at the top of the dome, because of their curved shape. This reduces the need for heating during the night or in cooler climates by capturing a warmer air layer separated from the living area below. This is an example of how building geometry can influence air movement and temperature stratification within buildings. Furthermore, the shape of the dome roof can help reflect more solar radiation compared to flat roofs. To get the most out of this curvature the angle of incidence of sunlight and the material's reflectivity needs to be considered. The more reflective surfaces, the less energy is being absorbed by the building, thus mitigating UHI effects (Liu & Morawska, 2020).

2.2.4 Narrow streets

Lastly, looking into the narrow street designs. Urban design choices can have a massive impact on lowering the surface and air temperature. Measures like the layout and shading of streets can be created through narrower streets with adequate building alignments and trees. This concept is especially beneficial in dense urban areas where these factors significantly impact the increase of thermal comfort for pedestrians. With the use of simulations, the effect of reduced solar radiation can be demonstrated (Liu & Morawska, 2020). Alongside the albedo effect of surface colors, design modifications in urban layouts, like the shaded pathways can help reduce the UHI effect. These choices can specifically have an impact on passive cooling in hot climates. By creating narrower, tree-lined streets an urban canopy can be created which breaks up thermal continuity, reduces energy consumption for cooling, reduces overall area temperatures, and enhances pedestrian comfort (Bansal et al., 1992).

2.3 Hypotheses/expectations:

- **H1:** Areas where the buildings are painted with high-albedo colors will show lower ambient temperatures compared to areas with low-albedo surfaces.
- **H2:** Neighborhoods, where the walls are thick, will maintain a more stable indoor temperature and therefore contribute less to the UHI effect.
- **H3:** Dome roofs will cause better heat dispersion compared to flat roofs and reduce local air temperatures.
- **H4:** Narrower streets will correlate with reduced UHI effects because of the decrease in exposed pavement and increased shading it provides.

2.4 Framework:

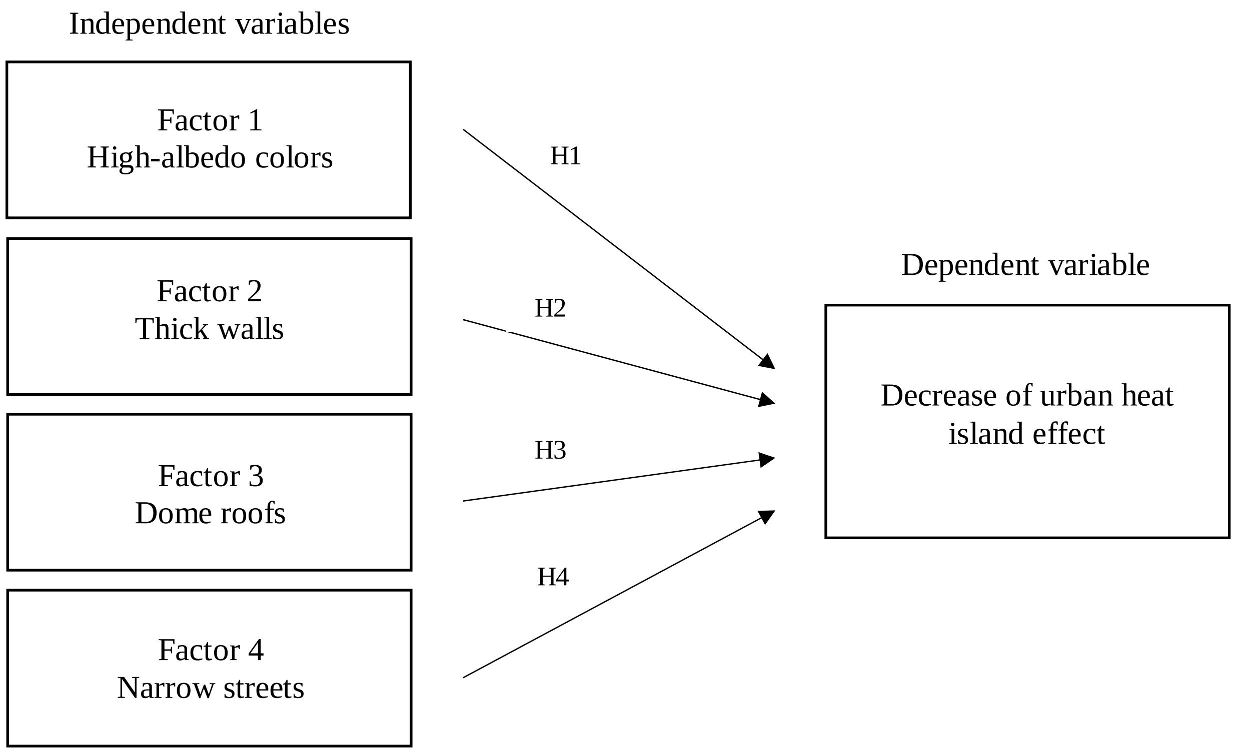

Figure 1. Conceptual model

3. Methodology

3.1 Research design:

Since the issue of how urban design has an impact on the UHI effect, a qualitative research design is chosen. This approach allows for an in-depth understanding of expert experiences and opinions; therefore, it is suitable for the question. By using qualitative information, the research goes beyond numerical data and captures nuances of materials, urban design, and their effect on climate.

3.2 Participants:

Interviews have been conducted with six professionals, to gain a comprehensive understanding of the applications and effects of albedo on urban temperatures. The group of interviewees consisted of two spatial planners, two architects, one project developer, and the city architect of Groningen. These participants were selected carefully because of their active involvement and extensive experience in development projects and urban design.

The choice for these professionals was deliberate and strategic. Spatial planners play a crucial role in ensuring that city layouts are sustainable, efficient, and conducive to reducing the UHI effect. The insights provided by the spatial planners on how high-albedo strategies and materials can be integrated into urban planning are invaluable. The study captures the systemic approaches needed to incorporate albedo measures by consulting spatial planners.

Architects provide essential perspectives on practical implications and the feasibility of albedo-enhancing techniques due to their deep understanding of building materials and design. Their expertise helps to assess the architectural opportunities and challenges presented by using white paint, thick walls, dome roofs, and narrow streets. The feedback provided by architects is essential for understanding how these design elements can be integrated into new and existing urban structures.

The project developer offers a pragmatic view of the logistical and economic aspects of the implementation of these measures in urban projects. Developers are pivotal in navigating financial constraints, translating urban design plans into reality, and ensuring that projects are both sustainable and viable. Their insights are needed to bridge the gap between theoretical designs and practical execution.

Lastly, including the city architect of Groningen will add a unique layer of expertise to the research. As a leading figure of urban design within Groningen, the city architect provides authoritative insights into cultural considerations, local regulations, and long-term planning goals. This perspective is key for understanding how albedo measures can be tailored to fit the specific characteristics and needs of Dutch urban environments.

By interviewing this diverse group of professionals with different backgrounds, the study ensures a thorough and well-rounded exploration of the subject. This approach allows for the identification of both challenges and opportunities in implementing albedo measures to mitigate the urban heat island effect.

3.3 Data collection:

For the interviews, a structured approach has been employed. Because of the many interviews there needed to be a clear structure. To be able to compare interviews there couldn't be differentiation between the questions, so therefore the interview consisted of only predetermined questions. However, there were enough questions so that every participant was able to give their insights and not leave out a single bit of information. This format facilitated well-structured and precise answers to the questions about the use of white paint, thick walls, dome roofs, and narrow streets in urban planning and their effect on the UHI effect. The interviews were recorded by the Dictaphone app on an iPhone to ensure accuracy in capturing data. Some interviews were done face-to-face because the participants were in Groningen, and some were done in a phone call because this was more manageable than traveling for a face-to-face interview. The interviews with the two spatial planners, the project developer, and the city architect of Groningen have been conducted face-to-face. The interviews with both architects were conducted in a phone call. There wasn't a difference in interviews whether they were conducted face-to-face or via a phone call, each one was around the same time and approximately the same length of answers. In the end, all interviews have been transcribed and kept all together in a single file.

3.4 Ethical considerations:

Before the interview, consent from all participants was obtained, ensuring that their information would only be used for this thesis. This process addressed any ethical concerns about personal data and professional opinions. The participants were informed about their rights, including the secure handling of their data and the confidentiality of their answers. The research respects the professional integrity and the privacy of the participants and adheres to ethical standards by obtaining this consent.

Moreover, detailed information about the types of data collected, the study's objectives, and how this data would contribute to the research was given to the participants. To establish trust and make sure the participants felt comfortable sharing their insights, this transparency was crucial.

Further details on the ethical consent and research questions can be found in Appendix A and B. These appendices give information about the consent forms, ethical considerations, and specific research questions that guided this study.

3.5 Quality of data:

While qualitative data doesn't help in generalizing information or making clear graphs for visualization, the validity of the answers is high because of the expertise of the participants. When the interviewees know what they talk about the quality of data is much better than quantitative data from random people that have no understanding of the topic. Furthermore, by the systematic structured approach, the answers can still be compared with each other to find similarities and differences between the participants. The systematic structured approach is when set questions are asked and no deviation is allowed and extra questions that come up during the interviews are not asked. This was each interview is the same and therefore easily comparable. The downside of this method is the potential for bias because of the limited number of interviews and the subjectivity of the responses. However, this downside is mitigated by the fact the participants have diverse professional backgrounds.

4. Results

At the start of this research, the idea was to see if the albedo houses, taking Santorini as a template, could be implemented one-to-one in the Dutch infrastructure. However, after some discussion, this would seem impossible, therefore the research changed, and the first step was to find out what makes the houses in Santorini what they are. Four main characteristics of the buildings stood out, being: white paint, thick walls, dome roofs, and narrow streets. Therefore, the research question focused on whether these aspects of the buildings could be implemented in the Dutch context with an eye on the future.

Figure 2. Santorini template (Tripadvisor, 2024)

4.1 White paint

4.1.1 interviews

During the interviews, many different opinions, and lines of reasoning about the white paint were given. There wasn't a clear pattern between the different professions, but each interview touched upon a different aspect and gave new insights. During the interview with the project developer, the fact was mentioned that the color white has good effects but might not be as aesthetically pleasing to Dutch people. Furthermore, there is a clear city view in every Dutch city that needs to be preserved and therefore painting it white would lose this value. On the other hand, the roofs are usually not that visible or important for the city view. Therefore, options present themselves on the roofs since this is the place with the most sun hours per day and therefore has the biggest impact. While the roofs are suitable for white paint, solar panels are suitable too, but these implications could co-exist since not every roof is qualified for solar panels, but paint can always be implemented. The last barrier for the white paint could be the costs, as a project developer the focus is on profit, and therefore if white paint only adds to the costs, it might be hard to realize. However, this statement can be countered by the fact that the paint will reduce energy consumption and therefore might be a good investment for homeowners.

4.1.2 Dutch context

White paint as previously mentioned is something the Dutch people are not used to. When interviewing the city architect of Groningen, some interesting thoughts about the implication of white paint in the Dutch context came up. The implementation would be hard because of the building style the Dutch people are used to, which is building mostly with red bricks made from clay. This building style is generations old and is logical because clay is one of the main resources we have in the Netherlands and, therefore easily accessible. Nevertheless, the city architect was intrigued by the idea but concluded that there needed to be pioneers who would take the first step toward such a project. When a new project is developed the architect would have to be inspired by an example like Santorini and convince other people why it is comfortable to live and the advantages that come with it. Moreover, during my interview with the first spatial planner, the fact that the albedo effect and its implications are not common knowledge was brought up. To increase the potential for success in such a plan the key according to the spatial planner was to raise awareness about the implications and positive effects the white paint has.

4.1.3 Hypothesis

The hypothesis stated for white paint is as follows:

H1: Areas where the buildings are painted with high-albedo colors will show lower ambient temperatures compared to areas with low-albedo surfaces.

The hypothesis is strongly supported by the insights from the professionals. However, the application of this principle in the real world requires careful consideration of economic, cultural, and practical factors. This is especially the case in the Dutch context with strong aesthetic values and architectural traditions. Educational efforts and pioneering projects are of great influence on the success of such initiatives. These projects must demonstrate the benefits of the paint to convince investors to implement it on a broader scale.

4.2 Thick walls

4.2.1 Interviews

During the interviews, the opinions about thick walls were mixed. On one hand, the implications were favorable because the effects caused by thick walls are perfect for keeping the inside of buildings cool. On the other hand, many barriers were hindering the implementation of thick walls. When interviewing the first architect it came up that building thick walls is very expensive, because this uses more resources. In the example of Santorini, there are plenty of resources since the stone used to build the houses is being collected near the city. Back then there was no second thought about the correct and most effective way to use the resources available.

4.2.2 Dutch context

In the Dutch context thick walls aren't used that often, the places where this building style is still visible are buildings from centuries ago, such as churches or some of the oldest houses in the Brugstraat. According to the city architect, no more thick walls will be built because the resources are simply not there. Since there is a housing shortage every brick needs to be used optimally, so instead of building a house with thick walls the favorable option is to build two houses with standard walls. In the Dutch context, the thick walls are substituted by isolation between walls which do a similar job but save the resources. All in all, the thick walls in the Dutch landscape will not be feasible.

4.2.3 Hypothesis

The hypothesis stated for thick walls is as follows:

H2: Neighborhoods, where the walls are thick, will maintain a more stable indoor temperature and therefore contribute less to the UHI effect.

The literature supports the hypothesis due to the construction materials involved and the thermal properties. Still, such building techniques face significant challenges when it comes to practical implementation in modern urban environments. Resource availability, architectural trends, and costs are all factors that influence the feasibility of using thick walls in construction. This is especially difficult in the Dutch context where other methods like wall insulation are preferred and more resource efficient. Hence, even though the hypothesis holds theoretically and in specific geographical and historical contexts, its broader application is limited by economic and practical factors.

4.3 Dome roofs

4.3.1 Interviews

The dome roofs sparked a discussion in most interviews. Some participants were wondering why this concept isn't being used and others were direct to point out its flaws. The second spatial planner was quick to give insights, according to this spatial planner the dome roofs even though they are functional, are not suited for the Dutch landscape. In the context of Santorini, it is built very horizontally with single-family houses. Yet the Dutch landscape is much more vertical with people living on top of each other instead of next to each other. Hence the dome roofs would only have implications for a small part of the Dutch buildings. Moreover, the spatial planner argues that because a dome roof is far from the typical Dutch style of engineering, a pioneer would have to take a risk and build such a project to see how people react to the style.

4.3.2 Dutch context

According to the city architect, dome roofs are difficult to implement in the Dutch context because of the vertical nature of the built environment. Nonetheless, there are some takeaways from the structure of dome roofs. The idea of trapping heat would be ideal in the Dutch context. This could be done by building higher ceilings and putting windows higher up so that the top layer of warm air can escape the room, thus cooling the living space. An example of where this technique is already implemented is in schools. Because the children are working hard a lot of heat is generated in a compact space, therefore the ceilings are high, and the top windows can be opened with a stick to let out the hot air.

4.3.3 Hypothesis

The hypothesis stated for dome roofs is as follows:

H3: Dome roofs will cause better heat dispersion compared to flat roofs and reduce local air temperatures.

Dome roofs are theoretically effective solutions for reducing local air temperatures and better heat dispersion due to their potential for increasing reflectivity because of their shape. Nevertheless, their practical application depends largely on urban planning constraints and regional architectural norms. In the Dutch context, where traditional and vertical construction is the norm, the adaptation of the dome roof principles needs to be reconsidered. Aspects of local aesthetic and structural norms could potentially be borrowed, such as thermal stratification through natural ventilation and high ceilings. Consequently, the hypothesis holds in specific contexts and in theory but in practice faces too many limitations in the Dutch context.

4.4 Narrow streets

4.4.1 Interviews

The narrow street measure was one that the participants hadn't thought about most of the time. Still, according to the second architect, there were a few obstacles in the way of implementing narrow streets. The first one is that the Dutch people are not used to these narrow streets, so therefore it would differ again from the standard Dutch infrastructure. This could cause a negative backlash and disapproval of the idea. The second one is that due to the narrow streets, emergency services like fire trucks, ambulances, and police cars can't get to the buildings next to the streets. This is of course essential to infrastructure and as a result, would make it hard to get a permit for such a narrow street. The last issue is that Santorini was built a long time ago when these emergency services were not standard yet. Nowadays there are standards and regulations in place that specify the way streets need to be constructed and it is not easy to overthrow these restrictions.

4.4.2 Dutch context

The idea of narrow streets is difficult to realize in the Dutch context because of restrictions and emergency services in place. Nevertheless, there are some takeaways from the concept of increasing shade. When interviewing the city architect, some good advice was given on how the idea of shade can be implemented more in Dutch buildings. First, instead of creating narrow streets, the idea was to implement more trees in cities. This idea however is difficult to realize in practice because under the ground in cities, there is a lot of invisible infrastructure like pipes, cables, or even whole parking lots. For that reason, the city architect came up with a different solution to make use of shadow. For a case study, the architect traveled to Venice to study the architecture there. During that time, it was discovered that wooden shutters were the best way to create shadow and thus reduce the room temperature. The shutters are on the outside and can be turned inwards to block the sunlight and radiation into the buildings. This technique has been used since the Middle Ages but doesn't seem to get the attention it deserves in the Dutch building style. When looking for future development of Dutch cities, both architects advised investigating adaptations and implementations that are done in areas like Bordeaux, Nice, and Venice. According to a climate expert who advised both architects during a project, in about twenty-five years our climate will look like that of these regions. Therefore, the building style in these regions is the one the developers in the Netherlands should adhere to when making future-proof plans.

4.4.3 Hypothesis

The hypothesis stated for narrow streets is as follows:

H4: Narrower streets will correlate with reduced UHI effects because of the decrease in exposed pavement and increased shading it provides.

The literature is supportive of the hypothesis that narrower streets indeed correlate with reduced UHI effects. In this literature the role of reduced pavement exposure and shading are highlighted to mitigate heat. Nonetheless, in the Dutch context, narrow streets are difficult to implement and require adapting these principles to local regulations and conditions. Hereby exploring alternative methods of increasing shade, like the wooden shutters from Venice and other implementations used in areas like Bordeaux and Nice.

5. Conclusion

This thesis has explored the potential contributions of albedo-enhanced houses in the Netherlands toward mitigating the urban heat island (UHI) effect. By making use of the exploratory research design, this study has examined the effectiveness of white paint, thick walls, dome roofs, and narrow streets. These aspects of albedo-enhanced houses are all architectural features that could potentially reduce UHI effects by making use of their natural properties to decrease ambient temperatures and enhance thermal comfort.

5.1 Key findings

- White paint: Due to its reflective properties white paint has, it can significantly lower surface temperatures by reflecting the incoming solar radiation. This is evidenced by the experiment where temperature differences were measured in a controlled environment (Bansal et al., 1992). However, the widespread adoption in the Netherlands is hindered by aesthetic and cultural preferences. In the end, pioneers are needed, and awareness of the benefits must be raised to see the future implementation of white paint.

- Thick walls: These thick walls offer better insulation and thermal mass, which contribute to indoor temperature stability. Nonetheless, the construction of these thick walls in modern urban environments is limited by current building practices and resource availability in the Netherlands.

- Dome roofs: Because of their architectural design the dome roofs are naturally able to facilitate heat dispersion. Despite that, the vertical nature of the Dutch urban landscape makes it hard to implement these dome roofs. All in all, the need for alternative strategies that better fit local architectural styles is suggested. Takeaway ideas of the dome roofs are the high ceilings and the natural ventilation that could be used in the Dutch context.

- Narrow streets: These narrow streets can significantly reduce ambient temperatures, especially in combination with trees to reduce exposed surfaces and increase shade. Even so, in the Dutch context, there are many restrictions and emergency access limitations, and therefore the idea of narrow streets requires innovative urban planning solutions to be feasible. Lastly, a hopeful concept to create shade and reduce the UHI effects is the wooden shutters from Venice.

5.2 Strengths and weaknesses

The strength of this study lies in the comprehensive approach that is used to explore innovative and traditional methods of urban design to address UHI effects in the Dutch context. It utilizes qualitative interviews that provide deep insights into the perceptions and practical implications of these solutions among professionals. Therefore, allowing for a nuanced understanding of how white paint, thick walls, dome roofs, and narrow streets can be implemented in urban areas to mitigate heat. The interviews have been conducted with professionals from different backgrounds, this is done to ensure a well-rounded and robust study.

However, because of the exploratory research design that is chosen there are some limitations. One such limitation is that the study relies on a small sample size for the qualitative data, this means the full range of public acceptability and possibilities might not have been captured. Therefore, even though the information is valuable, it might not represent the complete spectrum of solutions from a broader population. Furthermore, the focus on only the Dutch context might restrict the applicability of the findings to similar environments. Since the Netherlands' urban planning regulations, architectural style, and climatic conditions are unique. Nonetheless, the insights from this study could still function as a framework for similar research in other contexts.

5.3 Recommendations for future research and policy

Further research: Future studies should include quantitative measures and expand the sample size to provide a more generalized understanding of the impacts. Comparative studies where the climatic zones are different in Europe could help give broader insights into the adaptability of these solutions. Lastly, taking the albedo effect into broader climate adaptation strategies and studying how different measures could function next to each other.

Policy recommendations: Policymakers should consider creating regulations and incentives for the use of high-albedo materials in new and existing urban developments. Through educational campaigns, public awareness about the benefits of such materials could be enhanced. Additionally, urban planning guidelines could be revised to encourage innovative designs like narrow streets and dome roofs within urban development projects.

Finally, this thesis serves as a preliminary exploration into the possible integration of albedo-enhanced architectural aspects in the Netherlands. It lays the groundwork for policy adaptations and future studies that could affect more sustainable urban developments. In the end, reducing the UHI effects and improving the livability in densely populated areas.

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6.1 Appendix A

Before the interview, this information was discussed with the participant:

Dear Participant,

Thank you for participating in this interview for my thesis at the Rijksuniversiteit Groningen (RUG). The goal of this study is to explore the potential of albedo on urban temperatures, with the focus on high-albedo materials and designs to mitigate the urban heat island (UHI) effect.

The data controllers are me, Igmar Hoogendoorn, the primary researcher, and the Rijksuniversiteit Groningen (RUG). The RUG is responsible for ensuring that all collected data is handled in compliance with applicable protection regulations.

The data collected during this interview will only be used for my thesis. This research aims to understand how implementing high-albedo materials and other architectural strategies can reduce the UHI effect. The insights gained from the study will contribute to the fields of sustainable development and urban planning.

You have the following rights concerning your data as a participant:

- Right to Access: You can get access to the data gathered from you at any time.
- Right to Erasure: You can request deletion of any data if it is no longer useful for the research
- Right to Rectification: You can request a correction to any data is incorrect.
- Right to Restrict Processing: You can request limitations on the use of the data.
- Right to Object: You can object to the use of data on the grounds of your situation.

The data collected during the interview will not be shared with third parties without your explicit consent. The data will only be used for academic purposes within the boundaries of the research project. Participants will be anonymized if any publication results from this research to protect their identity.

The data that is collected during the interview will be retained for the duration of this thesis and the five years afterward, because of the University's data retention policy. After this period, all data will be destroyed.

Your participation in this interview is completely voluntary, and you can withdraw your consent at any time without there being consequences.

Thank you for participating and contributing to this thesis.

Sincerely,

Igmar Hoogendoorn

6.2 Appendix B

Research questions

Research Objective:
To explore the potential contribution of Albedo houses aspects, such as white paint, thick walls, dome roofs, and narrow streets in the Netherlands to mitigating the urban heat island effect, focusing on climate change adaptation and future-proofing strategies.

Interviewee information

1. What is your name?
2. What is your role?
3. For what organization do you work?

Introduction:

1. Thank the interviewee for participating.
2. Briefly explain the purpose of the interview and its relevance to your thesis research.
3. Assure confidentiality and consent for recording.

Background information:

1. Can you provide some context on the urban heat island effect and its implications for cities, specifically in the Netherlands?
2. What is your understanding of Albedo houses' aspects and their potential role in addressing the urban heat island effect?

Current state and challenges:

1. How would you describe the current situation regarding urban heat islands in Dutch cities?
2. What are the main challenges or barriers to implementing measures to mitigate the urban heat island effect such as white paint, thick walls, dome roofs, and narrow streets?
3. Are there any existing initiatives or policies related to these Albedo housing aspects or similar strategies in the Netherlands?

The potential contribution of building style:

1. In your opinion, what could be the potential contribution of white paint, thick walls, dome roofs, and narrow streets to reducing the urban heat island effect in Dutch urban areas?
2. How do you envision these aspects fitting into broader climate change adaptation and future-proofing strategies for cities?
3. Are there specific advantages or limitations of these aspects compared to other urban heat island mitigation techniques?
4. Would it be possible to adapt current infrastructure with these techniques or only for newly developed infrastructure?

Implementation and adoption:

1. What are the key factors influencing the adoption of white paint, thick walls, dome roofs, and narrow streets by homeowners, builders, and policymakers?

2. Are there any examples or case studies of successful implementation of techniques or similar initiatives that you are aware of?
3. What are the potential challenges or considerations for scaling up the adoption of this building style across different neighborhoods or cities in the Netherlands?

Conclusion:

1. Is there anything else you would like to add regarding the potential of albedo housing techniques in reducing the urban heat island effect in the Netherlands?
2. Thank the interviewee for their participation and insights.
3. Offer to share the final thesis findings with them if they are interested.