THE TEMPERATE URBAN MICROCLIMATE IN A CHANGING ARCTIC

BSc Spatial Planning & Design

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ABSTRACT

The increased threat of climate change is multiplied in the arctic due to arctic amplification as well as its unique environment, hence the future of cities in the far north appears more unpredictable. The urban heat island (UHI) phenomenon which currently is of little concern in these cities may therefore develop into a new area of consideration. Academically, arctic UHIs have been acknowledged, but given limited attention. Therefore the aim of this paper is to investigate the potential current and future impacts of UHI through a local scale analysis of the built environment (BE) and its planning process. Specifically, Tromsø, a Norwegian city above the arctic circle, is considered as a case study due to its current development plans of its center. The main research question is: *How and to what extent is the BE planning in Tromsø resilient to UHIs in a changing arctic climate?* To answer this question, 3 interviews were conducted with Troms municipality spatial planners about their approaches to the temperate microclimate. Additionally, using the program ENVI-met, microclimate simulations were set up of 3 analysis areas in Tromsø's city considering current and predicted climate conditions, as well as current and proposed BE. It was found that the BE in Tromsø does foster UHIs, and the proposed plans which do not consider UHIs minimize the phenomenon to a small extent. This extent however is near insignificant in comparison to a worst case scenario change in arctic climate. Currently the fostering of UHIs is not a concern, as warmth during summer days is desired. However, with the expected warming of the arctic the implications of UHIs may differently impact other urban microclimate elements and hence may create new dynamics in arctic planning. Current policy makers are not expected to need to significantly change approaches, however future policies are proposed to further acknowledge how UHIs may interact with the wider environment through the BE design.

Keywords: Urban Heat Islands, Arctic Cities, Tromsø, Built environment, Urban planning

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1. INTRODUCTION

1.1 BACKGROUND

As a consequence of the current rapid urbanization alongside climate change expectations, the Urban Heat Island (UHI) concept is of rising concern. UHI is a phenomenon where urban areas have been observed to rise in temperatures in comparison to the surrounding rural lands (Schwarz et al., 2012). This is due to erected urban structures and impermeable ground materials with relatively lower albedo being more efficient in trapping heat. In contrast, implementation of green infrastructure with higher albedo and the capability of evapotranspiration is considered one of the most effective mitigation methods of UHI (Schwarz et al., 2012).

UHIs are known to have a range of consequences, especially to human health, wellbeing and the urban ecology (Venter et al., 2020). Furthermore, UHIs will affect weather conditions differently per season, potentially creating colder winters and nights, creating less predictable variations in the climate and hence impacting the local environment (Ningrum, 2018).

Academically, UHIs in more temperate regions have gained significant attention, however arctic UHIs are understudied (Lussana et al., 2018). Despite arctic cities being located in a far colder climate which would intuitively lessen UHI consequences, urban structures nonetheless bring forth UHIs. The concern in the arctic is particular due to arctic amplification, a concept referring to how the arctic experiences magnified climate change effects (Konstantinov et al., 2018). Additionally, the unique arctic environment would be impacted differently than elsewhere. As an example, the thawing permafrost has caused damage to road and city infrastructures as the previously solid soil starts to sink and move (Esau et al., 2021).

City planning in the arctic has given limited attention to the microclimates formed in their urban areas (Miles & Esau, 2020). Tromsø, the largest Norwegian city in the arctic circle, has recently announced a new vision of its city center which makes extensive mention of its microclimate in relation to wind or sun conditions, but not the temperate microclimate (Tromsø Kommune, 2022b). Academically, the last few years has seen an increase in studies regarding arctic UHIs, however mostly make use of Land Surface Temperature (LST) data from satellites and hence created an analysis of what is known as Surface UHI (SUHI) (e.g.; Esau et al., 2021; Konstantinov et al., 2018; Venter et al., 2020). The SUHI analyses have concluded that there are indeed warmer temperatures in arctic cities in comparison to the surrounding areas, however are limited to analyses on these larger scales (Konstantinov et al., 2018). The satellite data

additionally means the SUHI analysis outcomes are based on data with specific weather conditions at the time of measurement.

1.2 RESEARCH PROBLEM

Uncertainties and gaps in knowledge regarding arctic UHIs raises the central research question: *How and to what extent is the BE planning in Tromsø resilient to UHIs in a changing arctic climate?*

The aim will be to investigate arctic UHIs in relation to BE planning with Tromsø as a case study. The potential consequences will be evaluated considering expected worst case scenario climate change predictions. According to Hanssen-Bauer et al., (2017) the temperature in Tromsø is expected to be +3℃ warmer in 2100 and +5℃ warmer in the worst case scenario. The study will address the research gap by making use of data on a more local scale allowing an analysis of how the built environment (BE) of the city could foster these particular temperate microclimates in an arctic context. Additionally, the intent of spatial planners in Tromsø is to be investigated to evaluate to what extent microclimates have been considered or may be considered in the future of the city and its new center plan. Hence, the sub questions;

1. To what extent does Tromsø's current and proposed inner city BE impact its urban temperate microclimate?

2. To what extent has the temperate microclimate been considered in current and proposed plans in Tromsø by its urban planners?

3. To what extent would expected climatic changes impact current and proposed inner city temperate microclimates?

1.3 STRUCTURE

Past the introduction, the theoretical framework introduces existing literature and concepts relevant to the topic and the subsequently derived hypotheses based on the research questions. Further, the methodology explains in depth the tools used to investigate the aim, the results of which are to be explained and discussed under the next section. The final section concludes the paper's main findings, shortcomings and future implications.

2. THEORETICAL FRAMEWORK

2.1 FRAMEWORK OUTLINE

In regards to this investigation, BE is to be split into two concepts; Green Infrastructure (GI) and Built Form (BF). The strongest recognized mitigation method for UHIs is the implementation of GI, referring to the incorporation of trees, parks, gardens or any form of infrastructure making use of flora (Kleerekoper et al., 2020). Unlike common urban construction materials, plants evapotranspirate. As a result the flora does not trap heat as concrete or bricks would (Balany et al., 2020). Alternatively, GI can passively provide cooling elements through for example shade from a tree. No vast amount of GI is required for its cooling effect to take place, as stated by Kleerekoper et al. (2012), depending on the water availability and BE design, vegetation can significantly cool a 100m-1000m radius area.

Furthermore, the BF significantly impacts an urban microclimate. This paper will refer to BF as the topology, density and location of buildings, which will determine various climatic factors and impact the temperate conditions (Kleerekoper et al., 2012). Directly, BF can actively trap heat depending on density and topology. Indirectly BF can also affect UHI through not allowing wind flow, as urban ventilation would limit a warmer microclimate (Crank et al., 2018).

However, as much as BF or GI may impact UHI, the extent to which the microclimates will impact a city's environment and inhabitants will remain dependent on the wider climate. Climate change is currently causing great uncertainty in regards to the future and hence city planning (Konstantinov et al., 2018). As a result of arctic amplification this uncertainty is only to be greater in arctic cities, and therefore assessing both the current and predicted climatic conditions alongside the state of BF and GI is crucial.

The impacts of GI and BF on microclimates are known, and multiple urban areas have been studied on micro and meso levels to determine this (e.g.; Chatzinikolau et al., 2018; Kusumastuty et al., 2018; Kleerekoper et al., 2020; Schwarz et al., 2012). However, these studies have generally been on warmer climates than the arctic. Arctic cities are known to experience the UHI phenomenon, however this knowledge comes from LST data, often presented on meso or macro scales, and not analyses of the more local scale (Konstantinov et al., 2018; Venter et al., 2020).

Furthermore, arctic cities have not presented much attention to microclimate considerations during planning processes (Konstantinov et al., 2018; Miles & Esau, 2020; Tromsø

Kommune, 2022b). Current academic works give the impression that arctic cities have not seen UHIs as a considerable risk. Ultimately it is the planning process and policies which shape the urban environment, and subsequently its resilience to UHIs. The physical BE interventions will alter the GI and BF which as established are crucial to altering the temperate microclimate. Although academically spatial planning in the arctic is sometimes acknowledged to be minimally considerate of UHIs, this acknowledgement is little present and never a focus of investigation. Hence there is a gap of knowledge as to how and to what extent some arctic cities, such as Tromsø, would be involved with and affected by microclimates based on their 3 dimensional local built environment.

Figure 2.1 presents the relationships between these key concepts. The climate is notably not a local element unlike the other concepts, however essential to the intensity of any UHI consequences.

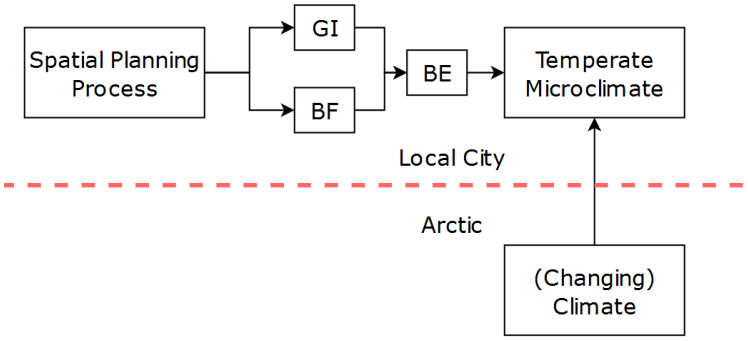

Figure.2.1 - Conceptual model

2.2 HYPOTHESES

Tromsø Kommune's (2022b) plan for the new inner city makes no mention of any temperate microclimates as of yet. As the planning process is incomplete more risk analyses may be created with time. However, the aims do make mention of GI considerations. Outside of what the intent may be, presence of GI is expected to lead to mitigating the UHI phenomenon in the city. Therefore this investigation proposes the hypothesis that (1) *the proposed city center BE will mitigate UHIs to a greater extent than the current BE*. Additionally, due to climate change as well as arctic amplification, this investigation proposes the hypothesis that despite any BE changes (2) *the UHI phenomenon will be more prevalent in future climate scenarios in comparison to the*

current context. Lastly, based on the apparent lack of focus on UHIs in the arctic, this paper hypothesizes that (3) *Tromsø's spatial planners do not extensively take the temperate microclimate into consideration.*

3. METHODOLOGY

3.1 PRIMARY DATA COLLECTION

INSTRUMENT & PROCESS

The primary data collection process was completed through 3 interviews with 4 employees of Troms municipality. The 4 workers are specifically involved with the spatial planning of the inner city and its new under development vision. The interviewees were found through the Tromsø Kommune web page listing its workers (Tromsø Kommune, 2022a). They were subsequently contacted through Gmail, introducing the concept of the paper and requesting an interview or alternatively other contacts who may be available for an interview. Initially, the case officer of the center plan, Heidi Bjøru was contacted. All subsequent interviewees were contacted through asking at the end of interviews for further contacts. Table 3.1 lists the workers interviewed and their relevance.

Interviewee	**Appendix #**	**Interviewee's relevance**
Heidi Bjøru	B.2	Case officer of the center plan and a city planner
Jacqueline Randles	B.2	Administrator in the section for city planning
Johanne Kryger	B.3	Spatial planner in the section of city planning
Tone Hammer	B.4	Landscape architect in the section of city planning

Table 3.1 - Interviewees overview

Due to convenience and availability, Bjøru and Randles were interviewed during the same session. Hence, 3 total interviews were conducted. As a result, the initial interview with Bjøru and Randles does have a different dynamic, allowing the two to build off of each other's answers and ideas and to elaborate more on certain topics, however may also lead to their answers being influenced by another unlike the other two interviewees.

Interviews were conducted via google meets or microsoft teams, depending on the interviewee's preferences, and recorded using samsung voice recorder. The transcript process was done by hand, due to the occasional switch in languages between english and norwegian. Coding was completed through the use of Atlas.ti (Atlas.ti, 2022).

DATA ANALYSIS SCHEME

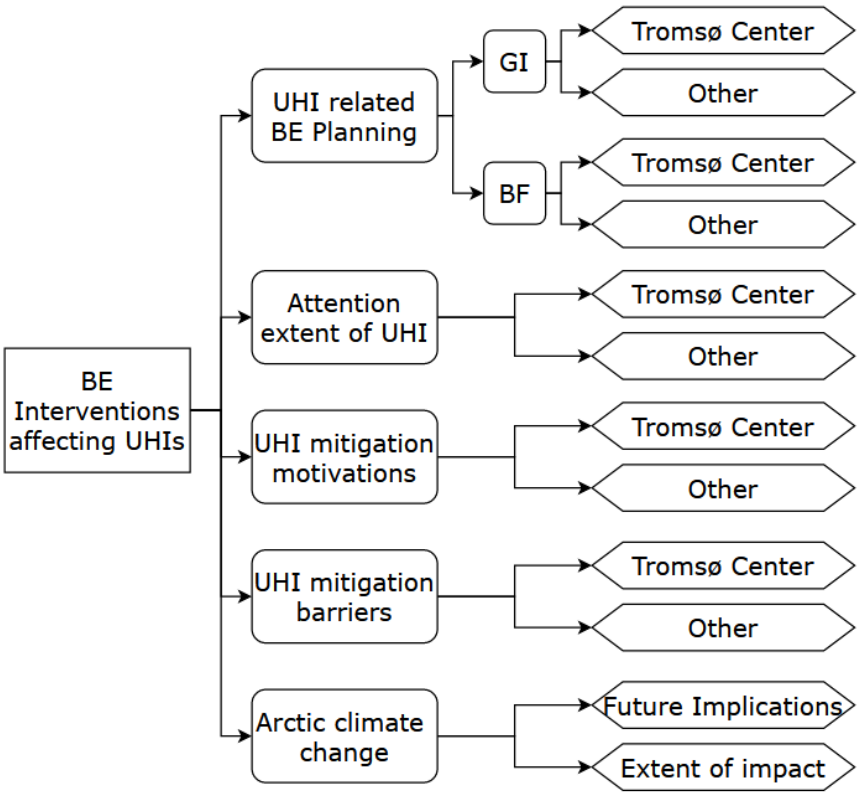

Figure 3.1 - Data analysis framework

The above framework (figure 3.1) is a guide for the interview process and subsequent coding. All questions link to the planning process and how the BE in Tromsø may affect the temperate microclimate. However due to the interviewees different backgrounds and may have additional information outside of the Tromsø context, hence all sections are split into coding for "Tromsø center" and "other". As mentioned by Miles & Esau (2020), planning in arctic cities has limited attention to UHIs, hence interviewees are to be questioned on the extent they give attention to UHIs in their planning. Furthermore, to what extent this attention if any is applied to

any GI and BF planning. To further investigate why or why not there may be attention on UHIs which otherwise is not academically elaborated on, two branches are dedicated to investigating any barriers or motivations to UHI mitigation through BE interventions. Considering the second sub question and the uncertainty derived from the arctic amplification phenomenon interviewees are also to be questioned on climate change and its future impact on BE in Tromsø and UHIs.

ETHICAL CONSIDERATIONS

Both prior to and during the recording, interviewees were asked whether they wished for anonymity and whether they consented to recording the interview. The interviewee was informed they may cease the interview at their comfort. No quotes have been taken from the interviews without explicit approval from said interviewee. The list of questions asked prior to recording are included in the interview guide in Appendix B.1. This paper has coded the interview transcripts, which reflects the interviewer's interpretation and may not be the interviewee's intent.

3.2 SECONDARY DATA COLLECTION

INSTRUMENT & PROCESS

Secondary data collection was done through running microclimate simulations in ENVI-met. ENVI-met is a program that allows the user to input a spatial model and climatic conditions to evaluate the potential microclimatic outcomes (ENVI-met, 2022). The spatial models were created using ENVI-met's tool *spaces*. This tool allows for an underlying bitmap to be placed and for a 2.5D model of the buildings, digital elevation model, ground material and vegetation to be created manually. The bitmap was taken from the Tromsø Kommune map portal, providing 3D models of both current buildings and vegetation as proposed building models (Tromsø Kommune, 2022c).

Due to the relatively smaller trees in the arctic and in particular in arctic cities, all trees placed in models were assumed to be "young" in order to cover a relatively smaller area of the model to match the municipality's maps. All buildings were given the same standard building material, excluding details such as windows or colors.

The climatic models were made using the ENVI-met tool *ENVI-guide*. All models based on the current climatic conditions assumed summer temperatures of 10 - 17 °C, whereas predicted climatic conditions towards the end of the century in a worst case scenario would be 5°C warmer,

hence these models were given the range of 15 - 22 ℃ (Hanssen-Bauer et al., 2017). The temperatures were based on the available data and averages from July from Yr (2022), which provides forecasts and weather statistics, hosted by the Norwegian meteorological institute and the Norwegian broadcasting corporation (NRK). Wind was assumed to be at a consistent 2.8 m/s from an eastern origin in all simulations. The assumed speed is lower than the averages as it made for clearer visuals to analyze. Emphasis was placed on consistency of climatic inputs to more accurately make comparisons between the final outputs rather than precisely reflect all averages. Therefore, the climatic input is a near average July day in Tromsø with a calm wind.

The final models were run through the ENVI-met tool *ENVI-core*. After being directed to an output folder, the simulation would take 12 to 32 hours depending on the complexity and scale.

The final output was visualized in the ENVI-met tool *Leonardo*. For consistency, the output data visualized was of the predicted temperatures at 12:00 at a 1.5m vertical height. Maps were made with a focus on predicted temperatures and wind, only highlighting the outlines of the building structures.

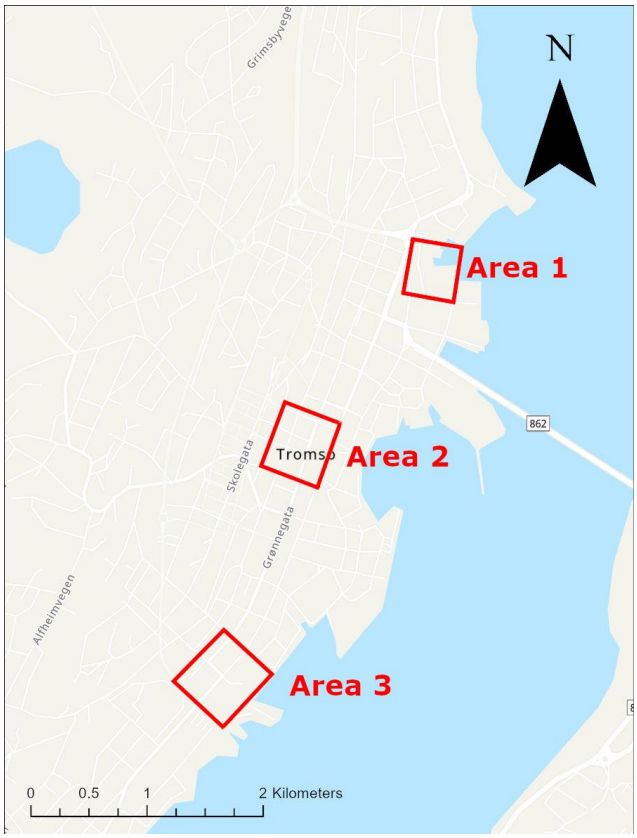

Figure 3.2 - Analysis area locations in Tromsø

Three areas were chosen based on data availability and BE variation (Figure 3.2). Area 1 and 3 are on the edges of what is considered the center of the city, yet still somewhat close in proximity. In terms of land use functions, area 1 currently has 3 larger industrial/office blocks, and a set of residential houses next to a bay. The proposed plan includes a complete renovation of the residential section, creating a new row of homes around an enclosed courtyard. The bay will also be changed with the addition of a promenade. The current residential homes have minimal GI in the form of bushes and trees, and the new residential plan also involves some GI on different locations (Figure 3.2). This is the only area with a seen increase in GI due to the additional visual provided in a separate plan document of the municipality as seen in figure 3.4.

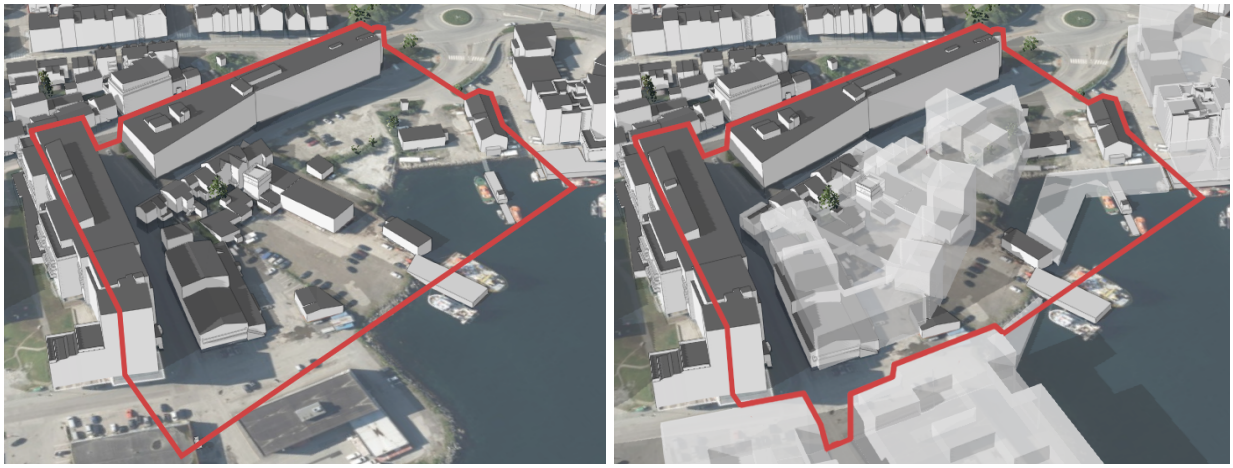

Figure 3.3 - Area 1 outlined in red, current BE (left) and proposed BE (right), view facing north-west (Tromsø Kommune, 2022c)

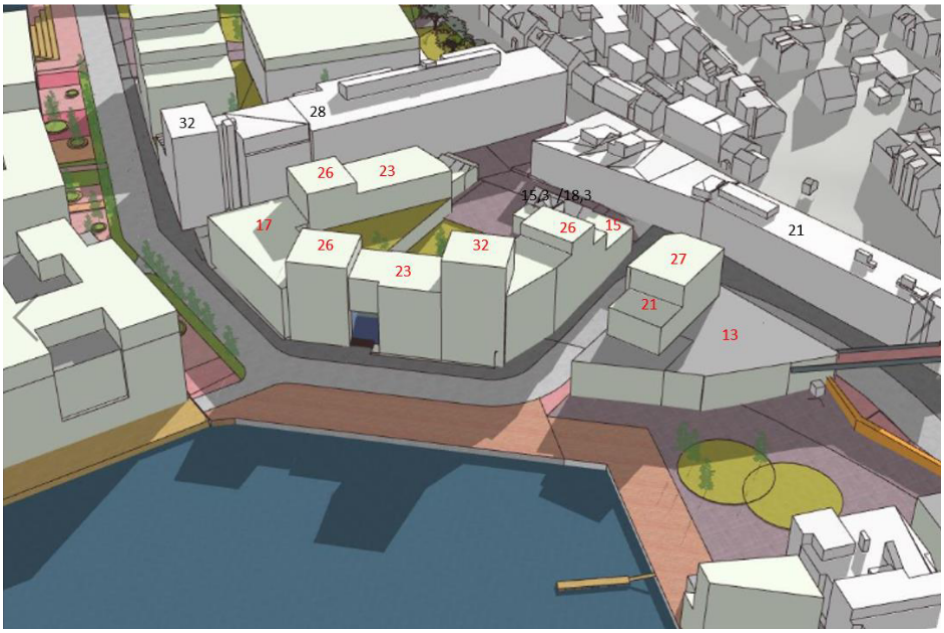

Figure 3.4 - Area 1 proposed BE visual, facing south-west, retrieved from Tromsø Kommune (2019)

Area 2 is the most centrally placed as it is located along the pedestrian center of the city (Figure 3.5). It is hence expected to be used most frequently as a public outdoor space. Due to its central location, the residential use is minimal. This area is part of the historic center of the city meaning there will be little to no change in these sections as it is to be preserved. The many low rise buildings along the street have commercial and leisure uses.

Figure 3.5 - Area 2 outlined in red, current BE (left) and proposed BE (right), view facing north-west (Tromsø Kommune, 2022c)

Area 3 has the most variation in BE, containing the most GI with a larger section of open space and grass surrounded by a row of trees (Figure 3.6). The parking lot in the current BE also has patches of grass and a few trees. The area contains a large, but low, square building block with mixed public functions (cultural, commercial, leisure, etc.). The area also contains a row of connected residential homes. Additionally to being the most diverse in functions, the proposed plans are significantly different, proposing the implementation of a more high rise university museum as well as a higher rise perforated apartment complex creating the largest change in density between current and proposed plans of all 3 areas.

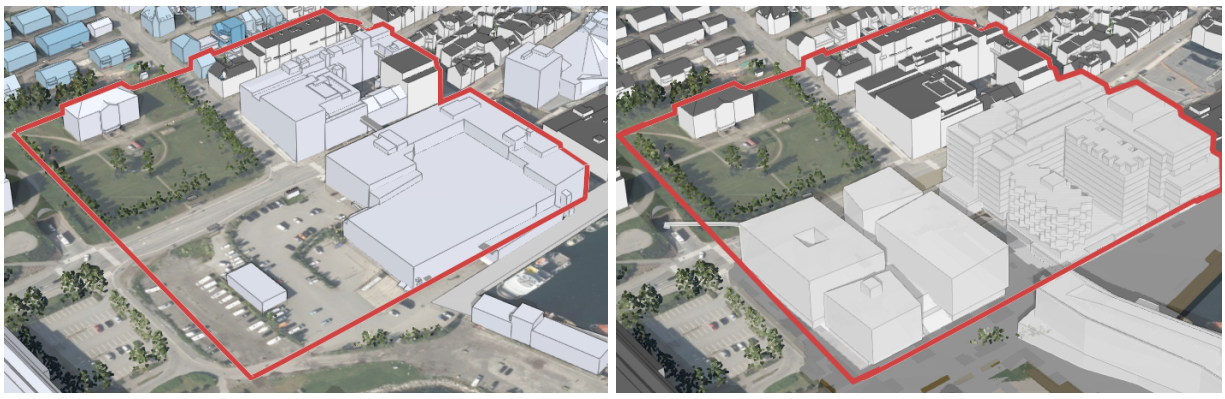

Figure 3.6 - Area 3 outlined in red, current BE (left) and proposed BE (right), view facing north (Tromsø Kommune, 2022c)

4. RESULTS

4.1 INTERVIEW RESULTS INTERPRETATIONS

The interviews of table 3.1 were coded using the coding tree of figure 3.1 as a guide. The result is the coding distribution chart of figure 4.1. The chart represents the amount of quotes placed under a specific code, however the quotes themselves may state contrasting concepts. It represents a distribution of the focal points throughout the interviews, the full coding overview is listed in appendix B.5. As stated previously, the coding process is the result of the interpretation of the interviewer and may not fully reflect the interviewees.

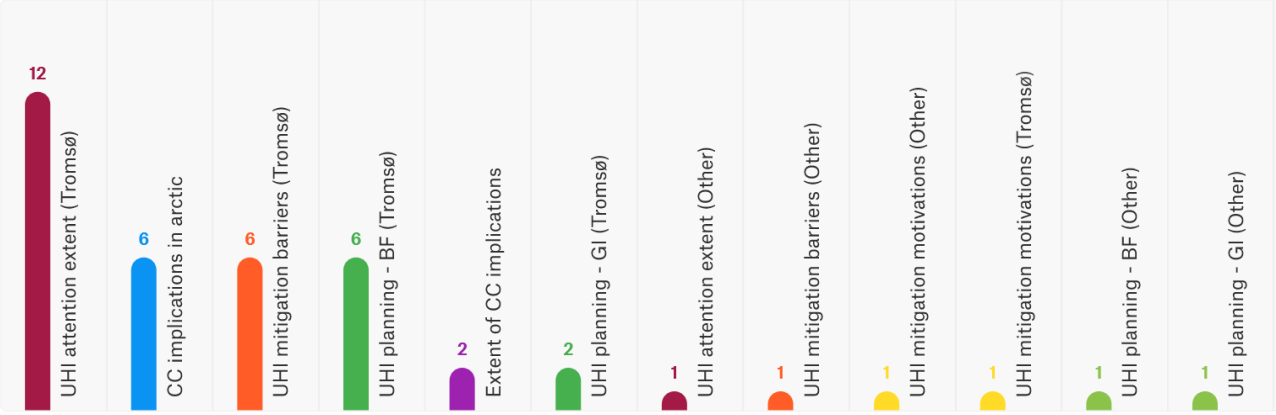

Figure 4.1 - Coding distribution chart

UHI AND CC ATTENTION EXTENT

It was made clear throughout data collection that the extent to which UHIs have been considered for current and future plans are minimal. The English term for UHI's was occasionally unknown to interviewees, though the concept was consistently recognized. A consistently noted reason for this lack of attention was the lack of UHIs being a concern in the current cold climate of Tromsø. As noted in the interview under Appendix B.3, UHIs are currently more likely to be desired than something to avoid. A warmer urban area would allow for more liveable outdoor spaces for longer periods considering the short summers experienced in arctic cities. Additionally, a significant reason for the lack of attention on UHIs is the emphasis on alternate concerns. Much attention is given to more pressing matters as a direct result from CC, mostly concerning water management. The fast rising sea level and change in spring melts overshadow the topic of UHIs which are not even considered unwanted at the moment.

CC is extremely relevant to nearly all planning avenues in Tromsø. Any proposals need to consider how it may be impacted by future climatic conditions. Although UHIs are not a current concern, temperate microclimates are due to their impact on various surrounding elements, notably water management as mentioned. Hence, currently Tromsø is in a situation of not considering UHIs, while considering the temperate microclimate of the city to a small extent and the wider CC consequences to a large extent. This is in accordance with hypothesis 3. Rather, the planners consider the topic less than expected, as it is near nonexistent in their work. Furthemore, this is in accordance with previous research noted in the theoretical framework, with researchers such as Miles & Esau (2020) stating arctic urban planners use limited information regarding the urban climate.

UHI RELATED BE PLANNING

As noted, the temperate microclimate in the urban areas of Tromsø — if considered at all — are more likely to promote warmer areas rather than not to increase comfort in public spaces. Hence, any BE interventions are unlikely to intentionally minimize UHIs. There was no mention of BE interventions specifically with the temperate microclimate in mind, however elements affecting the temperatures such as sun availability, trees or wind receive attention. Wind planning is of significant concern, as consistently stated throughout interviews. To preserve comfortable outdoor spaces, especially in summer, an area of amplified wind may negatively affect these spaces. Generally wind is not to be intensified by structures and minimized in public spaces. Wind conditions can significantly impact the temperate microclimate, where sufficient ventilation from wind is required to minimize the effects of UHIs (Kleerekoper et al., 2012). However ventilation is not a significant concern nor an aim in Tromsø. A common concept mentioned is the implementation of sunny walls which will have sunlight on them at opportune times as well as blocking out a cold northward wind for the warmer summer days. These sunny walls which may be a part of a larger structure are a basis for comfortable outside public spaces, blocking out wind and receiving relatively much sunlight which would create warmer areas. Another BE intervention noted was including lowered areas sheltered from wind, however this does not seem to be as widely implemented.

GI also is a significant element to minimizing UHIs and certainly is present in the city center. However GI is not present with temperate manipulation intent. As noted in interview Appendix B.3, trees and GI are desired for its multiple benefits, but a tree may cast a large

shadow considering the consistently low angle of the sun in the arctic. Hence, the size of the tree needs to be considered as shade is not desired in open public spaces.

ARCTIC CC

All interviews reflected a recognition of the widespread implications of CC on arctic planning across many aspects. Tromsø planners believed UHIs not to be significant enough to consider in the foreseeable future, as currently other issues take priority and would be costly to ignore. However, the long term remains very uncertain, and interviewees generally acknowledge there may be a shift in priorities or a shift between how different elements of planning may interact. For example, interview 2 in Appendix B.3 made the example of how there may currently be a misbalance between the national policies on air pollution of Norway which requires a certain amount of ventilation and the conditions of Tromsø, where wind is mostly minimized. This dynamic may change as the climate changes, where one issue may gain more significance and hence impact the overall priorities in policies and as a consequence, UHIs and temperate microclimate planning. However generally the interview consensus was that the future climate and hence state of planning is very uncertain in the long term yet the temperate microclimate is unlikely to gain attention in the short term.

4.2 ENVI-MET MAPS

AREA 1

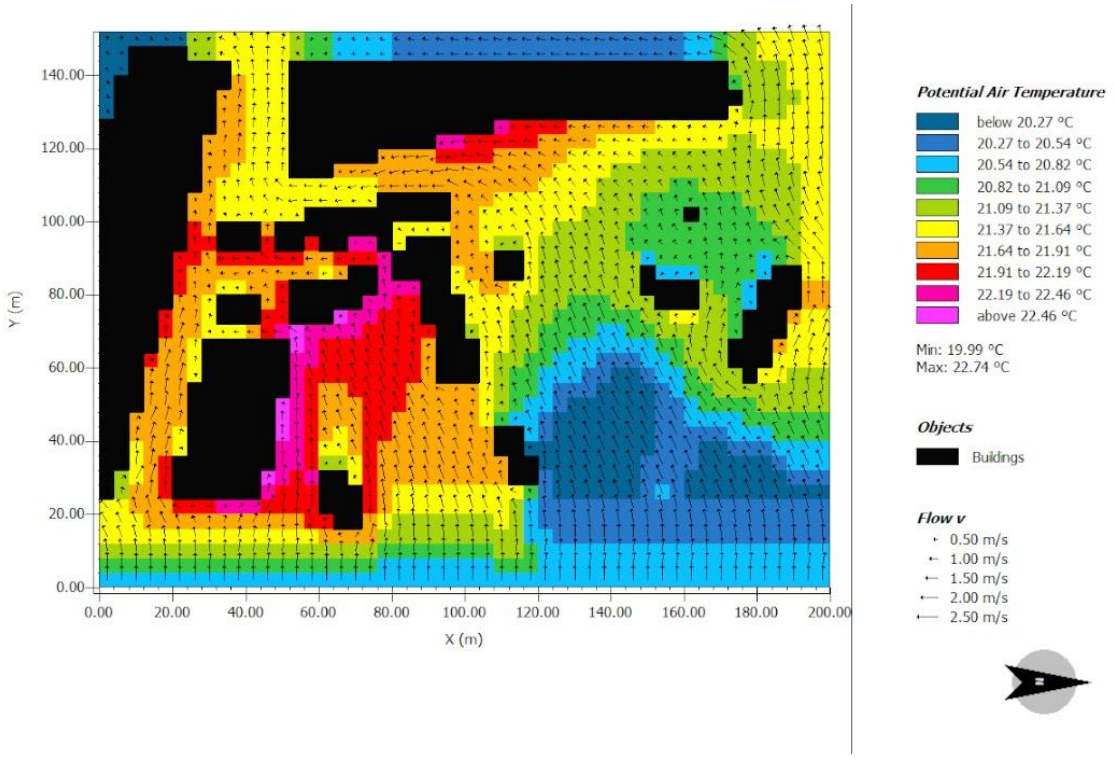

Figure 4.1 - Area 1 current BE and current climatic conditions simulation visualized

Area 1, currently containing small homes and two larger buildings by a bay, shows to have a significant temperature variation (Figure 4.1)(Appendix A.1). There is little permeable soil, and the vegetation present is minimal and ineffective. Rather the large water body is creating the coolest area, yet the effect of this cooling spreads little beyond the bay and land surrounding. The denser residential urban structures create a pocket of the warmest area. The buildings, made up of linear blocks and individual houses of varying heights allow for ventilation between the gaps. Nonetheless the wind flow is generally lower, creating a somewhat comfortable but warmer area by the BF.

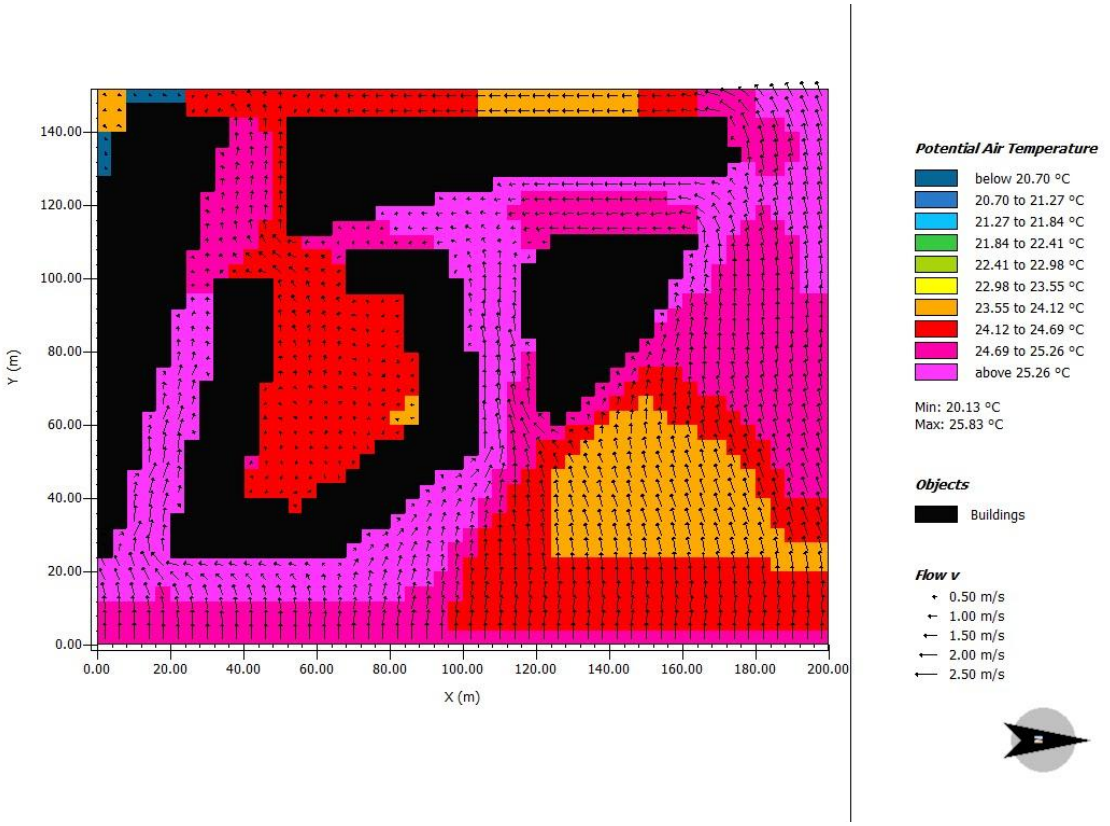

Figure 4.3 - Area 1 proposed BE and predicted climate conditions simulation visual

The proposed environment of area 1 is a significant change in BF design. The currently separated blocks in the center of the area become a taller u-shaped perforated block of dwellings, increasing the density and creating an enclosed space (Figure 4.3)(Appendix A.2). The enclosed typology is a relatively cool area, going against the expectation of u-shaped typologies increasing temperatures due to minimizing ventilation (Crank et al., 2018). The wind is near standstill inside the enclosed space creating a comfortable space for the arctic windy days. Despite this, the space is seen to be relatively cooler. This is assumed to be due to the surface material, as the enclosure was assumed to have some grass patches and permeable soil from the additional design proposal visualizations (Figure 3.4). Outside the residential block the temperatures are overall warmer however, potentially due to the removal of any grass, bushes or trees previously present.

The water body remains equally significant in cooling both the water and the area surrounding it. The proposed design has a slight impact on the bay through the addition of a

promenade, assumed to be of wood, which despite the overall increase of temperature in the second simulation appears to maintain the same cool level of the bay as in the initial simulation.

AREA 2

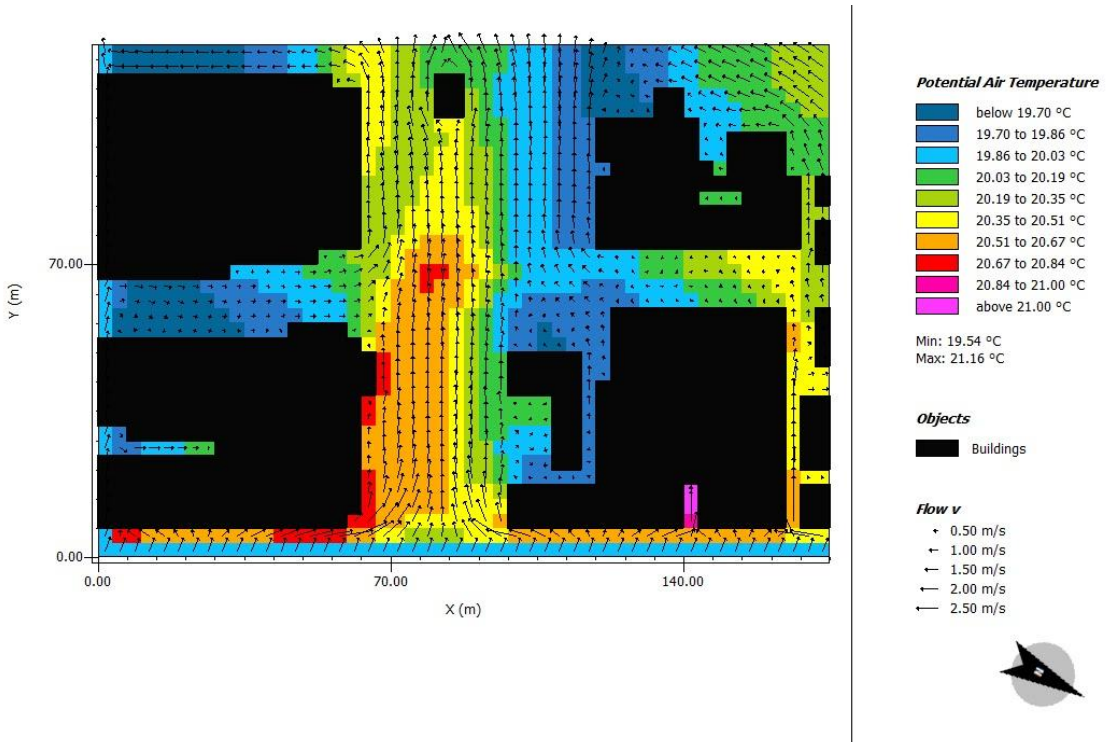

Figure 4.4 - Area 2 current BE and current climate conditions simulation visual

Area 2 is the most central location of all areas, being a part of the pedestrian center and expected to be used the most as an outdoor space (Appendix A.2). It will also face the least change in BE due to the preservation of the historical center. Consistent with the other two areas, the section with the most ventilation is not necessarily the coolest unlike expected (Figure 4.4). The open square along the center of the analysis area is the only section to contain GI, however also has more variation in ground material. It is not exclusively asphalt, but also contains bricks or pavement sections of differing albedo. Hence the open square is counterintuitively a warmer section, which would create a more comfortable outdoor space under the current climate's arctic summer days. It may still be assumed that the GI present is dampening any UHI phenomenon present, however the ground material is apparently more present and impactful on the temperate microclimate.

When assuming an eastern wind as in this scenario, the current BF creates a few pockets of near to no wind presence between buildings, providing shelter if need be. Most of the BF in area 2 are independent blocks or perforated blocks placed parallel to one another minimizing ventilation, and increasing temperatures very slightly in this scenario. Enclosed spaces do not appear to be a significant UHI factor in this situation, potentially due to the small scale of the enclosures.

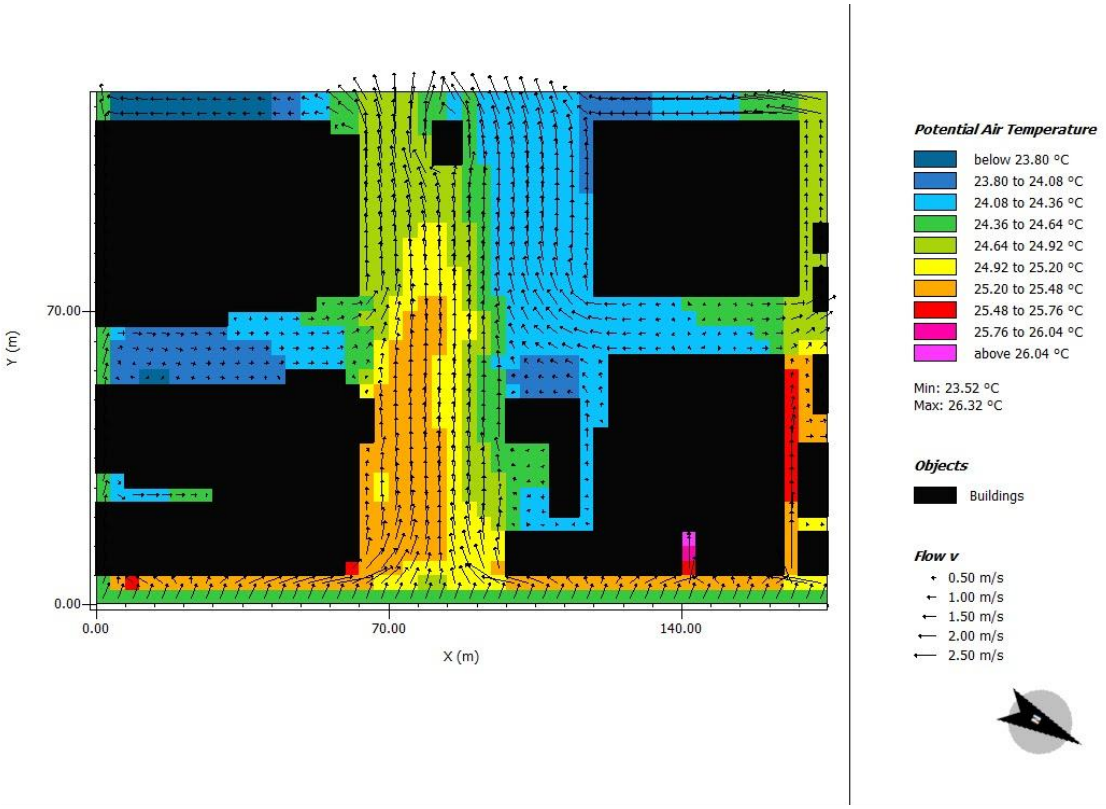

Figure 4.5 - Area 2 proposed BE and predicted climate conditions simulation visual

The proposed model for area 2 is overall quite similar to the current BE, having no change in GI and one of the four main building blocks significantly altered by being enlarged horizontally and vertically, impacting density (Figure 4.5). Hence nothing can be derived about GI. The increased density in one corner of the analysis area alters the wind flow around the building, causing a stronger flow around its southern corners, very mildly cooling the wall facing the open square. Otherwise, the proposed design in the pedestrian city center is of minimal consequence to the temperate climate, due to the small to nonexistent plans present to maintain the historical

center as well as any proposed plans not impacting the temperate microclimate to any significant extent.

AREA 3

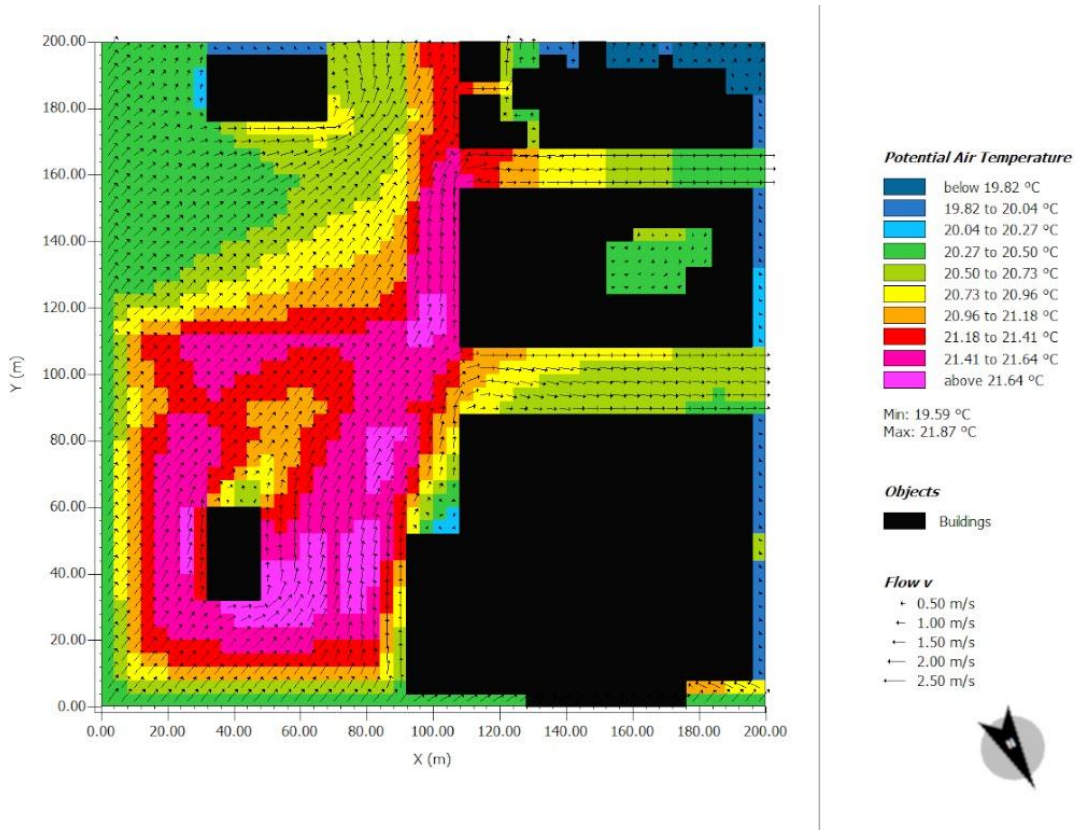

Figure 4.6 - Area 3 current BE and current climate conditions simulation visual

Area 3 which is shown to have the most significant amount of vegetation is the first model to show a notable impact of GI (Figure 4.6)(Appendix A.3). The large open area with rows of trees and ground covered in grass is generally the coldest section of the area. The wideness of the area allows for sufficient ventilation, and may be prone to discomfort under a northern wind. However, in the scenario of warmer summer days as in the simulation maintains a cooler section if required.

The parking lot, despite the few trees and grass patches present, is significantly warmer. The area is open with minimal BF, yet is warmer than the asphalt roads between the larger buildings with limited ventilation. This is assumed due to the increased presence of pavement and impermeable surfaces apart from asphalt road. The enclosed BF typologies are not shown to

be significantly warmer. Although, the BF of area 3 is somewhat low and sparse compared to area 1 and 2, which may impact this outcome.

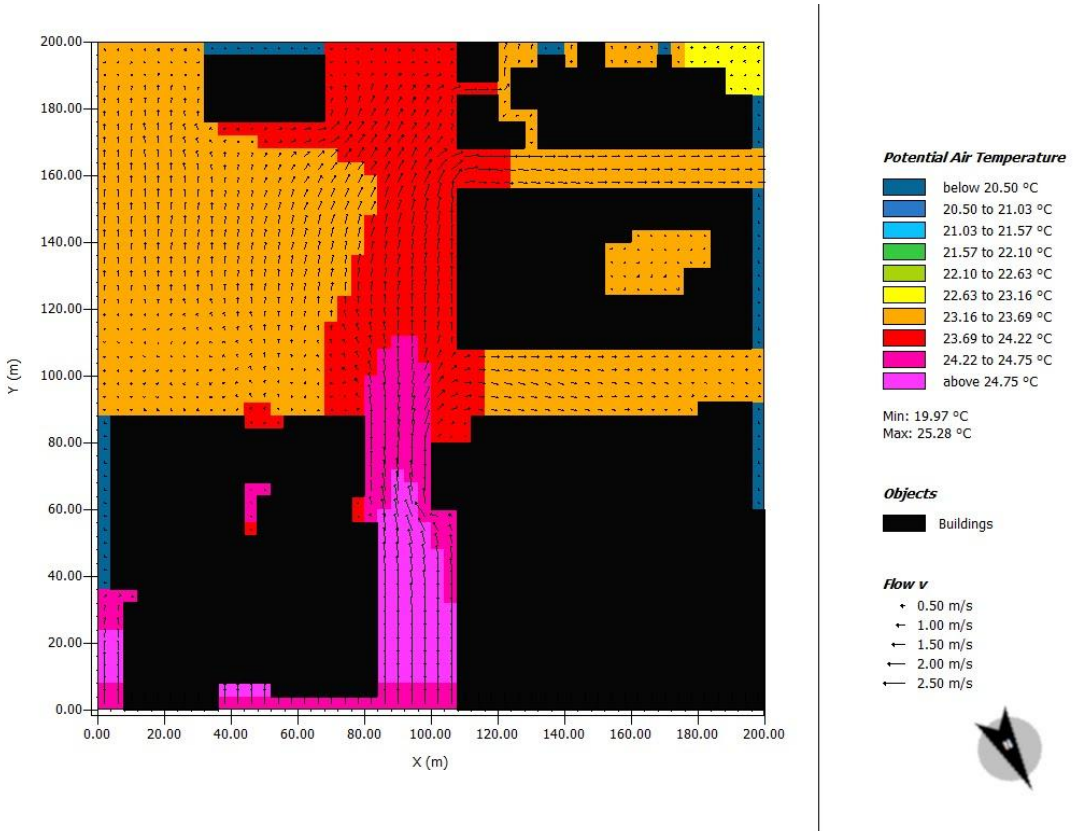

Figure 4.7 - Area 3 proposed BE and predicted climate conditions simulation visual

The proposed environment of Area 3 interestingly through removing the parking lot is overall cooler, even cooling down the open park area (Figure 4.7). The two added buildings significantly increase the density of the area, hence was expected to increase the temperate climate if anything.

MAIN INTERPRETATIONS

The simulations clearly show warmer and cooler areas, with predicted climate situations creating as expected overall warmer sections.

As expected from Kleerekoper et al. (2012), even the minimal presence of GI would have a noticeable impact on local temperatures. However, consistently in all 3 analyzed areas small sections of GI were shown to be of insignificant impact, with for example the open space in area

2 being the warmest despite being the only space containing GI. Under the presence of more widespread GI as in area 3, the temperate cooling effect is immensely impactful in the resulting simulations. The large water body of area 1 additionally had a large impact on cooling, however unlike a park, is not as accessible for public use.

Surface material was more consequential than predicted, with large spaces of impermeable pavement or brick surfaces consistently bringing forth the warmest sections.
Wind ventilation again did not appear to be as significant as ground surface, however does impact the temperate microclimate to an extent.

The results somewhat support hypothesis 1. When considering only the current climate or predicted climate, there are no significant changes in temperatures between the current BE and proposed BE in area 2, however area 1 and 3 create less warm areas when simulating the proposed BE. This appears to be partially due to the change in GI in area 1, and heavily due to BF in area 3. Area 2 with minimal change in GI and a slight increase in density is understandably the least impacted.

Hypothesis 2 is consistently supported. When considering the worst case scenario climatic changes, the simulations throughout the three areas changed far more significantly despite any proposed BE changes. None of the minimizing effects of changing BE in area 1 or 3 had a significant enough impact to deter the large temperature increase.

5. CONCLUSION

The aim was to investigate the extent of potential UHIs in the Tromsø city center considering the underlying planning process and current and proposed BE on a local scale. Academically, UHIs in the arctic have not been studied on a local scale, nor has arctic planning and its attention to UHIs been given significant investigation. Furthermore, UHIs could potentially become a greater concern in the arctic — specifically due to arctic amplification and the unique arctic environment — and hence increased research on the topic could aid the current uncertainty to the situation. Returning to the main research question, *how and to what extent is the BE planning in Tromsø resilient to UHIs in a changing arctic climate*, and its sub-questions, Tromsø noticeably experiences the phenomenon. Expectedly this is partially due to the city's current spatial planning process considering the temperate microclimate to a minimal extent. The city experiences other far more pressing concerns, and UHIs are not a current problem due to

the limited summer days and temperatures. However, if considered, UHIs are desired rather than something to avoid as it creates more comfortable outdoor spaces. Additionally, alternate elements of the city's microclimate which would impact any UHI phenomenon are more widely considered in all upcoming plans. The interviewees generally acknowledged the uncertainty of the future of microclimate planning and that UHIs might shift in priorities or how the phenomenon interacts with other elements of urban spaces. However currently excess warmth is not a present concern.

In regards to the BE in Tromsø, the three analyzed areas all foster UHIs, predicting temperatures above the climatic input of the simulations. Ground surfaces and impermeable soil appeared to be the most significant causal factors of UHIs throughout. GI was influential in minimizing UHIs when present in grander amounts, small grass patches or singular trees had little impact. Wind conditions had minimal though noticeable impact on the creation of UHIs. Future worst case climatic conditions considering an increase of 5℃ by 2100 would bring the city closer to the current climate of Norway's capital Oslo, which is more frequently experiencing UHI concerns (Venter et al., 2020). Depending on the extent to which climate change impacts the city and the web of interconnected elements to be considered in planning UHIs may become a more common term in future planning.

Both the primary and secondary data collection have notable limitations. As seen in the notes per interview (Appendix B.2.-B.4), some of the interviews were conducted partially in Norwegian. There was a language barrier in all interviews where not all parties were fully comfortable in either English or Norwegian. This may have led to misunderstandings from either the questions or the answers. Additionally, post-interview it was noted that not all interviewees were on the same page regarding definitions of terms.

The spatial models created in ENVI-met's *spaces* tool were limited to the LITE version of ENVI-met, or the free Demo version. Hence, the model could not be larger than 50x50x40 grid spaces, each grid potentially ranging between 0.5m to 10m. Additionally, the data from the map portal is limited to objects and shape, hence the standard building wall material of ENVI-met was applied to all buildings, details such as windows were fully neglected and roof angles or curved walls are less accurate. The same applies to vegetation, the data provided the location of trees for example, but not the type of tree. Ground material was assumed based on imagery from the municipality map portal, based on color and use (e.g. an asphalt road, short cut grass or

pavement ground). Hence the ground material, based on the visual interpretation of the maps is very prone to human error and may not fully represent the real environment.

The simulations are limited to their analysis area and are not representative of how the area would be impacted by the surrounding BE. For example area 3 and 2 are located by the shore next to a water body, which would most likely impact the overall temperate outcome, yet only area 1 includes a water body in the analysis area. Lastly, the areas chosen should be noted are in somewhat close proximity, despite the smaller size of the city. Hence a wider analysis would also allow for an investigation into more varied BE.

The use of more diverse programmes or use of more high resolution data would allow for a clearer and more certain conclusion. Currently the future of temperate microclimates in Tromsø is clouded by the uncertainty of how climate change will pan out in the arctic. Neither does this study consider wintertime UHIs, which are expected to impact northern cities uniquely (Varentsov et al., 2018). Additionally, Tromsø is but one of many arctic cities, and hence is not representative of the wider arctic conditions. The city also lies on an island, making it less comparable to inland cities. Therefore, further studies on the wider arctic context could lead to more varying results covering the somewhat understudied yet diverse arctic landscape.

In summary, this study implies there is much left to investigate and many uncertainties regarding the temperate microclimate in the arctic. Further research is encouraged due to the conclusion that UHIs have shown to be notably present and impacted by the BE of Tromsø with the potential of becoming problematic by the end of the century. Policy implications from this study are not significantly relevant to the current conditions of Tromsø, however expected to become more relevant with time. Hence, policy making may consider the temperate microclimate to greater extent during the planning process of future BE in relation to the surrounding impacted environment.

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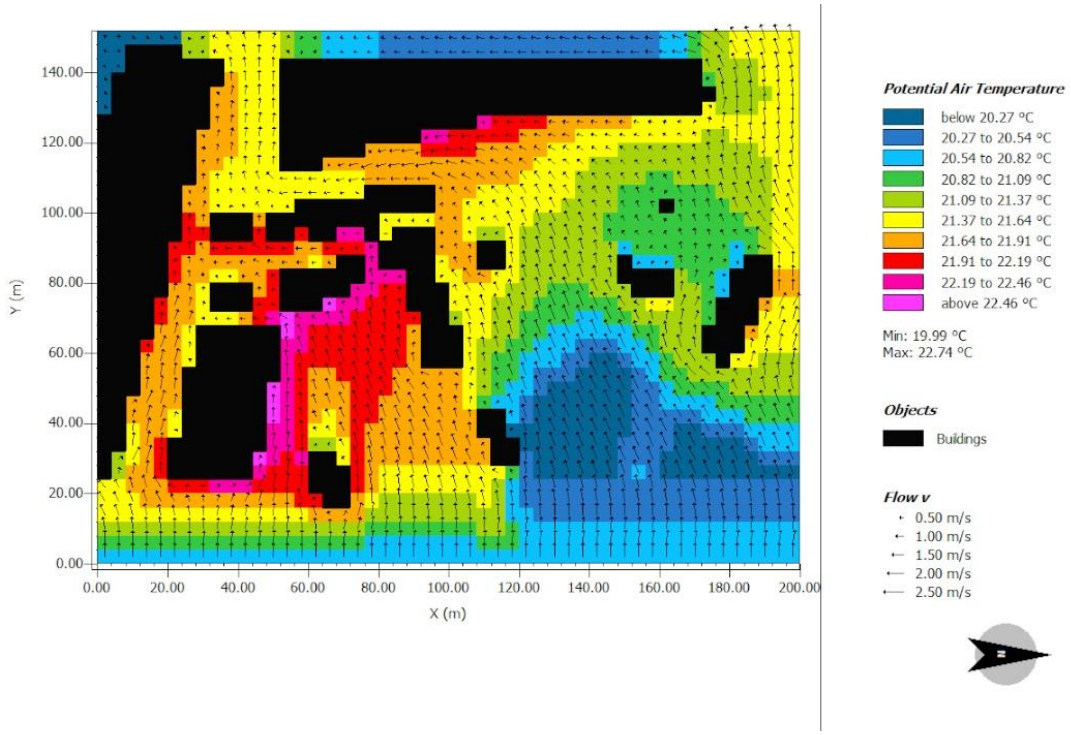
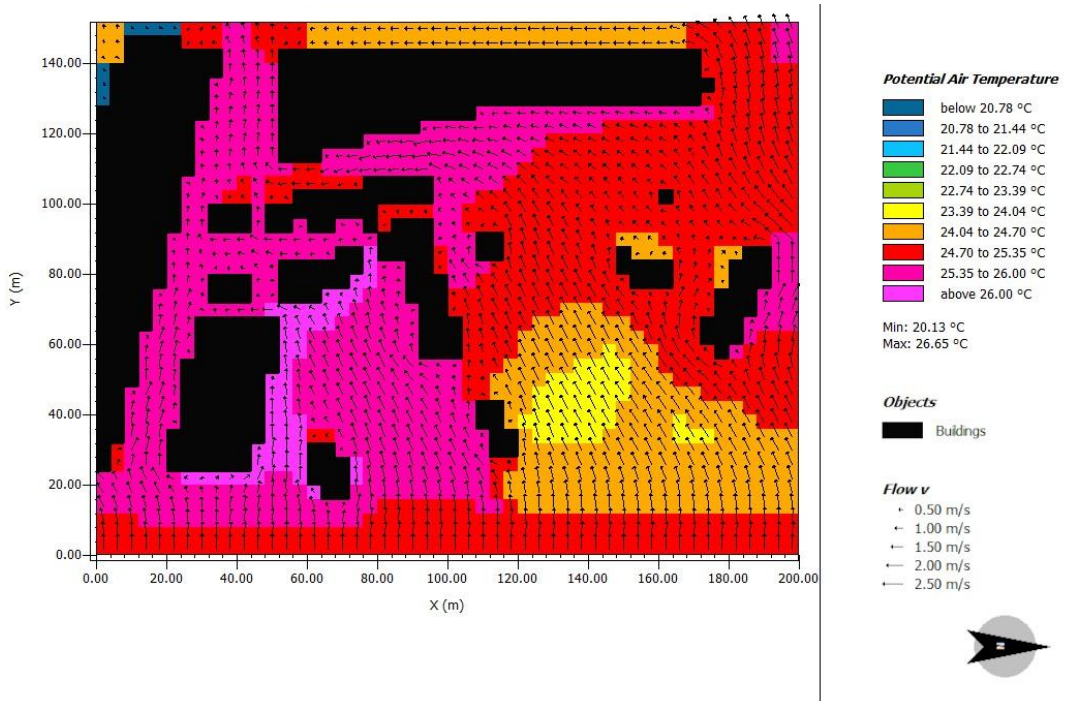
7. APPENDIX

APPENDIX A.1 - ALL AREA 1 SIMULATION VISUALS

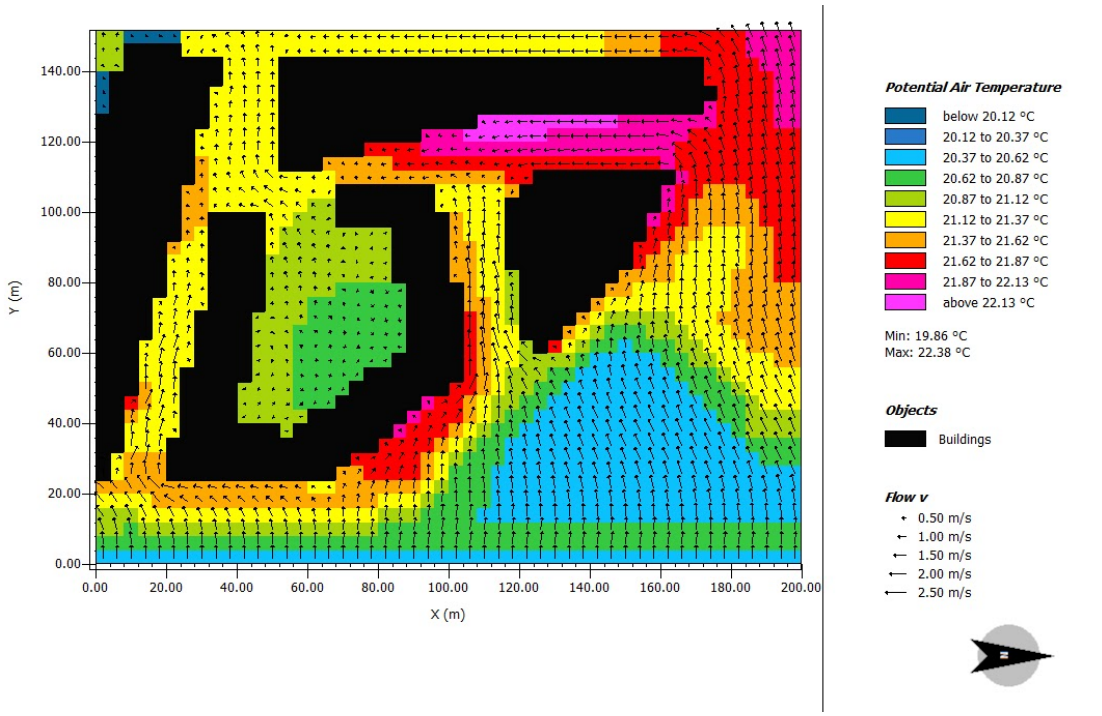
Current BE and current climatic conditions:



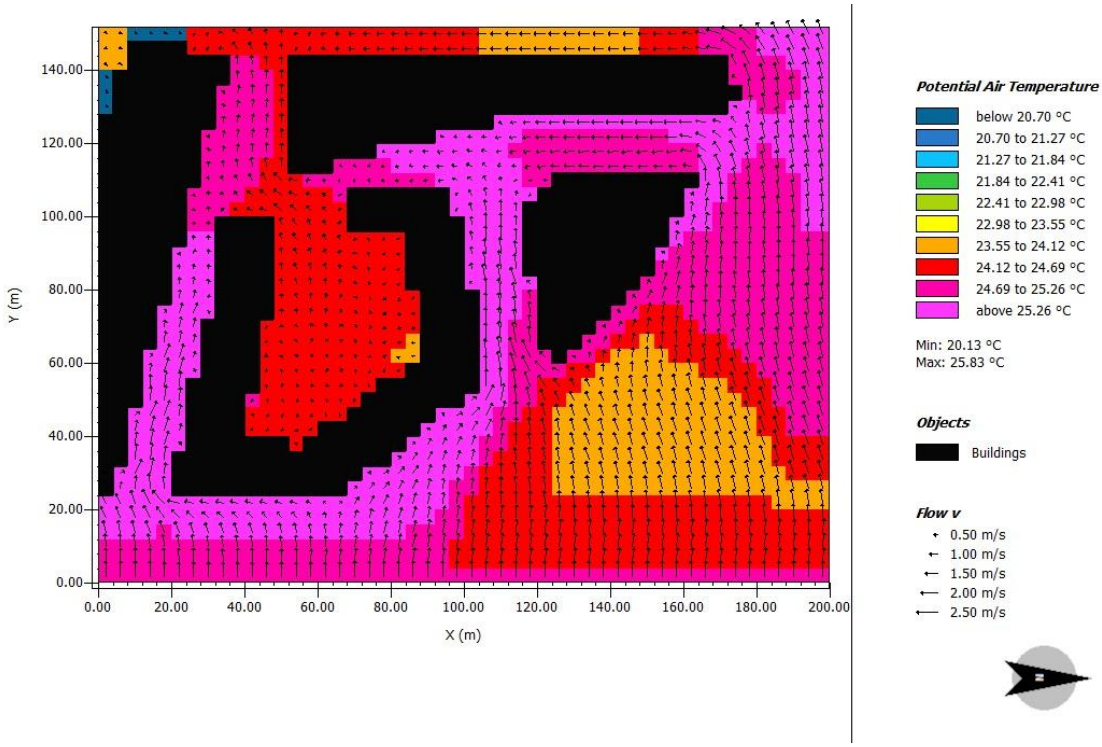
Current BE and predicted climatic conditions:



Proposed BE and current climate conditions

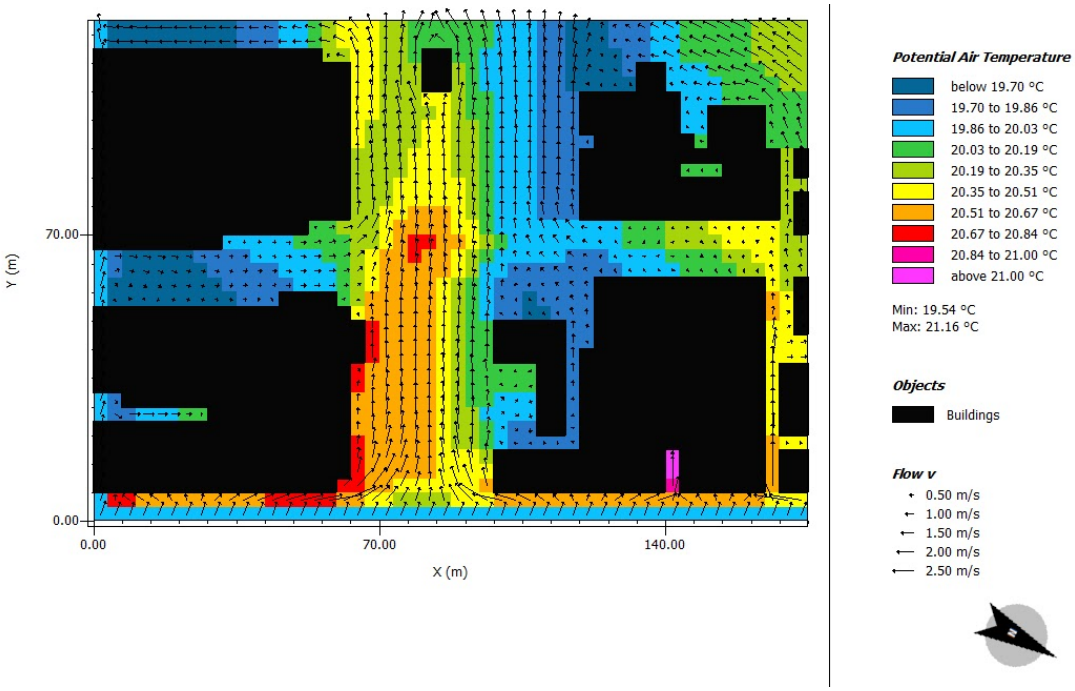


Proposed BE and predicted climate conditions



APPENDIX A.2 - ALL AREA 2 SIMULATIONS VISUALS

Current BE and current climatic conditions:



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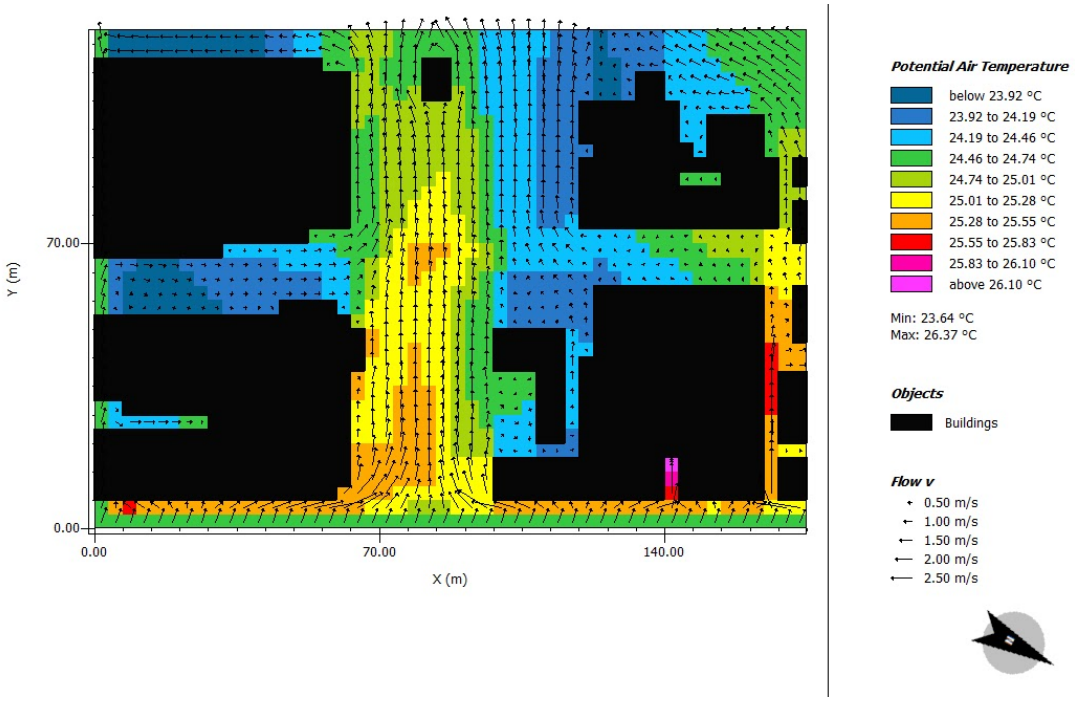

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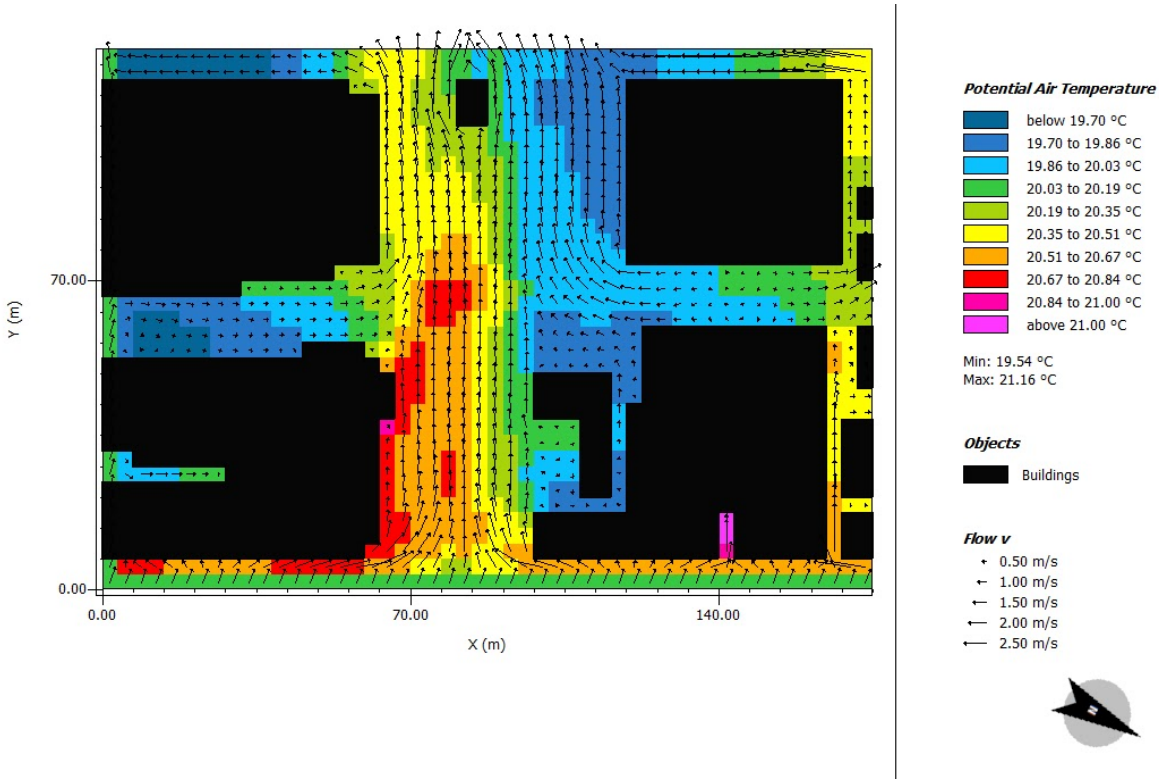
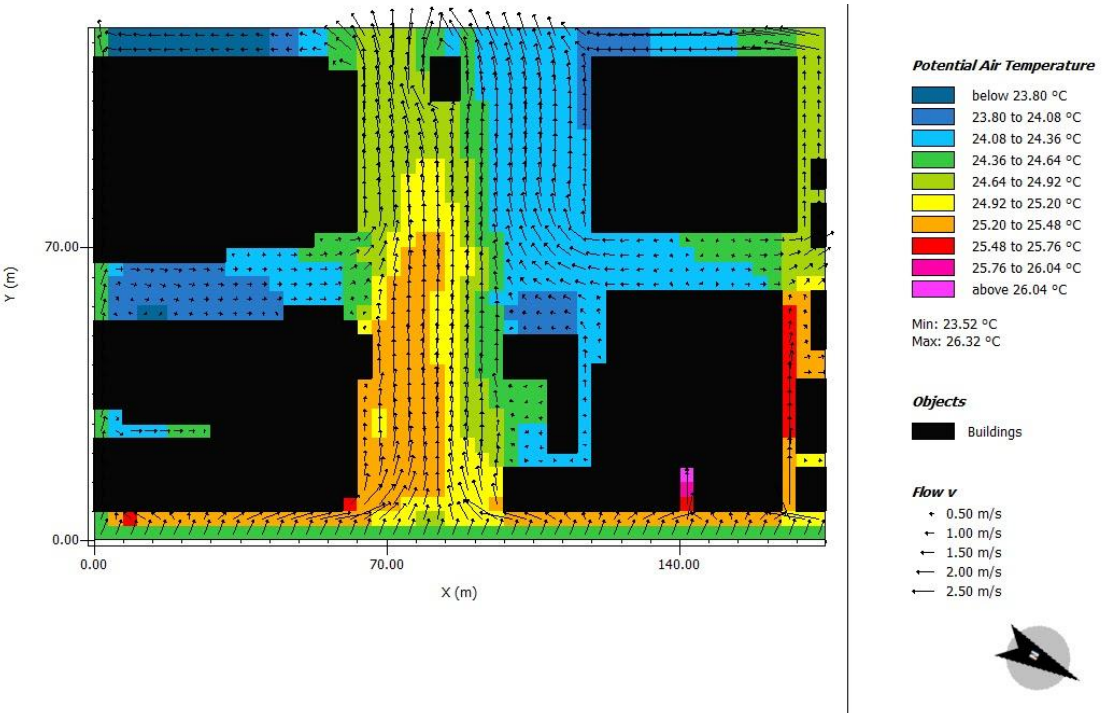
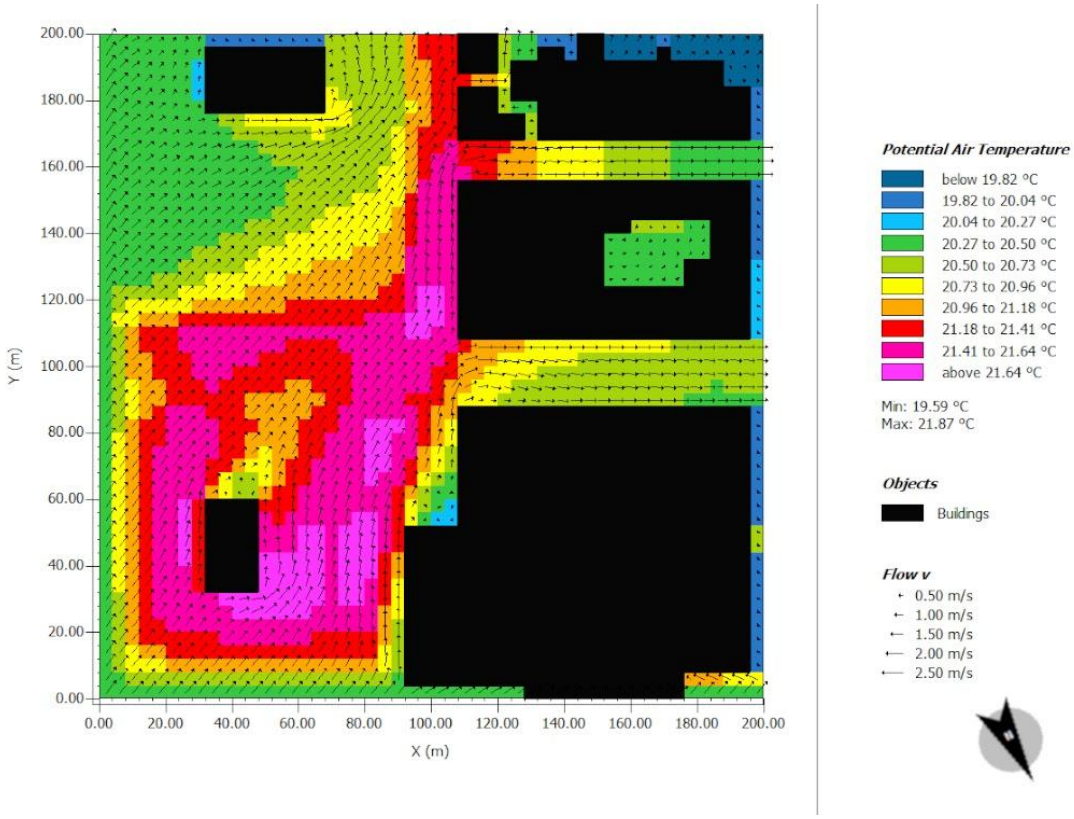


Proposed BE and predicted climate conditions:

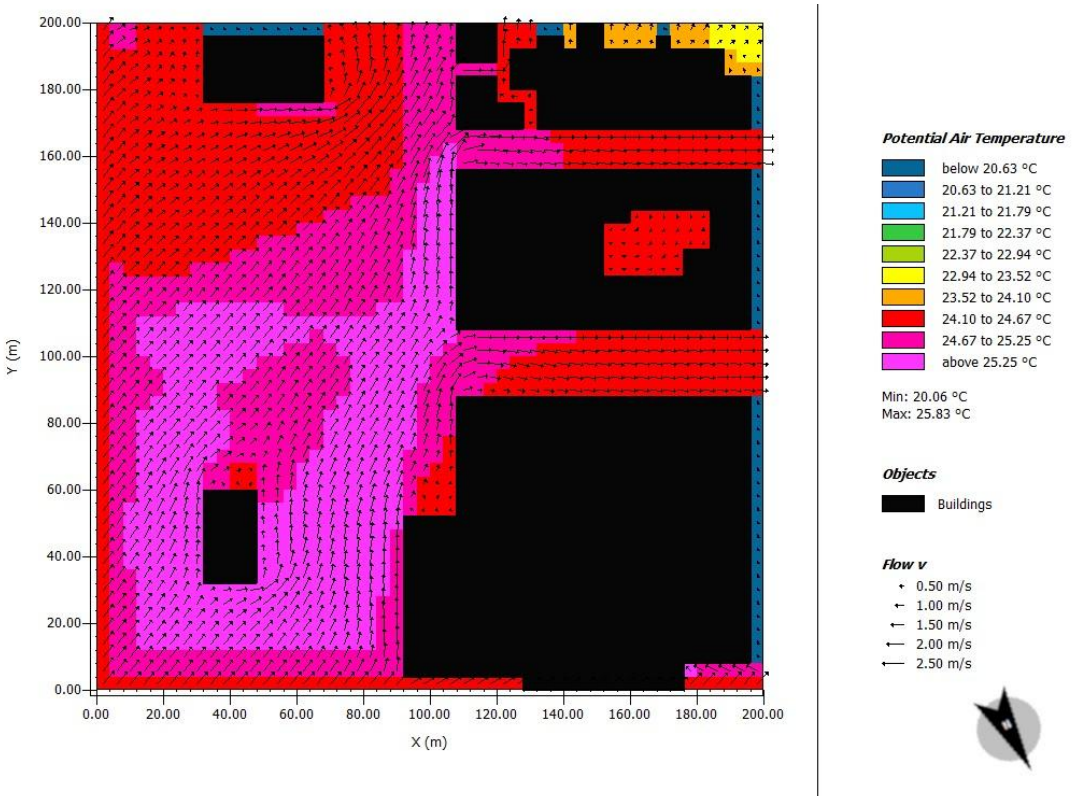


APPENDIX A.3 - ALL AREA 3 SIMULATION VISUALS

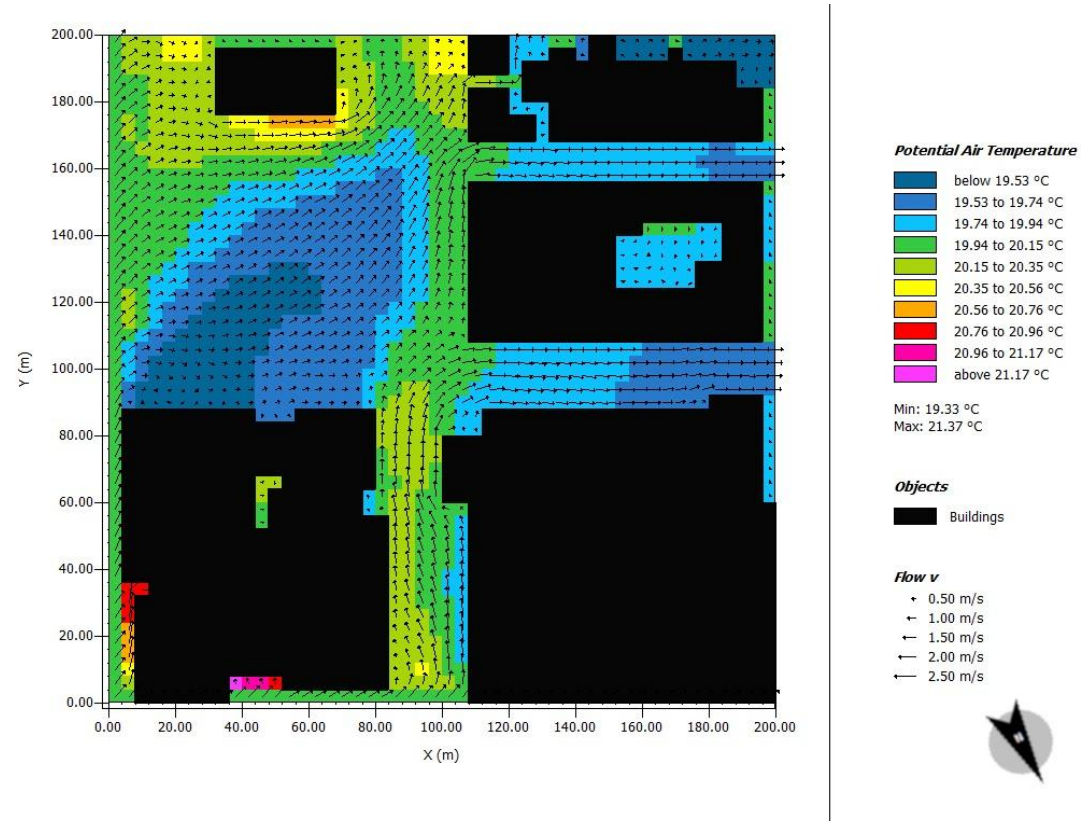
Current BE and current climate conditions



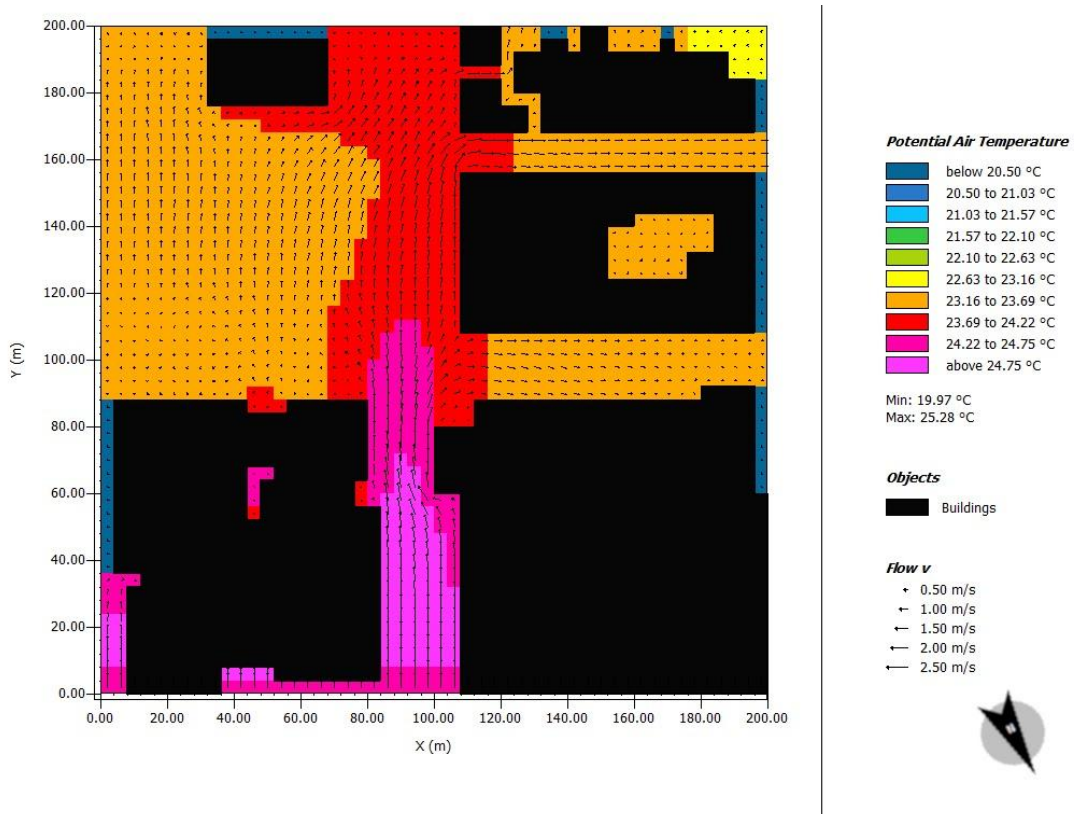
Current BE and predicted climate conditions:



Proposed BE and current climate conditions:



Proposed BE and predicted climate conditions:



INTERVIEW GUIDE

Wytske Kuipers s4017862 - University of Groningen - Bsc Spatial Planning and Design

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PRE-RECORDING

1. Introductions
2. Ask interviewee whether they wish to remain anonymous
3. Ask interviewee whether they accept the interview being recorded

\- START RECORDING -

INTRODUCTION (～5 minutes)

1. Introduce the project
2. Ask the interviewee if they understand and agree to the following conditions (on record).
    a. *This interview should take approximately 35 minutes.*
    b. *Their participation is voluntary, and they may stop the interview at any point.*
    c. *They have consented to the recording of this interview and wish/do not wish to be anonymous.*
    d. *The final paper will not use any direct quotes or statements without requesting permission from the interviewee first.*
    e. *If the interviewee wishes, they will be sent a copy of the final work.*
3. Ask about interviewee
    a. *Can you tell me about your work and your position in Tromsø Municipality?*
    b. *Can you introduce your participation in the Tromsø sentrumsplan and what it is?*

MAIN QUESTIONS (～20 minutes)

- To what extent do you have experience with Urban Heat Island (UHI) related urban planning? (Consciously planning with the urban microclimate in mind)
    - Extent of experiences in relation to Green Infrastructure (GI)
    - Extent of experiences in relation to Built Form (BF)
    - Extent of experiences inside / outside of Tromsø city? Differences?

- To what extent is UHI a concern in BE planning in your experience? Is it significant?
    - Any current or planned consideration in regards to sentrumsplanen?
    - Extent of experiences inside / outside of Tromsø city? Differences?

- Do you believe urban microclimates and the UHI phenomenon should be given attention in arctic urban planning? Why or why not?
    - Have you had any experiences that have motivated you to consider urban microclimate concerns in your practice? (Made it a more significant concern)
    - Have you had any experiences (or lack thereof) that have discouraged you to consider urban microclimate concerns in your practice? (Made it a less significant concern)

- In regards to climate change and subsequently arctic amplification,
    - What future implications do you expect for arctic BE planning?
    - To what extent do you expect CC to impact the urban landscape and microclimate considerations?

CLOSING QUESTIONS (～5 minutes)

1. Do you have any additional experiences/information you would like to share?
2. Is there any additional information you recommend the interviewer to investigate?
3. Do you have any additional contacts or organizations you believe the interviewer could request an interview from?

\- STOP RECORDING -

POST RECORDING

- Ask whether the interviewee would want a copy of the final work when complete.
- Clarify contact information in case of further questions.
- Thank interviewee for their time and help

INTERVIEW TRANSCRIPT 1

28th of March 2022

INTERVIEW NOTES

Interviewees:

Heidi Bjøru - Case officer of the center plan and a city planner
Jaqueline Randles - Administrator in the section for city planning

Duration of recording:

27 minutes

Additional notes:

- Jacqueline Randles had to leave 21 minutes in.

PRE-RECORDING

1. Introductions
2. Ask interviewee whether they wish to remain anonymous - They did **not**
3. Ask interviewee whether they accept the interview being recorded - They **agreed**

\- START RECORDING -

Interviewer: I need to read out a few statements first, and ask if you understand and agree with them, so first of all this interview is expected to take about 35 minutes with one person, your participation is completely voluntary and you can stop the interview at any point, you have consented to the recording of this interview and do not need to be anonymous, and my final paper will not use any direct quotes or statements without specifically requesting permission first. If you wish I can send you a copy of the final work when completed. Does all of this sound correct to you?

Heidi (H): It's okay.

Jacqueline (J): It's fine.

Okay, perfect, then we can move into the questions. The first thing that I was curious about was, well, to what extent you guys have experience with any kind of planning inside or outside of Tromø with microclimates or urban heat islands in mind.

J: I can say a little bit, I am from Australia, from Melbourne, where we have to have a lot of focus on heat, and how urban planning in particular can lead to very uncomfortable situations in the built environment. That type of focus is not something that has weighed really heavily in Tromsø in the last few years. Particularly when it comes to heat, which is something that has not really been a focus area. But when it comes to climate changes and how we deal with trying to ensure that the urban area is usable, by warming, heating, preventing ice buildup, that is something we work with all day every day in planning. So while it may not be a climate focus with regards to preventing that very uncomfortable heat island situation, our focus is more the opposite. How do we ensure that the urban environment is able to be used. Heidi, did you..

H: Yeah, I think for us it's more to take care of the heat that we can find. So we try to protect the sunny spaces, because the sun is very low here, the maximum degree of 44 degrees, and that means that the urban spaces are very easily - a lot of shadow in the spaces - so we try to protect them from high rise buildings so that we can protect our sunny spaces. Especially the facades that are orientated to the south and have no coming winds from the north are very important to us to keep these spaces. So this is an important part of the work in the Sentrums Plan. And the other thing which is - the... sea rise, sea level rise, it's a very, very important theme. This project we mentioned to you, it focuses on these problems of the sea rise combined with the more wet weather on land. When we have more rain instead of snow in winter we have these problems with water that is not soaking into land because it's frozen. So, by the sea we have this problem with, at the same time we have the sea rize and this water that is not sinking into the ground is flowing down. These two waters meet by the sea side, and is very special because Tromsø because the city is by the sea and a lot of the city is built on landfills, and fields, and the level of this is two to two and a half meters above sea level. It means in a hundred years a lot of the city center will be underwater, when the sea level is at its highest. It's called “stormflo”, it would be about the same in english,

Storm surges?

J: yes

H: Yeah, you get the point. So this report we told you about, it says that in the center the new parts we have to build it higher, both the landscape and the buildings, we have to go up three and a half meters above the sea level. The central historical part, we have to find another way to do it because we cannot lift the town that is there already. We have to find new solutions, and we have to build protection against stormflo (storm surges) on the piers. Maybe also, what do you say in english jackie, “sluse”

A sluice?

H: yeah, ah, I don’t know the word in english. You have it in the channels in Germany, in Holland.

Yeah, it's just a sluice as well

H: Oh, very good, international. So that is also, can be a solution in this part of the city center. So this is a very big thing, it's expensive, it calls for solutions that we can build in one piece. Its a very big challenge and we don't know yet how to do it. We have to have cooperation between engineers that can fix the technical part and architects and designers who can at the same time be sure that the way we do it will also be beautiful and look like a nice place to stay, ninety nine percent of the time when the stormflo is not there. Also, this very very special challenge with stormflo and, "overvann", the water that is coming down on frozen ground (spring melts). This is very special for Tromsø I think. We have a lot of snow in the winter, we already see that these periods of warm weather it comes more often in the winter and creates this situation. This is I think the real core of the challenges we have now. I would say so. What do you say Jackie?

J: I agree, what Heidi is talking about, the spring melts. The spring melts don't just come in spring anymore. We are still in the middle of winter here and we just had maybe fourteen days of spring melts here which affects our infrastructure, affects how we deal with infiltration. It also can impact how we are able to maintain our facilities and the town so having a good understanding with how we deal with spring melts time and also increases in precipitation, also in summer months it's incredibly important. Traditionally we'd just hoped it would run into the fjords. But in addition to water running, we also have a situation with pollution contaminants which are now more highly controlled through legal frameworks than we are used to to try and deal with these types of contaminated water situations. Increases in runoff which can affect properties, which can affect investments, it means that planning is more important now than it has ever been.

It clearly seems this is the largest concern at the moment, on the other hand very quickly; you have not considered temperate management or urban heat islands at all, right?

J: No.

No, and how about the wind conditions?

J: Wind? We definitely talk about wind.

H: Its wind and sun are the two most important issues when it comes to urban spaces. Because, we have a lot of wind, especially in the winter time. It takes down the temperature but it also makes it very not nice. So, we try to make, uh, we have tools, more tools to plan how the sun is. We have 3D models, digital models, so its easy to find out where the sun will shine or not when we study a building that is not built yet. When it comes to wind it's a little more complicated both to make the study and to use it. Because the sun and shadow is very concrete, its very clear what will happen but with the wind its not so easy to, especially to use it to tell to say this makes too much wind or this is okay.

What would be the ideal outcome with wind, the ideal plan, would you want ventilation or just minimize the wind?
H: It would be minimizing the wind. And it is very important to see the wind and sun together, as I was telling you about the sunny spaces that are oriented to the south and no wind to the north, which is the typical spring and summer wind when we sit outside. So the cold wind comes from the north, and it's perfect because the southward facing the sun will be the best place. So if we have a project that will make more wind on the sunny places, it is not a good project.

I see, and ...

H: So I think the ventilation, I don't think I have ever heard that it is a problem in Tromsø

No, it's mainly because the main focus of what I am investigating is the UHI phenomenon and ventilation is a significant part of this.

J: I have a meeting now, but I was going to say it's definitely not something that has been discussed in Tromsø. I would doubt very much that it is something that is discussed very much in Norway, coming from a country that discusses this all the time. It's not something that is prioritized in topics on climate.

H: Would you say it was interesting for us, or is it..

J: I feel like we have more pressing matters before we start prioritizing discussions around heat islands. Because often heat islands are caused by high levels of impermeable surfaces, lack of green space, not allowing infiltration, not allowing space to deal with the natural movement of water. Our considerations are more to do with other factors as opposed to heat islands.

H: I agree, and I think that's why us too, because I think it's quite interesting in itself that this is maybe another view on planning issues than we maybe have in Europe. So that is maybe in itself an “artig” (fun) view on planning. So that is quite interesting.

When considering climate change and in this case arctic amplification as well, I’ve seen some predictions regarding Tromsø and other arctic cities where the climate will change drastically in the coming 50-100 years. Worst case scenario it might become like how Oslo is now. This is also a big reason why I am studying this. In that sense, do you believe urban microclimates or urban heat islands might become more of a concern?

J: I think it’s really important to define the difference between microclimates and heat islands, because our microclimates are really different. So if we’re talking about microclimates, I believe that we can definitely contribute to those discussions but urban heat islands is a different set of principles.

H: Yeah, that's good, for me heat islands is a new, its something new, I don't know the expression. So yeah, that's interesting.

J: I don't think they're necessarily interchangeable.

No no no, sorry that's my bad I used microclimates as a sort of umbrella term where urban heat islands are one of the things affected by the microclimates

J: Often a lot of the measures taken are about vegetation and those types of things, those types of measures.

Mhmm,

H: Okay Jackie you have another meeting

J: Yes, but I'm more than happy to have another discussion with you at another time, so let me know but I have to run.

Oh yes apologies!

J: No not at all, but it was lovely talking to you and we'll talk again soon. You're in the best of hands with heidi.

H: I'll continue, goodbye!

Bye,

H: She had another meeting at four o'clock.

And it's already past four,

H: Yeah, but we can continue.

Yeah yeah, I think we have already covered quite a bit. I was not expecting urban heat islands to be a new term since I've studied it so much

H: I see,

But that is also partially why I wish to study this because I understand its not something people think of initially when thinking of arctic cities due to the cold. But I'm curious as to whether it might become a concern.

H: I understand, and it's very interesting, so it would be very interesting to see what you find out. I think also this, we mentioned the spring melt that we have now also in the winter with the frozen ground and the water is just running and is not infiltrated into the ground. Maybe this is a part of the theme that you want to discuss, maybe in a little other angle but its a part of the changed climate here.

Well that's not something I have considered before,

H: We have started to work with the blue green factor, which for us is the blue green white factor. So you have probably heard of the blue green factor before, for us it is the blue green white factor.

With the addition of snow I suppose?

H: Yes, that's right. So this is a more mathematical approach but we use it. We use it in both residential areas and in the more urban places.

Very well, If you would let me check something real quick... I believe most is covered but to add onto this, I wanted to ask about your opinion on the implications of climate change on the built environment in Tromsø in the future, though it was slightly covered.

H: I was looking for this report, as I said it was in norwegian but you can read it because your norwegian is quite good

Thank you,

H: So this email I have for you is a student email?

Its a personal email

H: Do you have a limit as to what you can receive?

The normal google limit I believe, I do have a student email if that is easier

\- END RECORDING -

POST RECORDING NOTES

- Furthered the contact Johanne Kryger
- Heidi Bjøru requested to know the name ENVI-met
- Requested 3D models of proposed plans for the center plan of Tromsø

APPENDIX B.3 - INTERVIEW 2

7th of April 2022

INTERVIEW NOTES

Interviewees:

Johanne Kryger - Spatial planner in the section of city planning

Duration of recording:

31 minutes

Additional notes:

- None

PRE-RECORDING

1. Introductions
2. Ask interviewee whether they wish to remain anonymous - Kryger did **not**
3. Ask interviewee whether they accept the interview being recorded - Kryger **agreed**

\- START RECORDING -

Johanne (J): Just, if you quote me, my english might not be exactly correct.

Interviewer: Oh no, that is actually a part of what the starting conditions are. So I have a few conditions and would like to ask you whether you are alright with them. So, this interview will take approximately 30 minutes. Your participation is voluntary, you can stop this interview at any point. You have consented to the recording of this interview and do not feel the need to be anonymous. The final paper will not take any direct quotes or statements from you without requesting direct permission first.

J: Sounds good.

If you wish I can send you a copy of the final work when I finish it.

J: Yep. I think this would be an interesting topic to read about, since I studied my bachelor's degree in environmental city and energy planning and also studied climate change strategies in Lund, and we did have some topics about heat islands.

Okay,

J: We had one course or two maybe, but it's been something we twist around up in the arctic, we definitely want those heat islands if we can get it.

That is something that surprised me in my previous talks, that the term Urban Heat Islands is not something recognized.

J: That surprises me as well because we use it, we think- they might not necessarily know the term but it is used definitely. As a concept it is more of knowing your local climate, have you started recording?

Yes, yes.

J: FIne, that was just to know whether you get what I am saying. Its just that there is typically, the wind usually comes from the south or the north and typically in summertimes it comes from the north. It can really ruin a sunny day if there is a cold wind coming from the north. It might not be a known term but it is something we do work with a lot.

Okay, so it is kind of the opposite in the arctic then.

J: Yes definitely, definitely the opposite.

That is interesting because I got the impression it was almost no priority, there was mostly talk about water management and the more pressing concerns

J: Its not really a topic we talk about in relation to climate adaptation, its a topic in making liveable areas where you... well we have very very few summer days, good summer days, we try to increase the numbers by making areas that are more sunny and guarding it against wind. We probably don't know of the technical how to do it but more from many years of experience of living here.

Do you, one moment. Have you ever worked on planning outside of Tromsø as well?

J: No I haven't worked there, only studied there. So my first job after studying was in Tromsø.

Okay I see I see. Do you have any examples of experiences in planning in relation to temperatures and the built environment?

J: In Tromsø?

In Tromsø or anywhere else

J: I think because a lot of the.... I wouldn't say we are doing it that much but we do in regards to wind and snow. Since snow is a big issue up here and its something that will easily bring up conflicts with neighbors. So if you built a garage that will result in more snow on your neighbors entrance then you are asking for conflict. Not that we are always that good at it since microclimate wind is tricky and difficult in small construction cases. But we know that it can become a problem with these microclimate issues and so, in regards to... Usually in the water front in Tromsø you would usually see houses, gardens, so the outside on the southside and the building on the north at least. Also, usually that would be building towards the east, there is a lot guarded from cold wind. We are focusing a lot on having sunny walls towards the north.

Sunny walls?

J: Sunny, so that when you have an outside area you have not too, like, on the south side of the building. To the north was probably not a good way of saying that. Thats often the case.

About blocking out the wind?

J: Yes, about blocking the wind and also it, well, often you would sit against a sunny wall in Tromsø because otherwise its pretty dang cold.

Are there any other particular physical measures you would take against the wind?

J: It could also be like, instead of a wall, constructing a bowl.

A ball?

J: Like a, smaller, what would you call that.

Like a dip? Oh, bowl

J: Yes, a dip, bowl, yes the danish haha... or something like that. Then, I don't think we do that much else in... then it would be something like, there is not a lot of tall trees in Tromsø. It's not that we dont want tall trees, but they are kind of something where, sitting in the shade is very rare. That is something you would like to do. Placing trees, where you place them is also something you should consider in regards to how would this affect the outdoors area. Also because the sun is usually, it has a low angle, so the shades can be very long. The same for when you put up buildings there is a lot of shade, rules that you can't increase the shade on your neighbors outdoor area. Then we have this in the masterplan of the kommune. Something like that. Then it depends on what types of outdoor area, if its a playground for young kids. Is any of this answering your question?

Yeah yeah yeah, its in the realm, either way I just want your perspective but,

J: Good, so these are kind of the principles we have in planning. It would be increasing this I think, it is in conflict with something like the national guidelines, for example air pollution. You should have flow of wind if you are in an air polluted area. Then there is a priority between having an outdoor area where you would want to sit, or having less air pollution, so that is something you would have to balance. Since, getting an airflow would often mean getting wind from the north.

So you have to find the balance,

J: Yep

It's very interesting to hear how different it is in arctic planning, it feels very counter intuitive.

J: I think it would yeah. It makes sense that it does. Very often we get these national guidelines and I think, yeah that doesn't really go here.

Okay, this has already answered a lot of my questions in one go. What I'm very curious about and what my paper looks into is the future potential of urban heat islands being a concern. I am for example looking at making simulations comparing current climatic conditions and predicted conditions alongside the proposed models of Tromsø,

J: That sounds very interesting, definitely, because at the moment planning is just, we want heat islands. This is definitely something, since the arctic walls have higher expected rises in general temperature then that is something which might not always be like that, that we want to construct our own heat islands all the time. But yeah, we haven't experienced that yet. But definitely its very interesting that you take up that topic regarding the arctic as well, because so far we're talking days. Summer days is like five days or something like that, that you would consider summer days. I don't know, five is just a number, might be something different, but its not a long summer season. But of course that will change.

Do you think that urban heat islands, or that instead of promoting them they might become more of a concern under climate change and the arctic amplification?

J: It's... I don't really know that it would be a problem necessarily, but that's not necessarily meaning we should not reconsider this. For example, we are at the moment balancing between air pollution and outdoors area and that if we get or when we get a warmer climate that that balances out because right now it often is that the air pollution will lose in comparison to having a liveable outdoor area. Especially on the nice southern part of the built area. Its, it might not be like, I don't think that it will be a big issue for us to get more good summer days, and also because there is... I don't know these are only outdoor heat islands you're talking about?

Yes that is all I have considered so far.

J: So, usually these heat islands its not difficult to find an area where you can sit in the cold usually. At the moment, but it might change how its balanced against other issues, or so like… because this way of constructing heat islands does not necessarily give the best architectural area. Since its a lot of blocking out stuff, maybe it will ruin a view but make a great outdoors area. I think that this warmer climate might just make some other priorities, not necessarily that we would not still want to have some heat islands around, but just change the balance in how we prioritize a little.

Okay okay, are there any other ways you might expect planning regarding microclimates to change?

J: There is also, again with the snow thing, we expected to have, I think first up until 2070 we predict we will get maybe more snow, because we will get increased precipitation, but it will fall as snow. That could also change something, because snow is a big issue when you are planning here, it takes up a lot of space. In spatial planning snow is a big issue, but you had to consider also how is things run in the winter, how do you make sure you can have it useful in the winter as well. With snow being maybe less by the end of the century then this might also change a little. We're not there yet definitely, because its a big issue as it is and if we don't plan for the snow it will cost a lot of money. If you don't have an area to store snow that means you will have to drive it away. If there is less snow it is not maybe disappearing, it might be less. The fluctuation between plus and minus degrees is usually making it difficult to predict the speed of the runoff of rainwater because it might fall on the new snow which takes up a lot of water, it might fall on a surface that has already had rain and snow and is icy, so the runoff is at high speed. Then it might be an area where if its in the garden, in the not concrete area then it, depends a lot on the season because we have a lot of both rain and snow in the winter. It can change from one day to the next, through the day it changes as rain or snow. I don't know that it actually goes into microclimates,

Ah, as it affects the cities,

J: What?

Its relevant to a city microclimate, and essentially again the priorities might just shift

J: Yep, probably it would at some point change a little. Depending on how it goes, and yeah, the predictions… Its also something where at the moment since wet snow, we would expect more snow in the next 30 years and after that it would be less snow but more rain.

So you mentioned a few things of how planning might change, but what about the extent? How significantly might priorities change?

J: I don’t think it would be to a great extent, not in regards to microclimates.

Okay,

J: But well, we’ll see. It also depends on a lot like, clear predictions, what will they show. But yeah,

It's just very uncertain at the moment?

J: Yep, I think at the moment the prediction is about 5 degrees, by the end of the century. We’ll still have a lot of cold months, but I don’t remember how it is on a seasonal basis, what the predictions are. If there is any difference on seasons.

Well, that covers most of my queries,

J: Yep, it's not a lot of clear answers I think...

No it doesn’t matter, it's much about your perspective and emphasis and I’m very happy with the variation you brought.

J: Okay, interesting,

Im going to stop recording as well,

\- END RECORDING -

POST RECORDING NOTES

- Kryger mentioned the contact Tone Hammer for further interviewing
- Kryger noted interest in receiving a copy of the paper after completion

APPENDIX B.4 - INTERVIEW 3

12th of May 2022

INTERVIEW NOTES

Interviewees:

Tone Hammer - Landscape architect

Duration of recording:

20 minutes

Additional notes:

- The interviewee preferred Norwegian, and hence sections of the transcript are translated by the interviewer into english.

PRE-RECORDING

1. Introductions
2. Ask interviewee whether they wish to remain anonymous - Hammer did **not**
3. Ask interviewee whether they accept the interview being recorded - Hammer **agreed**

\- START RECORDING -

Interviewer: But first I have a few questions, or terms I need to mention. First of all the interview should take 35 minutes at most, depending on how much we end up talking. This interview is completely voluntary and you can end it at any point. You have consented to the recording of this interview and do not feel the need to remain anonymous. The final paper will not use any direct quotes from you without requesting direct permission from you first.

Tone (T): Yes okay

And lastly, if you wish I can send you a copy of the final paper when it is complete.

T: That would be nice

Are you okay with all of these statements?

T: Yes.

Perfect! Then that is the formalities out of the way and we can start with asking about urban heat islands. Do you recognize the term?

T: No,

No, okay okay, can I ask have you ever worked outside of Tromsø in city planning?

T: Yes, I have worked in Frøya municipality

Oh okay! Essentially, how I'd describe urban heat islands, its a bit of a phenomenon where if you have more buildings and concrete rather than grass it tends to trap in heat and in english its called urban heat island. So now we're on the same page, you do know what it is but you just didn't know the english word?

T: Yes, I had not heard the term before.

Does it have a word in Norwegian?

T: No I don't think so

Oh okay. In that case, do you have any experience with your work regarding urban heat islands?

T: Yes I have that in Tromsø in how to take care of the water and asphalt or concrete. Because that has become a problem now with climate change. The system in Tromsø now is made so that the water runs in rivers to the sea, but now there is too much water to handle that. So now we are working on systems to take care of the excess water, and that is what I have worked on the last few years.

That is something I have heard has become a larger concern in Tromsø. Is there also something related to the temperature of urban areas?

T: Not so much the temperature. Its more the amount of water to be handled. Its not that warm here right, it really is the water amount and that it rains more in short periods that is one of our biggest concerns, not the warmth.

Was it ever something you considered at your other places of work?

T: No, not really. Because at Frøya there is more rural landscape and not much urban. More nature landscapes.

Okay,

T: So most of my experiences with water management and warmth is likely from Tromsø

Sorry?

T: I've mostly worked with this in Tromsø,

In regards with water?

T: Yes,

So almost no experience with working with temperatures then,

T: Yes.

All right, that covers a large part already actually, but do you think it might gain more attention in the future? The temperatures -

T: Yes, the global heating, will make it so the temperatures in Tromsø will become higher as well. But as of now we don't experience it as a problem because we are so far north making it, you know it's 2 degrees here today. It's rare we experience warmth, but generally temperatures globally are rising meaning we will experience it too. But because we live where we live we don't have to worry about it as of yet because it is so rare that we would consider the warmth as a problem if you get it. It is the water management we need to worry about. That it will become extremely warm, you know. But global heating is also our concern, even if we don't think about the warmth at the moment. Yes.

Its not a priority now?

T: No we don't talk about warmth, because we don't experience warmth as a problem. But either way the heating is causing us problems.

So rather eventually it might become a more common topic

T: Yeah, its just the words we use, right, which is not warming at the moment even though it is a cause of problems. We do have additional problems besides water management which need to be addressed, sea level rise. And it connects to global heating.

What about wind planning, how familiar are you with that?

T: With wind?

Yes,

T: That is also something we consider in building, with larger houses for example which will change the wind. In all types of planning in the physical environment wind is a consideration. That does impact the perceived temperature, how it feels. That is more planning that we do,

Regarding wind, what is the goal in wind planning? Is it something you want to minimize?

T: No, not completely, you need to analyze the building, where does it lead the wind. We have main wind directions per season and then we need to look at the wind changes. It is very important in relation to the outside areas, like a playground or such outside, where we are focused on not creating more wind. So there are analyses on what happens with wind.

So not no wind, a bit strange to phrase it like this but,

T: No, we want to know that buildings to strengthen wind, we want to lessen it it outside areas

Yes, okay. Very good, I do want to know about climate change and considering how it is amplified in the arctic. In what other ways do you expect it to change how you plan?

T: The change is we are more aware of it, we need to be aware of it and that influences all municipal planning, when there are any other new plans we need to ask what will happen in 15 or so years with a different climate. Climate change has become more significant in our work and it is relevant to every part of our planning now.

Do you believe it is impacting your work very significantly then?

T: yes

In what areas is it the most impactful then

T: In the city center,

In what aspects?

T: I think sea level, because the city is right by the sea and if its, you have to secure the areas which are to low. I think that is the biggest issue. In other places its the water falling down, and we need to take care of it, that the water runs normally.

Yeah, okay, are there also any other areas of concern?

T: Not too particularly

Aside from water planning?

T: You could say generally that we should not build on new areas, that we should make use of the area that already has buildings and rather densify and that we should not spread the building over all the nature. That is a large question overall, and I think, yeah

If I can go back to urban heat islands for a moment, the temperatures, and managing temperatures. Do you know what physical measures you would take to minimize this?

T: Vegetation, I think that's...

Certainly. Do you know any measures in relation to buildings or infrastructure?

T: No, I do not work with buildings. I am a landscape architect.

That might be useful to ask as well, what particularly do you do in regards to your work?

T: In planning?

Yes

T: I have responsibility to consider the whole and the context, and that is often in relation to the water as the green and the water elements. So the green aspects of planning are my main concerns.

Do you have involvement with the central plan for Tromsø?

T: Yes. Yes, the green part of it.

I see, I see. I'm not sure how much you may say about it but are there any plans regarding the green infrastructure?

T: Yes. We have described the open areas and how we should take care of that in the future, it's a part of the appendixes.

Okay I'll look further into this. I'm fairly surprised how efficient this was despite the technical troubles at first. I have some closing questions,

\- END RECORDING -

POST RECORDING NOTES:

- No further information provided

APPENDIX B.5 - CODING TABLE

Interviewee	Quotation	Codes
Tone Hammer	But because we live where we live we don't have to worry about it as of yet because it is so rare that we would consider the warmth as a problem if you get it. It is the water management we need to worry about.	UHI attention extent (Tromsø)
Johanne Kryger	but it's been something we twist around up in the arctic	UHI attention extent (Tromsø)
Bjøru & Randles	I am from Australia, from Melbourne, where we have to have a lot of focus on heat	UHI attention extent (Other)
Johanne Kryger	I don't think it would be to a great extent, not in regards to microclimates.	Extent of CC implications
Bjøru & Randles	I feel like we have more pressing matters before we start prioritizing discussions around heat islands	UHI attention extent (Tromsø)
Tone Hammer	in english its called urban heat island. So now we're on the same page, you do know what it is but you just didn't know the english word? T: Yes, I had not heard the term before. Does it have a word in Norwegian? T: No I don't think so	UHI attention extent (Tromsø)
Johanne Kryger	instead of a wall, constructing a bowl.	UHI planning - BF (Tromsø), UHI planning - BF (Other)

Johanne Kryger	it is in conflict with something like the national guidelines, for example air pollution	UHI mitigation motivations (Tromsø)
Johanne Kryger	It might not be a known term but it is something we do work with a lot.	UHI attention extent (Tromsø)
Bjøru & Randles	it's definitely not something that has been discussed in Tromsø. I would doubt very much that it is something that is discussed very much in Norway,	UHI attention extent (Tromsø)
Bjøru & Randles	it's more to take care of the heat that we can find.	UHI mitigation barriers (Tromsø)
Bjøru & Randles	It's not something that is prioritized in topics on climate.	UHI attention extent (Tromsø)
Bjøru & Randles	Its wind and sun are the two most important issues when it comes to urban spaces. Because, we have a lot of wind, especially in the winter time. It takes down the temperature but it also makes it very not nice.	UHI planning - BF (Tromsø)
Bjøru & Randles	lead to very uncomfortable situations in the built environment	UHI mitigation motivations (Other)

Tone Hammer	Not so much the temperature. Its more the amount of water to be handled. Its not that warm here right, it really is the water amount and that it rains more in short periods that is one of our biggest concerns, not the warmth.	UHI attention extent (Tromsø), UHI mitigation barriers (Tromsø)
Tone Hammer	So almost no experience with working with temperatures then, T: Yes.	UHI attention extent (Tromsø)
Johanne Kryger	That could also change something, because snow is a big issue when you are planning here, it takes up a lot of space.	CC implications in arctic
Bjøru & Randles	That type of focus is not something that has weighed really heavily in Tromsø in the last few years. Particularly when it comes to heat, which is something that has not really been a focus area.	UHI attention extent (Tromsø)
Johanne Kryger	The same for when you put up buildings there is a lot of shade, rules that you can't increase the shade on your neighbors outdoor area	UHI planning - BF (Tromsø)
Bjøru & Randles	The spring melts don't just come in spring anymore. We are still in the middle of winter here and we just had maybe fourteen days of spring melts here which affects our infrastructure, affects how we deal with infiltration.	CC implications in arctic
Johanne Kryger	there is not a lot of tall trees in Tromsø. It's not that we dont want tall trees, but they are kind of something where, sitting in the shade is very rare. That is something you would like to do. Placing trees, where you place them is also something you should consider in regards to how would this affect the outdoors area. Also because the sun is usually, it has a low angle, so the shades can be very long	UHI planning - GI (Tromsø)

Johanne Kryger	Usually in the water front in Tromsø you would usually see houses, gardens, so the outside on the southside and the building on the north at least.	UHI planning - BF (Tromsø), UHI planning - GI (Tromsø)
Johanne Kryger	usually these heat islands its not difficult to find an area where you can sit in the cold usually. At the moment, but it might change how its balanced against other issues, or so like… because this way of constructing heat islands does not necessarily give the best architectural area. Since its a lot of blocking out stuff, maybe it will ruin a view but make a great outdoors area. I think that this warmer climate might just make some other priorities, not necessarily that we would not still want to have some heat islands around, but just change the balance in how we prioritize a little.	UHI attention extent (Tromsø), CC implications in arctic
Tone Hammer	Vegetation,	UHI planning - GI (Other)
Johanne Kryger	We are focusing a lot on having sunny walls towards the north.	UHI planning - BF (Tromsø)
Tone Hammer	we can start with asking about urban heat islands. Do you recognize the term? T: No,	
Johanne Kryger	we definitely want those heat islands if we can get it.	UHI mitigation barriers (Other)
Tone Hammer	we need to be aware of it and that influences all municipal planning, when there are any other new plans we need to ask what will happen in 15 or so years with a different climate. Climate change has become more significant in our work and it is relevant to every part of our planning now.	Extent of CC implications, CC implications in arctic
Johanne Kryger	we want heat islands.	UHI mitigation barriers (Tromsø)

Tone Hammer	we want to know that buildings dont strengthen wind, we want to lessen it it outside areas	UHI mitigation barriers (Tromsø)
Johanne Kryger	well we have very very few summer days, good summer days,	UHI mitigation barriers (Tromsø)
Bjøru & Randles	What would be the ideal outcome with wind, the ideal plan, would you want ventilation or just minimize the wind? H: It would be minimizing the wind. And it is very important to see the wind and sun together,	UHI planning - BF (Tromsø)
Bjøru & Randles	when it comes to climate changes and how we deal with trying to ensure that the urban area is usable, by warming, heating, preventing ice buildup, that is something we work with all day every day in planning	CC implications in arctic
Johanne Kryger	With snow being maybe less by the end of the century then this might also change a little. We're not there yet definitely, because its a big issue as it is and if we don't plan for the snow it will cost a lot of money.	CC implications in arctic
Tone Hammer	Yes, the global heating, will make it so the temperatures in Tromsø will become higher as well. But as of now we don't experience it as a problem because we are so far north making it,	UHI mitigation barriers (Tromsø)
Bjøru & Randles	you have not considered temperate management or urban heat islands at all, right? J: No.	UHI attention extent (Tromsø)