SUMMARY

This paper is a continuation of our work on heat management in a kollegium, and is built on the findings and theories that were discussed within our paper, What is mine is yours: Exploring sharing as conceptual framing for community-based heat management. While studying the current state of sustainable HCI we found that a major part of research in the field had taken data-driven, individualistic approaches to design research, leaving out any cultural and social aspects that we know play a large role in adoption of sustainable solutions and behaviours. Even within community-oriented design, we found a lack of community research resulting in systems that were not able to engage their target user groups. Motivated by our collaboration with NeoGrid Technologies, an Aalborg-based cleantech company, we sat out to investigate how me might design community-oriented heat management solutions, and inspired by Elinor Ostrom's studies on what is known as 'Commons'; resources that are commonly available to a community and must be managed by them in order to prevent overuse, we designed a case study to research the values and practice within a local kollegium called The 4th of May Kollegium. The case study began in December 2020, where we through interviews with four alumni gained our first insights about the kollegium structure and community; how the levels of the kollegium work independently of each other, creating sub-communities within the kollegium, how sharing was, perhaps unsurprisingly, found to be an integral part of life at the kollegium, and how alumni reacted with mixed attitudes towards a scenario of sharing heat as a Common Pool Resource. Since the initial interviews, we have concluded our case study of several activities with alumni; a guided tour to get "a feel" of the kollegium and it's culture, a workshop to discuss heat, how we sense it and when we feel comfortable, a focus group introducing our technology probe, designed with ambitions to spark reflections on heat as a limited resource, and finally our closing interviews with four alumni. Our single-case study of the kollegium has resulted in interesting findings, and as discussed during the paper, we find several findings on practice and values to align with the principles behind Ostrom's theory on governing the commons. We find the alumni of the kollegium to value personal freedom to a high degree, while also respecting the community and each other; making the need for explicit rules almost non-existing. Alumni value the comfort of others, perhaps even more than their own, they treat each other with respect, and in the case of a broken rule, informal procedures are in place to deal with that. New procedures and initiatives that might affect the lives of alumni are addressed in a democratic fashion during common meetings. We also conclude, that in order to implement a commons-based system within the kollegium, the design process must follow the exact same values of democracy that are to be found within existing commons-communities and the 4th of May Kollegium; translated into design-language as a participatory design in which alumni are not seen as subjects, but cooperating partners and co-designers.

Making a Case for Context-aware Heat Management: A Study on the Culture and Commons in a Danish Kollegium

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ABSTRACT

This paper presents a case study as a means of painting a rich picture of community values, norms and management of heat and other commons within a kollegium in Aalborg. As a reaction to HCI research taking a turn towards community-based design, while still not adequately analysing and taking into account community values and practice, this study demonstrates how an in-depth analysis of a community can yield meaningful insights to inform the process of designing engaging systems for collective action. The study acknowledges heat as a commons managed within the community, and analyses through a grounded theory approach the culture, practice, and values that exist in the context around management. Data was gathered through mixed qualitative methods from ethnography and design research, with Ostrom's established principles on how communities successfully govern commons as theoretical background. The case study discusses how findings on fundamental principles within the kollegium like democratic decision making and trust aligns with Ostrom's principles, and how these should be seen as cornerstones in a future design process, suggesting participatory design methodologies to achieve engagement and participation from the participants which we conclude to be crucial in the design and realisation of a Common Pool Resource management system as well as within the unique community identified within the kollegium.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

Community-based research, commons theory, heating, case study, eco-feedback, co-living

1 INTRODUCTION

This study investigates social and collaborative practice within a co-living community through a case study as a means to inform future community-oriented design work within management of the commons. The case study revolves around a local kollegium; a co-housing solution for students, where facilities, common areas and dinners, among others, are shared. In collaboration with NeoGrid Technologies, a cleantech company that makes smart heat management solutions leveraging IoT devices, the research presented in this paper sets out to investigate how heat management systems for residents of a shared household can be designed in meaningful and engaging ways.

As smart meters and IoT systems are becoming more accessible, numerous attempts have been made to investigate how an information system might provide individuals with the right information for them to make rational decisions about their consumption of resources such as energy and heat. The theoretical background behind these efforts to engage consumers are typically rooted within "The Design of Eco-Feedback Technology" [7]. Here, Froehlich calls the HCI community to action to aid in shaping the future of eco-feedback systems, arguing that eco-feedback is a ripe area for research as it will require exploring concepts such as information visualisation and novel interfaces; areas in which HCI research excels. Froehlich's paper optimistically points towards how *"millions of households will be able to view their home resource consumption data on their mobile phones and web browsers"*, referencing the then emerging systems, Microsoft Hohm and Google PowerMeter, two smart meter applications that would eventually fail to gain adequate market adoption and were both shut down a year later. The fact that these two leading tech companies were both unsuccessful in creating engaging eco-feedback systems should be an indication that there is more to effective eco-feedback and resource management systems than putting numbers and graphs on a user interface and expecting users to understand and adjust their behaviour accordingly.

Responding to the lack of long-term engagement within traditional attempts to design eco-feedback systems, we find examples of HCI design research that implement seemingly community-oriented features, such as competition and historical and neighborhood data comparisons [1]. Though intended to cater to community members, we find this research to lack in gaining adequate insight into the community culture for which they design. According to Strengers, in order for eco-feedback systems to have an impact on the user's behaviour, the systems will have to integrate into the cultural, personal and social contexts of the user's everyday life [25]. We believe that to do so, efforts must be taken early in the design process to paint a rich picture of the community in question. Thus, as presented in this paper, we have undertaken a qualitative inquiry in the form of a case study into a community of students co-living in a kollegium, in order to identify mechanisms and values within the community to inform a meaningful design process.

*Both authors contributed equally to this research.

2 RELATED WORK

Within HCI research, many efforts have been made to design systems that accommodate global goals of reducing the carbon footprint of households to meet sustainability goals. As electricity production generates the second largest share of CO2 emissions globally[24], much research revolves around reducing household electricity consumption through eco-feedback systems that aim to persuade users to lower their usage[12, 17, 18, 20]. Cited over 800 times, Froehlich's 2010 paper on The Design of Eco-feedback [7] has informed countless SHCI projects within the design of eco-feedback systems aiming to equip consumers with sufficient data to make rational, informed decisions[12, 13]. As time has passed, and smart meter based eco-feedback systems have lived out their novelty effect, research suggests that data-centered eco-feedback oftentimes fail to engage their users in sustainable practises over time and ultimately becomes backgrounded devices within the household [25]. Researchers have eg. investigated the role that smart meters and thermostats play in users' homes and the effect that they have on their lives. Yang & Newman (2012)studied early adopters of the Google Nest through interviews to investigate how smart technology impacted the user experience of saving energy and controlling temperature in the home[26, 27]. Their studies found that users generally were confused with how and what the intelligent thermostat learned about them and whether they were actually saving energy by using it. This is a potential limitation that comes with smart thermostats - when users do not understand what is happening "under the hood", they will not be made aware of their own behaviours and therefore cannot take actions to modify them in a rational and sustainable way.

2.0.1 Adaptive thermal comfort. Other HCI researchers have looked at the personal and contextual experience of thermal comfort and other ways to achieve it, looking beyond the set-and-forget nature of automated heat management systems. The adaptive approach acknowledges that people will take active steps to secure thermal comfort and are not just passive recipients of their thermal environment. Clear et al. investigated HCI's role in adaptive thermal comfort with a climate control probe that provoked and challenged participants in the ways they could achieve thermal comfort [4]. Similarly, Huang and colleagues looked at adaptive thermal comfort, however with a system that takes a comfort-aware approach. Through their work they find, among other things, how some individuals value the comfort of others, such as family members, higher than their own [10].

2.0.2 Community-oriented design. Motivated to research smart technology in what was considered 'alternative forms of housing', Denefleh et al. (2019) conducted a study within a community of four co-living students in Germany. The group was provided with a "Sensorstation" consisting of two screens and four IoT devices that could be programmed with custom notifications when inputs met certain conditions. After Sensorstation's deployment, researchers concluded that *"there is an obligation for design to consider, how smart technology for shared places entrenches, extends, or equalizes power"*[5].

Dillahunt et al. (2014) deployed a community-focused, energy feedback application to 15 rental households across two distinct communities in attempts to disclose which group dynamics impact the level of responsiveness to social engagement techniques that encourage energy conservation. Based on their study findings, they speculated that more connected communities might be more likely to engage in social-energy applications[6].

Another approach to lowering carbon emissions is afforded by green energy production, which typically depends on wind or sun opposed to "classic" combustion of fossil fuels to generate electricity. Shifting heavy electricity usage towards "peak hour" green production periods can therefore minimize a household's dependence on fossil fuels. Scuri et. al. developed and tested a energy trading platform within a neighborhood of prosumers[23]. Findings from the study lead the article to call for more work exploring the effectiveness of different design strategies - namely social pressure, norm activation, and group contingency - in improving user's engagement and accessibility of the system to all family members. The challenges of engaging all household members and keeping up people's engagement echoes from critical assessments of the status quo of eco-feedback systems[3].

3 COMMONS

The commons are shared resources, cultural and natural, that are accessible to all members of a given community. The nature of commons as held in common, characteristically involves a variety of social practices constructed on both formal and informal norms and values in order to better govern the commons. Today, some argue that many modern conveniences can be seen as commons, from roads and infrastructure, to the heat, water and energy that we all share as a community. Theories surrounding the commons have existed for many years, the term being popularised in the 1960's in a famously pessimistic essay on exploitation and the fate of the common land. In 1990, Elinor Ostrom published a book containing her years of research on the matter of the commons [19]. In her book, *Governing the Commons*, Elinor challenges the pessimistic outlook that was prevalent in some popular theories of political economy, had on collective action for the greater good during the 1960's. In *The Logic of Collective Action*, Mancur Olson claims that self-interested individuals will not act to achieve group interests so long as they are able to obtain the benefits of the collective good. Similarly, Thomas Hardin in his *Tragedy of the Commons* [9], imagined a common pool resource (CPR) that was exploited as the individual sought to maximize their gains regardless of the collective good. While Ostrom did not deny that the tragedy was real, she sought to study why management of these resources failed and what made other communities successful in their governing. Through many years she performed case studies that investigated how communities from different cultures around the world governed their common pool resources, Ostrom was able to identify eight guidelines that she found to be present in the successfully governed commons. The guidelines are as follows:

1. Clearly defined boundaries. The boundaries around who can withdraw from the CPR must be defined. This principle for managing a resource pool is essential as it details who is entitled to what.

2. Congruence between appropriation and provision rules and local conditions. Rules that restrict the withdrawal of resource units from

the CPR must fit the local circumstances. These might be rules about when or how resources are withdrawn and in which quantities.

3. Collective-choice arrangements. Successful CPR institutions often take a participatory approach to rule-making. The rules can be revised as assets and knowledge becomes a part of the CPR.

4. Monitoring. Commons must be monitored in order to enforce the rules. The monitors must be the appropriators or accountable to the appropriators of the CPR.

5. Graduated sanctions. Punishing those who break the rules is done by the appropriators themselves, and not external enforcement. The sanctions are likely graduated based on the context and severity of the offense.

6. Conflict-resolution mechanisms. Mechanisms must be in place to resolve and discuss conflicts as they arise and whether the situation constitutes an infraction.

7. Minimal recognition of rights to organize. When CPR appropriators make their own rules, external officials must recognize them as legitimate.

8. Nested enterprises. Larger CPRs are usually nested in layers of enterprises, and work best when rules are organised and enforced by different layers of government.

It is important to note that to Ostrom, these principles were still speculative, however the principles were meant as a way to explain the efforts that successful CPR institutions make in order to keep appropriators committed to conforming to norms and rules, while minimizing the incentive for individuals to act opportunistically. As evident from the participatory nature of the principles, following them requires a measure of involvement from the appropriators, as well as properly established communication. Another point Ostrom makes about limiting opportunistic behaviour and encouraging cooperation is the importance of proper, shared norms within the community. In her book, Ostrom states;

"In a setting in which few individuals share norms about the impropriety of breaking promises, refusing to do one's share, shirking, or taking other opportunistic actions, each appropriator must expect all other appropriators to act opportunistically whenever they have the chance."

Not having shared norms about cooperation can make long term commitments difficult, which may result in more extensive monitoring and sanctioning being needed in the community. These are some of the fundamentals needed in order to effectively govern commons and ensure cooperation from community members.

As Ostrom's theory explains how communities might successfully govern their shared resources and we are studying heat management in a community, we recognise heat as a resource belonging to and accessible to all members of the community, which is not owned by individuals but held in common, thereby classifying heat as a commons. We believe that with the emphasis on collaboration, social values and democracy, Ostrom's principles and their community-driven nature can prove valuable within the process of designing commons related systems, with regards to both informing which design considerations to prioritize in such a process as well as during study design planning.

4 CASE STUDY

Motivated by our objective since fall 2020; to investigate heat management as a social and collaborative practice within a co-living community, we sat out to conduct a case study of a local kollegium. To gain insight into how heat management for communities might be designed, we found it crucial to first and foremost study what makes a community; which values and beliefs should drive a design process. The following sections describe our chosen case, our data gathering activities, and analysis.

4.1 Case

Building upon our initial interviews in 2020, we set out to further investigate community-based heat management by carrying out an embedded, single-case study of the kollegium. The case study was explorative in attempting to understand a, within HCI, novel situation; co-living communities, with the ambition to inform new design; community-based heat management [28]. We carried out the embedded case study with two units of analysis; *the community* and *heat management*, as we consider an understanding of the lived experience of being part of a community and the values it is built upon are essential in understanding and informing the process of designing engaging and meaningful heat management solutions. We perceive the setting of a kollegium to be an interesting case in which to explore heat management in a non-traditional household. We believe that gaining insight into the culture of co-living individuals and the community they contribute to and experience to be valuable, not only in regards to designing for kollegiums, but also modern co-living household constellations.

Our studied case is the 4th of May Kollegium in Aalborg (4MK), a kollegium housing 47 students residing in rooms over three floors. The alumni of 4MK have something quite special in common; to get priority for a room at the kollegium, potential alumni must prove descent from a member of the danish resistance movement of World War 2. Our activities with the kollegium are summed up in figure 1 and further elaborated in the next section.

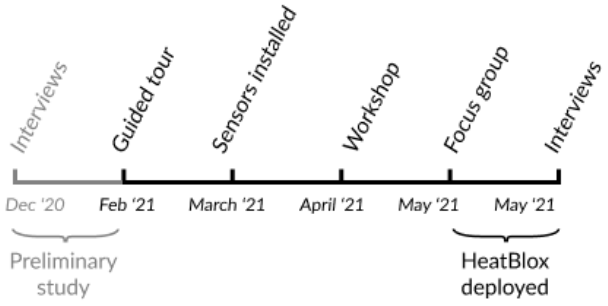

Figure 1: Timeline of case study activities

Since the study had an objective of investigating heat management, some assumptions were made before beginning the study. First of all, we expected kollegiums to practise some kind of unique community that we could learn from. Secondly, we found theory on the commons inspiring for community-based design, which

also guided the case study and provided a theoretical framework through which we could discuss our findings. While ethnographic studies excels at describing communities, the primary difference between ethnography and case-study research lies in the use of theory [2]. While ethnographic studies are completely exploratory, case-study research is often based on hypotheses or propositions to guide the questions being asked[28].

4.1.1 NeoGrid Technologies. The chosen subject matter of heat management is motivated by our cooperation with NeoGrid Technologies, an Aalborg-based cleantech company that makes smart heat management solutions. Their system is an online application called PreHeat, which is currently aimed at providing building administrators with control and information on heating and its cost. Their aim, however, is to provide better information for residents with their smart technology as well, which motivated this research of understanding how communities might hold certain values and beliefs to account for when designing engaging heat management systems. During the case study, NeoGrid installed sensors on the radiators in each of the kollegium's three common kitchens on each floor. The sensor data was later used with the technology probe introduced in the following section. The data was used during the final interviews as well, condensing heat usage within the ground and middle floor kitchens in a graphic to engage discussion.

4.2 Study design

Our case study served as a design research with the ambition of gaining insight into the structure and values of the 4MK community and their current management practises of shared facilities, resources, and spaces. Our underlying assumption prior to the study was that commons-based solutions might fit as an approach to designing community-based heat management systems, which would be evaluated on based on findings from the kollegium. An overview of the activities are presented in table 1.

Activity	Agenda
Interviews (2020)	Insights on structure, administration, and rules. 4 participants.
Guided tour	Get a first-hand sense of the kollegium's layout, facilities and "vibe" guided by an alumnus
Workshop	Understand alumni's understanding of and relationship to heat and thermal comfort with 13 participants
Technology probing	Present heat as a CPR, probe alumni on ground and middle floor to reflect upon heat management
Focus group	Introduction to probe and discussion of managing heat as a common pool resource with 6 participants
Interviews	Heat management opportunities within the kollegium and thoughts towards heat as a CPR with 4 participants

Table 1: Overview of case study activities with 4MK alumni

Through interviews and focus groups, we gained insight into the resources that the alumni share and how they do so. From the field of ethnography; *"the art and science of describing a human group — its institutions, interpersonal behaviors, material productions, and beliefs"* [2], we borrowed methods to paint a rich picture of the culture within 4MK. Early in the process, we performed an observation of the kollegium guided by an alumnus, while we later deployed a technology probe, to inspire reflections on new technology. Within Sanders' Research Design Landscape [22], our research is situated mainly as research-led with an expert mindset, studying the alumni of 4MK as subjects, while some data gathering activities, such as technology probing, generative tools and applied ethnography, has taken a more design-led and participatory form.

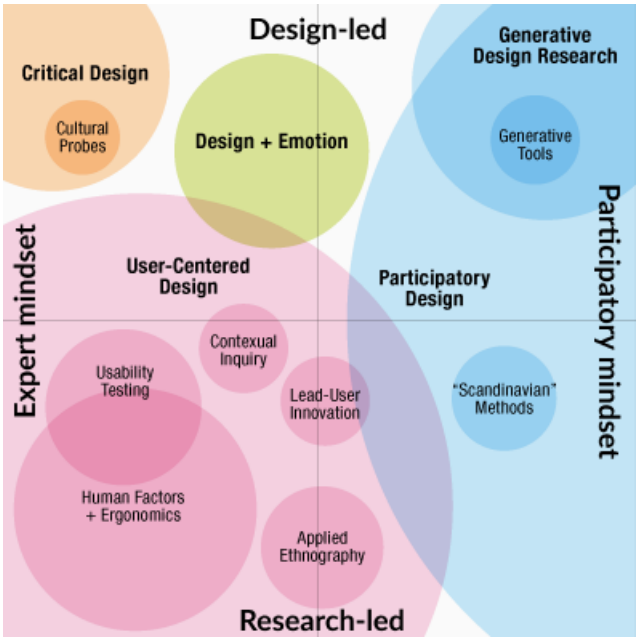

Figure 2: Our study was compiled of activities from mainly the research-led, expert mindset quadrant within Sanders' Design Research Landscape. Figure is extracted (edited to fit) from "An Evolving Map of Design Practice and Design Research" (2008)

4.2.1 Guided tour. In order to better be able to understand and capture the 4MK context in which alumni interact, we started out the case study with a guided tour at the kollegium, inspired by the emphasis on observation from ethnographic methodology as a means to better understand social dynamics[14]. The tour was guided by a volunteer alumnus who showed us around while telling us about the different common spaces' facilities and how they were used. The tour was documented with photos and a debriefing session was carried out immediately after and documented in field notes. As this was our first visit it would serve as a way for us to get a sense of the kollegium's layout and facilities, and, most importantly insights into the culture that might escape awareness when talking to the alumni, or things that alumni might be unwilling to discuss in an interview.

Figure 3: The workshop took place in the common dining room.

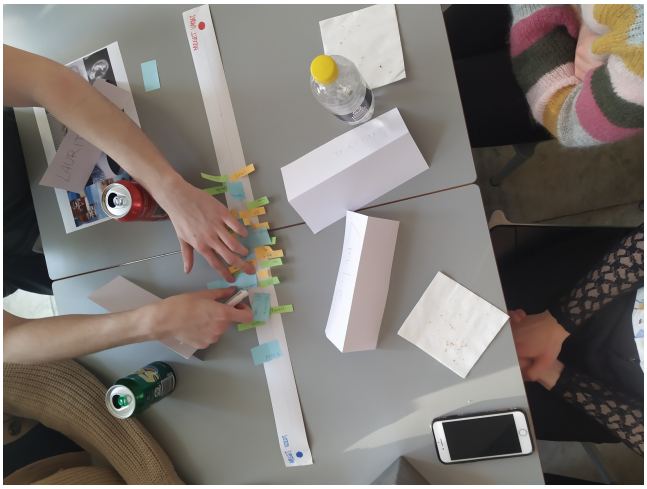

Figure 4: Common rooms being placed on the scale. Orange notes: alumnus' preferred room temperate relative to their perception of the current room's temperature (green notes).

4.2.2 Workshop. To gain insight into the alumni's experience with heat, we conducted a workshop where we discussed heat and how they perceive and talk about heat. The workshop started with a priming exercise discussing how different senses register hot and cold. The purpose of the priming exercise was to get the alumni in a mindset of talking about heat. Next we put a linear scale ranging from hot to cold on the table, on which the participants were asked to plot how they experienced different areas of the kollegium. The tool was inspired by Liz Sanders' work on generative tools, which are tools that take advantage of the visual ways of sensing, knowing, remembering and expressing [21]. First, alumni plotted their current surroundings with stickers on which they had noted their name. Following this, we asked them to use a new sticker to approximate their personal comfort temperature. They were finally asked to plot where the common areas fit on the scale. This initiated a lot of discussion between the alumni. It quickly became clear that the alumni had vastly differing temperature preferences and opinions about which areas were comfortable and where on the scale they belonged. Throughout the scale activity we asked questions about how they handled and talked about adjusting temperature in the different common rooms. The last part of the workshop consisted of talking about how living in the kollegium influenced their outlook on heat, and whether their use of heat was different from other living situations they had experienced. We then gave the participants prints of the PreHeat user interface to annotate and discuss what they found interesting. Finally, in order to get insight into how living in a community might have changed their heat management practices, we discussed how their individual needs in a heat management system was different from if they took the community into account. Data gathering was done through video, however, as we were unsure of the quality of the recording, we decided to do a debriefing session to sum up the most important findings. Furthermore, we collected the temperature scale that had the stickers of the different rooms and preferences, as well as the other material that we had given the alumni to draw and write on.

4.2.3 Technology probing. With the purpose of inspiring alumni to reflect on the kollegium's heat as a limited resource, a technology probe by the name HeatBlox was deployed at the ground and middle floor of the kollegium. A technology probe is a a kind of cultural probe [15] introduced by Hutchinson et al to gather information and inspire ideas for new technologies for and with families. Opposed to prototypes, technology probes are open-ended tools with few functionalities that are meant to encourage reinterpretation[11]. The probe, pictured in figure 5, used sensor data to show how heat rations were spent during the day, having each of the nine blocks represent one out of nine rations. The idea was to give the alumni a set amount of heat each day and show it in nine parts. Due to delays in the construction process, the probe was not deployed until mid-May, where weather conditions allowed the alumni to not use the floor kitchen radiators at all. This led us to change the heat data that HeatBlox represented from live to historical data. Of the same reason, HeatBlox was only deployed for four days on each of the two floors after being introduced in the focus group. The probe was not installed on the top floor as their kitchen radiator was not functional and therefore the data was not usable.

4.2.4 Focus group. On the day of the first deployment period, we conducted a focus group with alumni from the three floors. The focus group as a whole was meant to inform the participants about the probe and prepare the floors to consider heat as a common pool resource that should be managed collaboratively on both floor and kollegium level. As we had heard both from one of the interviews and the workshop that their energy consumption budget would actually cut into the budget for fun activities if the alumni consumed too much water, heat and energy, we used this insight to frame our concept. The main insights we wanted to gather, however, was about what their initial considerations would be regarding having to live with heat as a limited resource and their thoughts on how they, as a community, would manage such a change. This included managing distribution of the nine rations to each of the

floors; for example whether they would consider it most fair that all floors had the same amount of heat to use, or if certain factors should have an impact on the perceived fair distribution. We also wanted to investigate what ground rules for heat usage they could imagine in order for each floor to keep their consumption within their delegated ration, and how they would follow up on such rules.

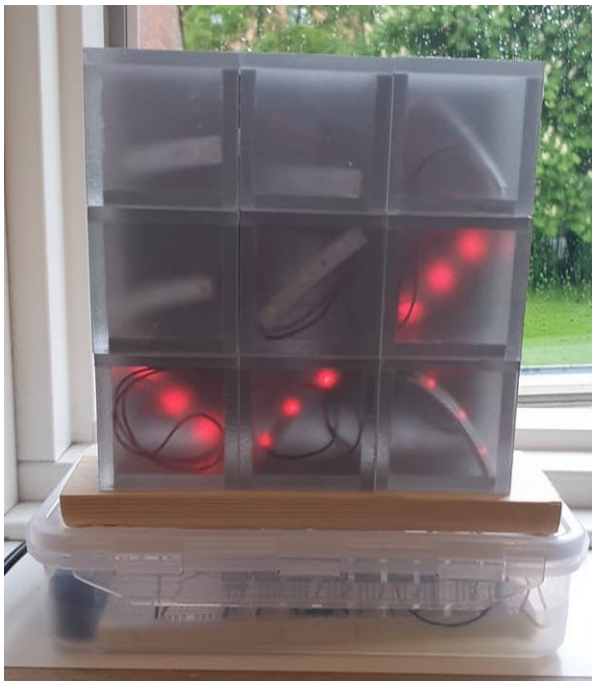

Figure 5: The HeatBlox technology probe, deployed in the window sill above the kitchen radiator

Figure 6: Getting ready for the focus group in the "fireplace room" where two alumni had spent the afternoon doing a jigsaw puzzle

4.2.5 Interviews. After the probe had been deployed for four days in each of the two kitchens, we held the final interviews to gather the alumni's thoughts and opinions on the probe and the overall project. All in all we had four semi-structured interviews of 30-45 minutes in length and all done online through video conferencing software. We chose a semi-structured approach to keep the questions open while adhering to the structure of an interview guide that would keep the conversation on the topic of heat management. The interview guide was structured into three categories. The first part had to do with the overall project, in which the interviewees were asked how they had experienced being part of the project, and share any experiences about the project that stood out in their memory. During the second part we asked the interviewees about the probe and what their experience of having it installed in the kitchens had been. This section covered many aspects of the probe, and the interviewees were first asked about how they thought the probe functioned and whether they had been keeping an eye on it. We then asked whether the alumni had talked about the probe and the content of the conversations. We then dug deeper into what they thought about the information and if it made sense to them, before showing them the data that the probe was based on. This led to a conversation on data visualisation and how to present data in a way that makes sense for the alumni. The last part of the interview had to do with heat management and handling heat as a limited resource. Here the interviewees were asked about the impact rationing would have on their life, what they thought it would take for such a system to succeed and potential challenges.

4.3 Analysis

The case study was analysed through Straussian grounded theory analysis[8], a method of coding different sources of qualitative data and finding meaning in the data through iterative arranging codes in themes. By coding documentation from the case study activities consisting of field notes, pictures, recordings, and transcripts through open coding, capturing any interesting concept derived from a quote, attitude, or belief on sticky notes. Through the coding process 209 codes were collected and color coded according to the activity in which the phenomena was captured, codes found from the finishing interviews were annotated with a letter. From the codes, 11 concepts were found across three categories; 4MK culture, current practices, and heat as a CPR in the kollegium.

5 FINDINGS

This section presents findings from our case study analysis. Our findings within the kollegium culture unit is presented in the category "4MK Culture" and holds three concepts. Findings of resource management in the kollegium is presented in the two categories; "Current practises", consisting of three concepts, and "Heat as a CPR in the kollegium" with five concepts.

5.1 4MK Culture

This category holds three concepts about the culture in the kollegium. How alumni organise, their ideological beliefs and views on sanctions and authority; and values such as their pride in the kollegium's history which is also rooted in the alumni's shared ancestral histories.

5.1.1 One big family with a common history. When entering the corridor between the kollegium's residential area and dining room, a wall full of newspaper articles about the kollegium meets the eye (pictured in figure 7). Centered, a two-pager with the title "Like one big family" report how 4MK is a kollegium like no other, with proud traditions, such as communal dinners and breakfast each week night, going back 70 years[16]. Honoring the history of the kollegium, we found each room named after a prominent member of the Danish Resistance Movement. When applying to move in, the alumni are encouraged to research their ancestor and their work in the resistance movement in order to prove they are a descendant. In the basement of the kollegium a room of old furniture and memoria can be found, documenting the institution's long history and emitting a proud feeling of the kollegium's history and the brave work of the alumni's ancestors.

Figure 7: Wall of newspapers in the corridor. Photo taken during the guided tour.

5.1.2 "It's their own room". This concept emerged as it became evident that there was a clear separation between the alumni's personal rooms and the rest of the kollegium. During the guided tour, we saw how doors were personalised with stickers and posters, and beside them hang framed A4-sized "profiles" with a picture and both fun and practical info about the alumnus living there. As much as the community is valued within the kollegium, one's agency of their own room was an important value within the kollegium culture, as Daniel told us: *"they all feel ownership of their own room"*. During the final interviews, Jane did not like the idea of measuring heat consumption in the alumni's private rooms; *"it's their own room and choice"* she told us. Emily as well did not think that disclosing whether the radiator was turned on within a room would be a good idea, expressing that it would be crossing a line. Emily however did tell that once in a while they might turn off the light in someone else's room if the alumnus forgot to: *"If somebody forgot to turn off the light in their room, and you know that they are downstairs watching a movie, you just stick your hand in and turn it off"*.

5.1.3 Ideology. A key stone within the 4MK culture is the democratic processes where every voice has a chance to be heard. This is accommodated through monthly meetings and councils who make sure to engage and discuss initiatives with the rest of the kollegium before implementing changes that may affect the residents. Making room for everybody to voice concerns and express their values seems vital for the kollegium. This, as well as the value of personal freedom, was illustrated when Emily shared an anecdote from a time when the Alumni council (A-council) decided to implement a new system in the basement where alumni hang their laundry to dry. The system was meant to solve the issue of dry laundry taking up space on the drying racks by making the alumni note their name on a board declaring which rack they were using, making it easier for other alumni to tell if they had taken down the laundry to make space for their own: *"It was received really poorly because some saw it as an encroachment on their personal freedom. It was probably that they felt that there were some who ruled over them. A matter of principle."* This emphasis on democracy and personal freedom echoed findings from the focus group, where the participants, even though the discussion was entirely hypothetical, found it challenging and almost uncomfortable to discuss possible heating guidelines on behalf of the kollegium, as they did not think they had the mandate to do so. From our pre-study we had already established that there is next to no sanctioning in the kollegium, and that any issues or rule breaking is handled through conversation. During the focus group, it became clear just how strange the thought of sanctioning are to the alumni, when a participant jokingly phrased an earlier alumni who believed any rule should come with a sanction, which scattered laughter among the group. We consider this attitude towards sanctions combined with the personal freedom to prove trust to be highly valued among the alumni, who expect members of their community to have good intentions and care for the kollegium and its alumni.

5.2 Current practices

This category is within the theme of managing the kollegium resourecs. It contains concepts that describe how alumni handle and consider heat differently as individuals in their private rooms and in the common rooms as part of the community. It also describes initiatives that have been taken to conserve resources in the kollegium, and the information the alumni receive about their consumption.

5.2.1 The right to heat. The alumni of 4MK is a community of individuals with different heat preferences and strategies to achieve thermal comfort. During our workshop, all participants mapped their perceptions of temperature in the common areas on a scale from hot to cold (pictured in figure), and where on the scale they themselves experienced a comfortable temperature. The activity gave rise to a lot of discussion between the participants and the scale depicted just how different the participants' experience of thermal comfort was. While HeatBlox was deployed, Emily had talked to some alumni on her floor and reported during the final interview: *"Some turned off their radiator a long time ago, while others still have it on"*, which confirmed how the alumni experience thermal comfort differently. While some alumni achieve comfort in their room by turning on the radiator, others are more hesitant and consider it to be the last option, only employed if other initiatives

do not achieve the goal, as illustrated in a quote from Mike during the final interview: *"I never turn it on unless I'm still cold with 3 layers of clothes on."* As described in the category of the kollegium culture, alumni feel ownership and agency of their own room, and respect others' right to practice heat management as they wish; this became evident during the workshop where participants told us that they *"don't interfere with others' heat consumption"* as well as during the focus group where it was expressed that *"they would not blame anyone for using the heat they want; it's their room"*. Though the general belief that heating one's room is a personal matter and right as it is payed for in their rent; *"Heating comes free as part of our rent"* - Jane. A single alumni did have another point of view on this matter: *"The way that we live, we all pay for it, so I think it is OK to talk about it"*. The complexity of this matter was also illustrated during the interview with Daniel: *"People should be allowed to use heat… but a penny saved is a penny earned for the kollegium"*.

From their attitude towards their right to heat in their own rooms it was also clear that they felt they could spend it more liberally there compared to the common rooms. Jane expressed that she would use the kitchen radiator if it was cold during the day, however the other interviewees did not mention using the common area radiators. One alumni, Emily, mentioned sometimes turning off radiators that had been forgotten in common rooms, a sentiment that was shared by Daniel who might go around and check radiators "in secret", if he had to. The fact that radiators were sometimes turned on and forgotten was something we experienced during our tour where the kitchen radiator on the bottom floor was turned all the way up while no one was present. When we commented on the high temperature in the kitchen, Daniel, our guide, gave a remark about the radiator always being on.

5.2.2 Efforts to conserve resources. From the administrative layer of the kollegium there seems to be great focus and ambition towards lowering resource consumption primarily motivated by a rising cost of resources such as food, heat, and water. As we interviewed Emily, she had just returned from a general meeting where, once again, the alumni had been encouraged to consider and reduce their resource consumption. She noted, however, that no action plans have ever been made to reach goals of conserving resources, though she expressed how she believed an action plan would make sense in a place like 4MK. The biggest initiative that had been taken towards lowering resource consumption was the making of a special saving committee whose purpose was to engage the alumni in resource conservation. The committee had produced posters and stickers informing the reader about the environmental impact of their actions in different contexts within the kollegium, eg. posters in the kitchen about lowering electricity usage and avoiding food waste and a sticker above the radiator encouraging alumni to limit heat consumption. The effect of these encouraging messages have not been measured, but some alumni noted how it had affected them; one alumni expressed that *"by the showers it says how much money it costs when you run the water for one minute [...], I look at them every time because they are huge posters."* She continued to explain how it makes her think about the consequences to their budget if they overconsume. Another alumni was more cautious to conclude if the posters had affected him, explaining during our first interview: *"There are some posters on the toilets that say 'spend less time in the shower and the like'. I do not know if it is something that indirectly affects people, but it is something I have thought about a bit, so I may have taken some slightly shorter baths because of it."* The committee however were by unknown reasons no longer active, and no initiatives had been taken since.

5.2.3 Lack of feedback. Though the administrative layers of the kollegium repeatedly try and encourage alumni to save heat and water, not a single alumni from any of the activities had insight in the kollegium's resource consumption. Though the lack of feedback was not expressed as an actual issue to the individual alumni, it does make it impossible for the alumni to know if the initiatives described in the previous section are adapted and if anyone actually cuts down on consumption when encouraged to. When discussed during the final interview, the alumni showed diverse opinions towards what level of feedback would be valuable to them, from having a visual clue when a radiator was turned on, to seeing actual consumption levels compared to last year's data. These insights are further elaborated in the goals for heat management category.

5.3 Heat as a CPR in the kollegium

This category reflects how the alumni imagine the kollegium would handle implementing a system in which heat is explicitly a limited resource; what would be necessary and what challenges it might introduce. Insights about framing heat as a common pool resource within 4MK builds primarily upon abstract conceptualization during focus group, workshop and final interviews, while some insights were also gathered based on alumni's thoughts on HeatBlox.

5.3.1 Agreement between alumni. In order to make changes to the kollegium's established practices, such as using rationing as the means to manage heat, the alumni all agreed there would be a need for the whole kollegium to agree, as Emily put it: *"We would all have to agree that it is a good idea and why we do it"*. When, during the focus group, presented with scenarios about rationing, the alumni were careful to make statements without having heard the opinions of those in the kollegium who wanted to take part in the decisions. The importance of total agreement on such a change and how it should be managed within the kollegium echoes the ideology concept as earlier described, as it shows how some alumni might take it as a personal intervention in their life when a practice is changed without their consent.

5.3.2 For the greater good. During the focus group the participants agreed that for the kollegium to reach agreement upon sharing heat as a limited resource, it must appeal to the alumni's sense of community with a goal that can be justified and resonate with alumni. When talking about motivation and end goals for cutting down consumption, the topic often led to talks about how the community as a whole could benefit by saving money which could then be spent on activities and material goods for the kollegium. If such a system could assist the alumni to more carefully make use of their heat, the money could be put to better use, as Mike explained: *"Instead of heating up a room during the night we could get something out of that money"*.

5.3.3 "Heat Police". This concept revolves around monitoring how the heat is used by other alumni and how to handle the monitoring

of consumption in general. The concept of "heat police" was taken from a quote from the interviews, when an interviewee stated that he would not use information about other floors' consumption to *"play heat police"*. Unsanctioned monitoring is seen as intrusive and unwelcome by some, while others do not have a problem with being confronted this way. During the interview, Mike mentioned this as an obstacle as *"Most heat is used by individuals, it would be hard to implement without singling people out."* Some joked during the focus group that overconsuming might be addressed in a passive aggressive Facebook post in their online groups, however they had told us in previous meetings that this was something that had happened before with other incidents which tells us that this way of handling these matters would not be unusual. A way to circumvent the need for unsanctioned monitoring came with the idea of having 'elected' monitors who make sure the heat is under control with one alumni suggesting *"A handful of alumni on each floor could make a habit out of checking the radiators"*, while during the focus group they came up with the idea of handling it by electing one "heat master".

5.3.4 Built environment. A topic often brought up by the alumni was the condition of the building itself. As it is an old building, the insulation is not the best which led to many alumni using the building itself to rationalise why limiting heat consumption was a challenge and how it acts as a constraint on their actions to conserve heat. Not only was the insulation a problem, but as one alumni told us during the interviews *"some radiators only work on max setting"*, this included her own. Meanwhile, the top floor kitchen radiator was almost completely inaccessible and therefore almost never in use. All of this meant that the different floors had different needs when it came to heating, which as we learned through the focus group, was felt hardest on the bottom floor, where the cold from the basement meant that their heating needs were higher than the other floors.

5.3.5 "Objectifying heat". Having lived with the HeatBlox probe, some alumni saw real value in having heat visualised through quantifiable units, such as boxes. To Daniel, seeing the probe in the kitchen served as a reminder for him to check if the radiator was turned off, which he confidently told that he would not have done under regular circumstances. He believed that a *"visual cue"* near the radiator could mean that alumni would check the radiator when waiting in the kitchen, rather than checking their phone. Mike believed that visualizing the heat could help him and the rest of the alumni to *"get a relationship to the heat we use"*, something that he had described otherwise as *"something that is just there"*. To actually be able to see the heat, Daniel also thought well of - he described that he found that *"boxes is a nice way to objectify heat"*. While it was both mentioned during the focus group and our interview with Daniel, we found that most alumni would rather encourage awareness than make explicit rules, as expressed by Daniel: *"guidance is better than forcing"*. Sophie, however, did not seem to mind implementing a more restrictive handling of heat. She showed the most optimistic attitude to handling heat as a CPR, as she believed it would make good sense and noted *"it would make sense with all of our resources"*. Mike did not believe in making kollegium wide restrictions, he believed that heat should be handled on a floor level: *"Show floors how much they use and let them handle it as a group"*. Climate and economy were the two motivating factors that were talked about by all alumni during the interviews. Some alumni speculated that keeping the kollegium updated on either the effect on the climate or the cost of heating would result in a change in heat consumption practices. Sophie expressed that, should heat be a limited resource, she would encourage alumni to put on an extra layer of clothes before turning on the heat.

6 DISCUSSION

This section presents and discusses the main findings from our case study analysis. First, findings are discussed in relation to the principles suggested by Ostrom when governing the commons. Then, we discuss methods and how to plan the design process for a commons based system for the kollegium. Lastly a discussion of the uniqueness of the 4MK kollegium case.

6.1 4MK practices and the commons

Through the findings of our analysis we discovered several parallels between the current practices and Ostrom's theories on successfully governing common pool resources. These findings have been summed up in table 2, and the most interesting will be discussed further here.

Ostrom argues that the impact of shared norms and values is the biggest factor when it comes to building trust between appropriators of a common pool resource and limiting behaviours that are detrimental to the commons. We see 4MK as having a high degree of trust and cohesion in their norms, however through the study it has become clear that, when it comes to the consumption of resources, not everybody shares the norms and vision on resource conservation. Some expressed how they or others did not follow the appeals from the council to save on consumption, while others expressed a wish to save. The alumni themselves expressed how this difference in opinions was the biggest challenge in changing to a commons-based system.

Another aspect of this that arguably exacerbates this issue is the fact that there is a lack of feedback on their consumption. According to Ostrom's theory, there is less reason to adhere to the rules if you expect that others do not and we know that some alumni consume more resources when living in the kollegium. While we do not expect it to be widespread, there might exist a mindset among some alumni that as resources are seen as "free", there is no reason not to get as much out of them as possible. This then also becomes an issue of monitoring and sanctioning, as the alumni have no real way of knowing what constitutes over-consumption when they have no overview of whether or not they are overconsuming. While the alumni are already doing some informal monitoring, there is no organised effort to make sure certain alumni do not repeat bad behaviour such as opening windows while radiators are on. The mechanisms for sanctioning that are in place for the kollegium are graduated, but mostly informal. As we learned during the preliminary interviews, severe rule violation might constitute a talk with the ephor and in the very worst case getting evicted. Most sanctioning, however, is done by the alumni themselves through conversation and meeting at floor-level. Looking at Ostrom's theory on the impact of shared norms, we see the informal nature and

Commons theory	Case study findings
Clearly defined boundaries: The first step in organizing for collective action, boundaries must be set on who has authority to use the CPR	• Alumni pay rent to have access to the kollegium and its resources • Lesser, but defined boundaries between the floors of the kollegium
Monitoring: Monitors must be accountable to appropriators or be the appropriators in order to make sure rules are upheld.	• Some types of monitoring more acceptable than others • Monitoring already a part of the alumnis practices to some extent
Collective-choice arrangements: Individuals who are affected by the rules can participate in modifying the rules	• The culture in 4MK relies heavily on democractic decision making • Board of directors give alumni direct access to highest authority through the a-council
Graduated sanctions: Sanctions are likely assessed by appropriators and graduated based on severity of rule violation	• The alumni have an aversion to explicit sanctions • Informal systems are in place to deal with rulebreakers
Shared norms are important in organizing commons in order to minimize opportunistic behaviour	• Norms about heat consumption highly diverse • High degree of trust between the alumni

Table 2: Overview of findings and their relation to Commons theory

aversion to explicit monitoring and sanctioning as an indication of shared norms about trust and responsibility between the alumni.

The last principle we will bring up is the principle of collective-choice arrangements. This principle is of high importance for them, as new alumni join the community as others move out in a steady rotation. We see the importance both in the alumni's own statements on democratic choices as well as their structure, which put alumni directly in the highest level of their institution through the a-council. Referring back to the anecdote about the drying racks however, the rules are not always to the satisfaction of everyone, though actually having people follow the rules when strong temptations or feelings arise is, as Ostrom puts it, *"the significant accomplishment"*. The high degree of possible involvement for the alumni in making the rules, however, is the crucial part, and where both the norms and actions of the alumni align.

All in all, some conditions are still in the way of transitioning to a commons based system for heat management in 4MK. Other than the complete lack of feedback making it impossible to get an overview of consumption, a big factor that contributes to inequality in the alumni's access and need for heat is the building and equipment itself. Problems with insulation and radiators would make a commons based system harder to implement as alumni live under vastly different conditions even though they live under the same roof.

It is important to note that the theory of the commons is a lot more complex than what we have presented here in this study. When Ostrom talks about commons she is talking about resources that are clearly in danger of being depleted and the same cannot be said of heat in a kollegium. We do however see some strong parallels between the inner workings of 4MK and the principles and issues that Ostrom brings up in her work. This leads us into the next point of discussion.

6.2 Designing with 4MK and the commons

Having discussed whether governance of the kollegium's heat as a commons according to Ostrom's principles and theory fits within the community of 4MK, a new question arises: How might we design such a management system? To choose a fitting approach among design research methodologies, we might take a look at Sanders' design research landscape (figure 2 in section 4.1), in which design research is plotted according to their position on the underlying dimensions; "design led vs. research led" and "expert mindset vs. participatory mindset" [22]. The desired outcome of the design process would be a design, thus we should look within design schools and methodologies within the design-led quadrants of the map. In an Ostrom perspective of commons government, commons and associated rules have been managed through democratic decisions, by and for the people of a said community; with other words, the design process see users as co-creators, which indicates a design process should be planned with a participatory mindset. This places us within a quadrant of participatory design, where generative design research is supported through methodologies such as generative tools[21]. Our study of the kollegium have found the importance of democratic decision making to be critical to the kollegium culture, which also suggests that designing from an expert mindset could lead to big dissatisfaction and perhaps resistance towards

the system. Throughout our case study process, we have become acquainted with some of the challenges that collaborating with a kollegium can bring. First of all, the range of engagement alumni show towards the community is a wide spectrum. It seems that those more engaged in the community has also been the ones more likely to participate in our activities. A future design process must deal with the challenge of non-engagers and those more afraid of conflict so that every alumni feel save to express themselves and their opinions. On a more practical note, researchers/design practitioners must time their activities with respect to the fact that the alumni are all students who typically have deadlines piling up during May/June and December/January.

6.3 Co-living and the case of 4MK

With the goal of exploring community-based design, we have performed a thorough analysis of a local kollegium. Our case study has investigated the values and practices within 4MK, and on the basis of these insights we discuss that a commons-based heat management system might be viable within this specific kollegium. We, in no way, however, know if this is the case for other kollegiums in Denmark. The kollegium going back to 1950, their shared history, and the high level of trust within 4MK points towards this community has an extraordinarily well established kollegium culture compared to others. In an article of the kollegium, an alumnus shared her experience from another kollegium in which she lived before. The alumnus reported how she could buy groceries in the afternoon, and by the evening somebody had taken them from her cupboard. A situation like this seems very unlikely to happen within the 4MK, but might not be such a rare sight in the whole of Danish kollegiums. One might wonder what sort of values would be identified if replicating our study in another kollegium; perhaps here the thought of relying on each other when managing resources would show a lot less feasible.

7 CONCLUSION

Based on a seemingly missing link between community-based design and research, we have analysed a specific community within a single-case study of a local kollegium. Based on a theoretical framework of the Commons and through qualitative data gathering methods, from interviews to technology probing, we have identified community values and practices to inform potential future community-based heat management design. Though not generalisable, this study has, in the context of the kollegium, highlighted certain values and beliefs of democratic decision making and the rights of the individual, that, if not respected, might lead to rejection of any technological innovations that can be perceived as restrictive to the individual alumnus.

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