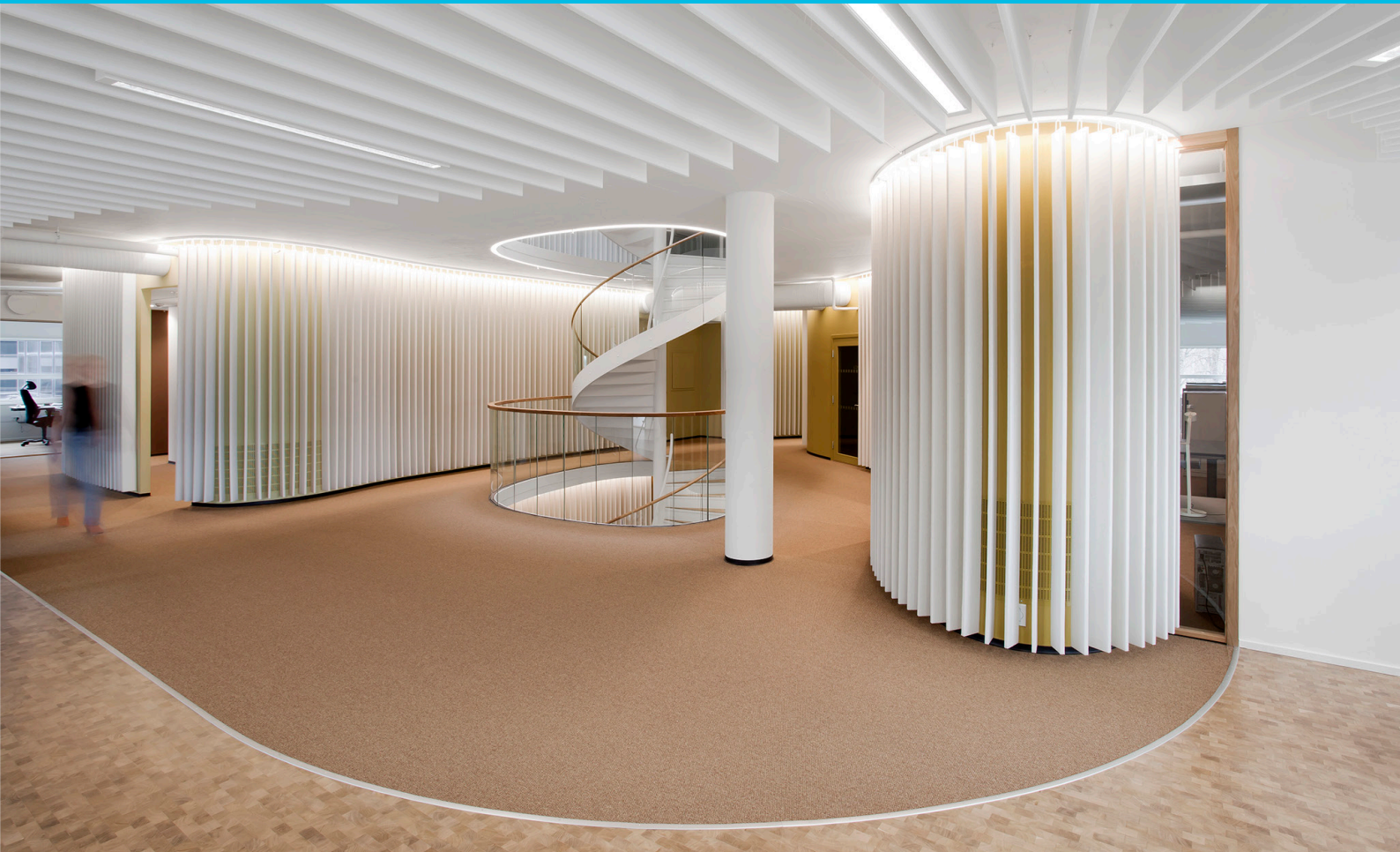


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Powerhouse Kjørbo. Evaluation of construction process and early use phase



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William Throndsen¹⁾, Thomas Berker¹⁾ and Espen B. Knoll¹⁾

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Contents

1. SUMMARIES	5
1.1 SUMMARY OF PART 1: DESIGNING AND BUILDING A ZERO EMISSION BUILDING	5
1.2 SUMMARY OF PART 2: TAKING A ZERO EMISSION OFFICE BUILDING IN USE	6
2. INTRODUCTION.....	8
3. THEORETICAL FRAMEWORK: DOMESTICATION.....	9
4. METHODS	11
5. PART 1: THE CO-CONSTRUCTION OF A POWERHOUSE	12
5.1 THE DESIGN (PRE-PROJECT) PHASE	12
5.2 THE ENERGY ACCOUNT AS CENTRE OF COLLABORATION.....	13
5.3 THE DETAILING (PROJECT) PHASE	16
5.4 A CASE FOR A DIFFERENT CONTRACT FRAMEWORK WHEN PILOTING	19
6. PART 2: USER ACCEPTANCE, EXPECTATIONS AND NEGOTIATIONS	21
6.1 LIGHTS.....	21
6.2 VENTILATION	22
6.3 ACOUSTICS.....	24
6.4 OUT OF THE ORDINARY?.....	26
6.5 THE SUM OF EXPERIENCE	26
6.6 THE USER AS “DATA SOURCE” FOR THE COMFORT THRESHOLD	27
7. IN LIEU OF A CONCLUSION: THE THREE QUALITIES OF PH KJØRBO	30
7.1 QUALITY 1: GOOD FOR THE BOTTOM LINE	30
7.2 QUALITY 2: SHOWING THAT IT CAN BE DONE AND THAT IT CAN BE DONE BEAUTIFULLY	30
7.3 QUALITY 3: SKILFULLY WEAVING A WEB OF OCCUPANTS, COMPONENTS AND ARCHITECTURE	31
8. REFERENCES.....	32

1. Summaries

1.1 Summary of part 1: Designing and building a zero emission building

As a tool for cross-disciplinary collaboration, energy and emissions calculations were central as common reference point throughout the whole process studied here. Considering only the design phase, it is clear that particularly the energy account was useful in defining both the necessary amount of work and the methods of the collaborative work. One of the merits was its ability to force each participant onto neutral ground based on shared information and work requirements. The energy account served as a boundary object (Star 2010) in this way as it provided “something” around which to collaborate across disciplinary boundaries and something that could translate different disciplinary specialities into a mutually comparable success criterion: the primary energy factor. The primary energy factor was both the what and the why of this collaboration, simultaneously a process of creation and a guiding force.

The effort that went into creating the energy account and collaboration in workshops, which were employed as a sort of management tool, were argued by some informants to have made the process ‘heavy on the nose’. This was largely due to design aspects and the signal effect, which was important for PH Kjørbo as a pilot project. As this was a pilot project, it has received a certain degree of special attention from all involved institutions. The participants describe the special requirements connected to this building as

- trust in the concept,
- broad participation in the project’s definition process,
- trust between partners, and
- high level decision making at the different partners’ companies to cater to an acceptable risk allocation for all parts.

According to the respondents, the design process benefited much from the oversight of a dedicated process manager, a role that was served by one of the project’s senior architects. In fact, many respondents noted the exact point in time when the process manager exited the project was also the point when the project encountered problems.

The participants agree that “closeness” (in terms of frequent communication both face-to-face and by other means) between the central and defining actors in the project team was a key to success. Failures accrued once the distance between actors increased due to their involvement in other projects. According to respondents, one important role for a process manager in the later stages could have been as a liaison between project management levels (contractor) and subcontractors. Some problems that appeared in this phase involved the sheer disbelief shared by the subcontractors when they first became acquainted with the calculations, the functional demands, and the specifications that had resulted from the design process - a process they knew little about. This constituted a failure on behalf of the PH collaboration to translate the concept to the hired hands, which complicated the execution phase.

Contract frameworks were also mentioned as a contributing source of errors as turnkey contract frameworks dis-incentivised subcontractors from making order changes also after they were clearly deemed necessary by consulting engineers. This is not an unusual mode of contracting in the construction business from a traditional viewpoint and could perhaps prove to work better in the future as the concept matures along with the market. A greater level of detailing in the design phase is one way to address this. However, in light of the experiences gathered at PH Kjørbo, the question is whether a more collaborative framework could have been applied to allow subcontractors to identify and share in

the risk taking with the main contractors and/or project owner - or, in fact, to take part in the social learning that occurs as actors make the project 'their own'. One way to incentivise junior contractors to join in more time-consuming, perhaps less profitable, contract arrangements could be to highlight the skill and knowledge development benefits available for participants in such projects. This would, however, require some proof of concept to be sufficiently translated into a clear added value for suppliers. At this juncture, the newly constructed Powerhouse is one such proof. In replicating elements of the Kjørbo project, it is likely that resources can be saved on design and parts of the pre-project phase. However, to avoid the amount of order changes seen in the execution of PH Kjørbo (especially for different projects), more resources must be spent on learning for junior contractors.

Finally, the symbolic value that was characteristic of Powerhouse Kjørbo contributed to both its ability to be realised and concrete benefits for actors involved in the time after completion. Many have drawn parallels between PH Kjørbo and Tesla, implying that PH Kjørbo is for the building industry what that electric car is for the automotive industry. As many of the respondents emphasised, the building is a statement that says "it's possible." The goal had never been accomplished, let alone attempted, before, and success hinged on the project participants' belief in that final statement. A radically different approach combined with an ambitious goal made that belief possible, and it was reinforced by the interdisciplinary work that was the basis of the project. This extra effort was a necessity in this project, but it might not be in the next. Some of it can most likely be implemented in other projects. However, as this report also demonstrates, picking pieces out of the success story PH Kjørbo may not yield equally impressive results because there is a connection between the pieces that is important for the whole building to succeed.

1.2 Summary of part 2: Taking a zero emission office building in use

The second part of this report examined the early use phase of PH Kjørbo, which was undertaken by local actors with the tenant as well as the project team. Although it is clear that the planning and design phase and the technological solutions played important roles in the success of PH Kjørbo, the way in which the running-in period was handled contributed some crucial finishing touches to the users' overall very positive experience with PH Kjørbo. Notwithstanding the technical calibrations themselves (which are outside the purview of this inquiry), the way user expectations were met by specific consideration of practical and cognitive aspects of the use of the building created a good use experience and not just an energy-saving machine. Great care was taken to prevent technical shortcomings from interfering with work and causing frustrations, even when it has compromised energy targets temporarily. A positive use experience was considered "elementary", an attitude that, at least in theory, denied allowing money to become an issue in this pulling contest between energy efficiency and user experience. Challenges experienced in the running-in period overall were experienced by the tenant as lower or not above what was considered normal based on experience with previous moving processes.

In PH Kjørbo the ventilation system was allowed to let temperatures drift more than in a normal building. However, this system also proved that indoor temperatures experienced as normal do not necessarily require them to stay consistently at "22.2 degrees" - in fact, a drift in temperature between 20-25 degrees was found to be perfectly acceptable by the occupants. Temperatures in the lower end of this range were considered cold by some but were manageable by providing information and handling practical and cognitive expectations - or, simply speaking, a sweater kept handy. Indoor temperatures in the top range or above, should they occur at all in the Nordic climate, are equally badly handled in most Norwegian buildings, according to the informants. Again, handling users' expectations with care in this phase proved helpful in improving user acceptance.

This same characteristic of the running-in period at PH Kjørbo was found when examining the acoustic issues posed by the extensive use of exposed concrete. Negative experiences were reported largely by

users who were used to extremely silent conditions. Addressing the reasons for the design choices openly (thermal mass) allowed users to settle into their new surroundings. As one of the respondents noted, when viewing the experience of this particular building as a whole, the somewhat increased noise levels caused by scarce sound roofing due to a minimal ventilation system meant that the ventilation noise normally endured in other buildings was totally eliminated, but the indoor climate was still described as extremely good. The result was a sum of experiences that evidently surpassed any conventional building.

PH Kjørbo shows that treating the user as a form of “sensor” and devoting resources to the “processing” of information from such “sensors” in the running-in period provides substantial insight into the user experience that is crucial for improving the use experience. At Kjørbo, user experiences were collected through the office link system by the office manager, who then bore witness for the users in the user forums that guided the work of the running-in team. This provided a unique data source for detecting the comfort threshold. When complaints started to come in, they could be addressed quickly - either through informing about the reasons or through actual technical fixes. According to our informants, at the time of the interviews, as issues were picked up, negotiated and solved, complaints began to disappear.

2. Introduction

This report accounts for the experiences of central actors in the design, construction and running in period of the office renovation project at Powerhouse Kjørbo (PH Kjørbo).

John Law (2000) makes a case for understanding sociotechnical systems in a relational manner as composed by heterogeneous networks of different but interconnected technologies, people, and materials that all have the potential to affect each other's functions. If we take a building's energy performance, for instance, it is not only composed of the interactions between the many different technologies, materials, and designs that make out the building's physical appearance, its performance will in most cases be also profoundly influenced by how it is operated and used.

According to Law, the opposite of such a relational perspective assumes a functionalistic, pre-determined understanding of technology in which existing elements are plumbed together without producing any value that is larger than the sum of its parts. It is no coincidence that such an understanding assumes that users have fixed "preferences" and "behaviour" that is stable and not easily changed by experiences with the building or any other condition for that matter. In Law's words this bereaves us not only of "creative possibilities" (ibid:8) that lie in the acceptance of mutual interaction between users, building, sun, rain, work culture, etc., it also misunderstands the nature of technologies that are - whether their designers want it or not - placed in a web of relations that produce its effects together.

While all this may sound abstract at first, as we will argue in the following, PH Kjørbo's key to success was that it harvested the benefits of a relational approach in building design and construction.

But before we come back to this point in the last part of the conclusion, the first part of this report follows the design and construction process leading up to the finished state. Establishing a continuous narrative from design phase to finished building, it takes a closer look at the design and pre-project phase as well as the detailing and execution phase. The second part of this report examines the result as built, which at the time of inquiry had seen eight months of running-in operation since commissioning.

To understand what has happened in these distinct phases, in the following the theoretical framework of domestication theory is employed. Before continuing with the empirical findings, a brief look at this theoretical tool as well as an overview of methods will be provided.

3. Theoretical framework: Domestication

Buildings are not static components removed from the passage of time, the context of their existence, their designers' idea of the intended users or their activities or, indeed, the actual users and their constant negotiations with the building. Robert Bye (2008) notes that the word **building** is both a verb and a noun and therefore well captures the insight into how to view a building as an ongoing process (Bye 2008: 12). In his book "How buildings learn", Stewart Brand (1995) shows how buildings go through large changes in their lifetimes. These changes can be manifested through simple re-purposing of rooms, rebuilding, renovation, and the addition of annexes or other user adaptations. Brand claims that the flexibility of a building is determined in the design phase. In this sense, the design phase can be viewed as avoiding a prediction of the building's use and users. Like Bye Brand maintains that these predictions are necessarily problematic exactly because of the changing nature of a building and its uses. Bye argues that not accounting for a mismatch between design and use invites the view of technological determinism in which users are expected to passively adapt to a technology's inscribed "script" (Bye 2008: p. 12-13). Such a focus on process and change leads to a more active user role. Viewed from this perspective, the building is never truly complete. Instead, the building-user relationship is a process of learning in which different skill sets develop and changes in the relationship between professionals (e.g. operators), users and buildings occur (Bye 2008). Therefore, buildings are objects that are being constantly interpreted in new ways, which makes them a subject of changing narrative understandings and representations (Gieryn 2002).

A theory of human-technology-interaction that incorporates this symbolic dimension as well as practical and cognitive aspects has been proposed under the name domestication. As can readily be grasped from the word itself, domestication theory is about the process of taming, understood originally as bringing something into the fold of the domestic sphere. In the late 1980s, it was first employed by Roger Silverstone et al. (1992) in his studies of media consumption. Part of a turn away from simplistic "what the media does to people" models, Silverstone and his colleagues sought an understanding of users' relationship with media technologies that more resembled active use than passive consumption. This provides users with agency of their own, a useful antidote for our immediate understanding of users as victims of, for instance, "bad performance" of technology (Berker 2011) or, in successful instances, as fortunate - but passive - beneficiaries of cunning design.

This is not to say that technologies are not influential in most of our undertakings. They are appropriated and integrated more or less pervasively in the seamless web (Hughes 1988) that constitutes everyday life in modern societies. In a similar vein, in the concept of domestication, the conjoining of users with technological artefacts is characterised by reciprocity; users form relationships with the technologies they use (Lie and Sørensen 1996). The term "everyday life" indicates a recurring context in which the use occurs, which itself is constituted by activities that contribute re-productive and stabilising forces. This way of understanding the relationships between users and artefacts may become especially useful in instances where designers "miss" their target and technology consequently "fails." These can then be cases of failed domestication, where, for several reasons, users may have "failed" to reproduce the specific use design of the object, or what is often referred to in Science and Technology Studies (and elsewhere) as "script" (M. Akrich 1992). Understanding technologies as containing within them, much like a text, the instructions and explanations for their own interpretation leads to a view in which the designer presents to the user an ideally "adequate puzzle" that is solvable which then results in "correct" use (Woolgar 1991). In successful "readings" of a technology, the intended use on the part of the designer is what is also understood by the user. Domestication theory deviates from this view by extending on the "reading" activity on the side of the user. Instead of finding users eagerly deciphering how artefacts are used in the "correct" way a much more common use pattern follows Hirschman's (1970) categories of "exit", "voice", and also "loyalty" (to the script). Following Akrich (1995) Berker

(2011) maintains that as design contains “user representations”, i.e. ideas about how the user looks like and what s/he does, it is necessarily subject to users’ negotiations and may even meet outright opposition and that mismatches between design and use context are common. Such a mismatch, however, is not the same as a bad use experience; good results may still be achieved because of this space for negotiation opened up by inadequate scripts.

Empirical studies of domestication processes have shown the importance of practical aspects related to the technology as well as cognitive and symbolic aspects of use. Negotiations between users and technology happen within these three domains. In the symbolic domain, a higher (order) “value” may be attached to the use of the object, which is capable, in some instances, of conveying parts of the users’ identities to their surroundings. Practical aspects address the actual use of a technology, its practical workings and how they fit into existing practices (or not). Finally, cognitive aspects are related to learning, how and in what ways users are given a chance to get to know a technology, how they come to learn or teach themselves or each other, how to use it - and, of course, whether learning occurs at all (Holtan 2005, 47).

4. Methods

The second part of this report is based on seven expert interviews with a total of eight respondents conducted at PH Kjørbo with seven employees from Asplan Viak and a facilities manager from Entra, all of whom were involved with the running-in period and provided to the project by Asplan Viak staff. These interviews were conducted by William Throndsen and Espen Knoll face to face during the fall of 2014, when the running-in period had been going on for approximately eight months. Representation was provided by two administration staffers (i3 and i4), two consulting engineers (i1 and i6), one facilities manager (i8), an architect (i7), and two executive officers (i2 and i5).

An additional twelve interviews, 10 of which were included in the report, were conducted by William Throndsen in the spring of 2015 to shed light on design and construction phase. Representatives from Entra (building owner, respondent i18), Asplan Viak (the tenant, providing consulting engineers on the project, respondent i12), ZERO (environmental NGO, respondent i10), Skanska (contractor, respondents i11, i14, i19, and i20) and Snøhetta (architects, respondents i15 and i17) were all collected through referrals from earlier respondents and subsequently interviewed by phone.

The duration of each interview was approximately one hour. Interviews were recorded and transcribed, and all quotes were translated from Norwegian to English by the authors.

5. Part 1: The co-construction of a Powerhouse

The work that initially was begun by the Powerhouse collaboration revolved around shaping a concept and defining how an energy-plus house could actually be accomplished. There was agreement in the initial process that the goals should be “astronomical” and that reaching the goals would require a process that was “especially designed” (i10). This was explained by a project manager from a not-for-profit zero emissions organisation, who elaborated,

“[...] that has been the basis all along; at least, there have been discussions continuously about how we should understand and resolve our own ambitions. For instance, there is nothing, or there was nothing in the original goal about... well, it stated that it was going to be a plus house, but there was nothing there about how to achieve net plus.” (i10)

He continues:

“We had theories that this was the only way in which to achieve it: put in place ambitions which were so tall that they seemed unattainable almost, to force us to find different ways of doing things” (i10).

This adequately describes the first challenge presented by the design phase of “the” Powerhouse. Definitions and rules about the requirements of reaching the ambitions and how to achieve them would need to be solved beforehand. For instance, should it be a zero-emission building or a plus house? If choosing the latter, how would it reach net plus? There are many ways to negate emissions, but in the case of a Powerhouse, it was a high priority not to generate them at all. To escape the conundrum of negative emissions, calculating with energy was chosen instead. The stricter the method for approving what would be count as a contribution towards net plus, the more complex the task would become. To make an energy-plus house from scratch, it is necessary to begin by setting some rules.

5.1 The design (pre-project) phase

From the beginning, energy calculations served as the main foundation for the entire concept. A definition of the concept was provided by a senior advisor for the contractor, who also served the project as the designated BREEAM accredited personnel (AP) and whose job it was to ensure that the many activities in the project at all times were geared towards fulfilling the many targets required by BREEAM to reach the “Outstanding” certification:

“The overall definition is that a Powerhouse a building that during its life-cycle produces more renewable energy than it consumes for production of building materials, construction, operation and demolition of the building.” (i14)

This generates many caveats. For instance, energy produced off site, such as a nearby wind energy farm, cannot be considered because it is not part of the project. For a production facility to be considered eligible to deliver energy into the energy calculation, it needs to be close by. The solar panels serving PH Kjørbo are placed on top of a conjoining garage, and the heat pumps utilise the fjord that lies adjacent. The energy spent in producing these facilities needs to be included. In short, everything that is done and built in a Powerhouse project consumes energy and represents a quantity of embedded energy that is already consumed and that must be counted and accounted for. This means that an equivalent of this one-time consumption has to be compensated for by the on-site production of renewable energy over time. The question thus becomes where to set the line for what consumption to take responsibility for.

An answer for the equation, the sum of energy consumed and produced, already existed. The goal that was set provided a number (kWh/m²/year) that represented the acceptable limit of bought energy over the designated life span of 60 years. This meant that the remaining math consisted of a calculation of the impact of the many sources of energy consumption in the project, which formed the basis of material choices (both regarding production and consumption) that in sum would need to stay below the limit. Further compounding this task was the question of what number to attach to energy consumption sources because asking such questions would be entering into the murky depths of life-cycle analysis. This resulted in a necessary work requirement, the creation of an artefact, or boundary object, in the shape of the energy account, that had to be consulted at every turn to control the overall impact on it by all material additions. For instance, when adding some pillars, what would be the impact in terms of energy consumed (and thus the energy footprint) of choosing pillars made of steel versus wood? The information and work requirement of providing detailed information from producers about the energy cost of their materials to measure their impact in the overall energy account thus arose, constituting the energy account as the boundary object of this project.

The task proved difficult as many producers are unaccustomed to providing this type of information (i.e., it is not in demand). When the information does not exist, it needs to be established from generic values or national databases that “might not be representative at all” (i14). As admitted by an architect, “These models, as I understand them, are theoretical assumptions [...], it's not an exact science, so you have to take your departure point in what is the best possible judgement or knowledge as of today” (i15). Therefore, much of this information is based on assumptions. However, in terms of achieving some goals, if they are strict assumptions, they may produce something rather than nothing:

“[...] materials weren't calculated by bought energy, which is common today, [...] it included a so-called primary energy factor, which is the energy that's been consumed by obtaining the energy carriers. [...] Our entire energy account needed to be converted with the primary energy factor; that is [...], when we calculate electricity it's not just the amount of kWhs that have been paid for [...], we include all the energy that was spent producing coal power, gas power, hydro power, nuclear power [...] the composition of the electricity production in Europe towards 2070.” (i14)

As the complete energy consumption of the building site and subsequent operation was necessary to take into account, energy goods produced or consumed by PH Kjørbo within its lifespan needed to be converted by the primary energy factor. As mentioned, a considerable amount of bound energy had gone into the on-site solar plant. If the bound energy was included in the energy account there, it had to be included for other production capacities as well to ensure the internal consistency of the account. The primary energy factor thus included extrapolative scenarios for Europe in the years to come, future changes in energy composition, and the energy consumed in producing relevant power plants and the extraction of their combustible resources. At the time of writing, the result of this accumulative work was a primary energy factor of 3.5 - that is, that 1 kWh bought equals approximately 3.5 kWh of primary energy.

5.2 The energy account as centre of collaboration

The reason for this rather lengthy introduction to the work of the Powerhouse collaboration in the design phase, with the primary energy factor showcasing the comprehensiveness of the scope, is to show the intricate foundation on which the concept of a Powerhouse energy-plus house is based. Indeed, as one of the architects explained, “Every single choice we have made has been measured by how it impacts the energy account” (i15). This marks one of the main characteristics of the PH Kjørbo project phase that makes it different from conventional building processes and will surely leave its mark on future PH projects. The energy account was given a central and authoritative part in the entire process, almost like a management tool, and has functioned, to a certain extent, as an arbiter in every question that arose in outlining the design of PH Kjørbo in the detailing and construction phases (and, as we have seen, was

instrumental in the running-in period as well). As the process manager explained, “The motivation is more about that you need a lower number. And that is more, sort of, neutral ground and a neutral field. It’s not a case for one or another [...]. It affects everyone equally” (i17). The energy account and reaching “the number” proved conducive for a collaborative effort that crossed disciplinary boundaries, which was a prerequisite for the success of the project. Figuring out the numbers represented the information needs that all parties shared. In the opinion of the architect who served as the process manager of the design and detailing phase,

“[Mainly] what has made the process in the Powerhouse projects different: the number of people and complexities and enjoyable meetings, in a way, is because everyone is a little bit on thin ice in regard to talking about their own subject area’s CO2 imprint. You might as well just admit it, that you have no idea how to handle it, so in a way no one’s going to make a fool out of themselves. If you examine how much steel actually goes into a ventilation system, you will be shocked. And so will the ventilation guys. So then suddenly it’s all the rage having as few pipes as possible. [...] It sort of creates a competition for having the least amount of pipes.” (i17)

As the project manager representing the zero-emission organisation in the team iterated, a large effort was put into the design phase discussing the definition, where the level of ambition was “always kept up or made stricter, and it was out of a fear of diluting the product” (i10). The collaborative environment catered to a “competition” to provide energy-efficient solutions. On this note, the main reason PH Kjørbo has become such a formidable energy-plus building actually has very little to do with state-of-the-art technology in every subject area. The formula that was employed emphasised what could be called a holistic approach but has perhaps better been described in the above as relationally sensitive. “It’s not that we’ve invented new solutions; we’ve used known solutions [...]. It’s mostly known solutions which have been put together and which have been dimensioned optimally” (i2). Instead of choosing installed systems in the design based on isolated performance criteria in each specialist area (e.g., HVAC, acoustics, electric installations), the approach emphasised the function of each part in view of the whole. Once again, quite contrary to consensus and what can better be described as a pure lack of knowledge, this information need created an understanding that collaboration was a virtue of necessity:

“No, we just understood that here we just had to deploy every specialist area, and very many of them too. We have, of course, the architect, then the energy specialists, and we have—of course we need a good indoor climate, then we have the acoustics, that’s got to do with the thermal issue, especially with the thermal mass. We have fire, that has to do with the ventilation solutions, the open solutions, we have rigging [...] it’s all so incredibly interconnected, all of this, and of course the interior has an interest, the interior architect, so it’s all very connected.” (i14)

This uncommon mode of designing buildings was explained by several of the informants from the project team as an interdisciplinary effort. Beginning with so many new problem questions imposed the realisation that “a bigger meeting was needed” (i17) and that this would cost money, for which someone with high ambitions was needed “to go all in” (i17). As an executive with the tenant emphasised, “It’s in the whole concept, how it’s been thought out and followed through, which is where the innovation here lies” (i5). To achieve this, the entire process, from the design phase to the detailing and construction of the project, required all the key members of the project team to work in tandem on all the solutions - at least when they related to other systems. As another executive with the tenant who now occupies PH Kjørbo explained, the symbolic aspects of PH Kjørbo were a driving force for those involved in accepting the new work ordering:

“[...] everyone have been more concerned about achieving a certain level in the project. They have been more concerned with that than catering for one’s own interests. That is to say, the collaboration effort here has been unique. From the building owner to the contractor, from architects to consulting engineers [...] everyone’s been interested in making the project happen. And to say it crudely, the money has been counted at the end.” (i2)

Usually such processes are managed sequentially, starting with a building owner programming the project followed by architects who are included for drawings. After a while, technical consulting engineers detail solutions before a contractor is hired to execute the building. When realising PH Kjørbo, all of these actors were engaged simultaneously in the design phase, and many of them were involved in the execution phase and beyond. As the executive explained, this way of focusing on the overarching goal in concert is sometimes called

"[...] the cathedral effect. A well-known story about two masons who are asked what they are doing: one of them says he's laying bricks, and the other says 'I'm building a cathedral'. And they're doing the same job, right? And there's something about that, that here we're building a Powerhouse, and that has made everyone oriented towards building a Powerhouse. That is what we're doing." (i2)

To enable and support this collaboration, several workshops led by a senior architect functioning as a process manager were convened in the first days of the Powerhouse collaboration as part of the work method for defining the gist of what a Powerhouse should be. As explained initially, this was a venue where headroom was tall and many actors were involved. As a project manager with the contractor explained, this "was where the project was created [...] a quantum leap compared to each sitting at their own desk writing some premise note, which was never lifted up or considered interdisciplinary" (i20). Some 25-30 participants participated in the first sessions, including guests from research and academia. This was the natural way to begin work and establish trust: "[the] building owner and contractor needed to clarify risk [distribution]; [...] we thought we would be building something which did not exist and which many thought wasn't even possible to realise" (i10). In a straightforward, conventional construction process, space is "made to accommodate some kind of standard HVAC system" (i14), and the HVAC engineer comes in sometime after the building is mostly detailed to implement some standard system with its many channels and shafts going in wherever there is room. What they then experience is that "90% of the premise [for their work] has already been made" (i17). In PH Kjørbo, this kind of thinking was turned upside down. This was reflected in the priorities at the workshops: "the first meeting was about where to put the mechanical room [...], and the architect was sewn around [the rest of it]" (i14).

Initially at such workshops, questions may be posed by some of the participants, as they are not used to this kind of work in construction projects. A chief consulting engineer with the contractor said, "Objections always come up when you start having workshops in order to build houses and stuff, and how that's considered by some as a waste of time" (i14). However, as the problems with conventional building styles are approached by a zero-emissions researcher pointing to, for instance, the vast amounts of embedded energy contained within the above-mentioned spiro-tubing and the extensive thermal capabilities of exposed concrete, the reason for the presence of a representative of the acoustic discipline will materialise:

"[...] choices we usually just make out of technical or economic considerations suddenly develop a broadside. However, when those broadsides materialise in a way, those folks who will be affected by it need to be in the room, right? In order to gain that experience for themselves given that this isn't how decisions usually are made. [...] So if that acoustician is left being allowed nothing with which to regulate the acoustics and has no idea why we've put such a straitjacket around the assignment, then that person won't be especially inspired to solve it." (i17)

In the judgement of the process manager, "It's time consuming in the first phase, but I think you regain it by setting the most important premises early on, and in that way the time after the detailing phase won't be so demanding" (i17). Moreover, this negotiation is an example of the cognitive aspects of the domestication of these project participants of the object they are about to design. Learning about the conditions for the design becomes relevant in this case as the consulting engineer has become the "user" who needs to accept them. The level of interdisciplinary work seemed to have a refreshing effect

on the project team, who stated that they felt a greater sense of respect for each other's work and that the separate specialist areas achieved a more naturally interwoven state, a "complete necessity when you need to innovate and find good solutions" (i19). The process manager made the following point:

"This becomes very clear when you realise we are all just as interested in building, and we are just as highly educated. And we all share a common goal to deliver first class every time if the framework for it is present [...] This isn't the normal way of doing things. However, that isn't because we don't want to work like that, it's because it's expensive to work like that." (i17)

5.3 The detailing (project) phase

A great advantage for the PH Kjørbo project was that it benefited from having emerged from the working environment hitherto described and brought with it most of the same people. This wellspring of comprehensive planning work and know-how that was created in the initial Powerhouse project (Meistad and Strand 2013) should not be underestimated in considering the particularities of Kjørbo's success:

"[...] it was a collaboration which was well established when departing from Powerhouse Brattørkaia [Powerhouse One], and the team consisted of many of the same people. So the development of Kjørbo was based on the experiences on Brattørkaia, and of course we held interdisciplinary workshops at Kjørbo." (i19)

The closeness of the PH Kjørbo project with the initial birth and definition of the overall goals of the Powerhouse collaboration most likely benefited the design phase substantially. In fact, the transition from one to the other can be difficult to trace exactly. However, when the project moved closer to the built product, the closeness of some actors with the concept of the Powerhouse gradually began to erode, and some problems were introduced as more personnel who were more or less familiar with the project were involved in the construction phase. The technical architect with the main contractor described it as difficult to bring new people on board who were unfamiliar with the overarching ambitions: "It's hard when not everybody understands what they have to deliver [...] and] you won't get a plumber to read the energy account" (i11). Bringing everyone on board with the "spirit" of the project - and, in fact, translating to them the symbolic gravity of the concept and ambition - proved difficult as the distance between many of the outlying personnel and the core of the Powerhouse project increased.

"A lot was sitting in the heads of those who had been part of the development [of the design of the Powerhouse concept]. That is to say, not everything could... we were supposed to document everything in writing, right? And then we were connected with a new team in the detailing phase [of PH Kjørbo], and they kind of just took the report and expected that in it was everything they needed to know. [...] Not all the conceptual solutions were fully understood. So there a lot could have been gained." (i19)

As a project manager explained, the construction project phase "suffered" from this; they "had not defined thoroughly enough exactly what it was they were building. [...] Compared to what was going to be built, the level of detailing was way too low" (i20). This "created miscommunication in a way about what parts we were confident in - what do we know is good enough of what is there, and what do we need to clear up further" (i20). The project was initially unsuccessful in even getting an HVAC contractor on board who was willing to take the financial risks associated with the function of the designed ventilation and its uncommon pressure drop rates and other untested solutions, such as the lack of panel ovens underneath windows. The project manager said, "Call it belt and braces which you have in any project, but here we had removed them entirely...."

"The lack of understanding was there among many, as well as the scepticism towards the solutions. [...] An energy project was laid to ground which everyone had seen and said, 'OK, we're good with this', where we had made some calculations: the theoretical temperature loss isn't higher, we built a climate envelope that is that tight, we have such good windows that 'the draft you're talking about, it won't be there,' we don't need that panel oven [...] That way of thinking is hard for people to take responsibility for. They don't believe; 'Are you serious? No need for an oven? I won't take responsibility for that, I need to make reservations, and

someone else needs to take responsibility.' [...] They won't take responsibility for the entire function: 'We'll give you ventilation, but I can't guarantee the temperature will stay within 22-26 degrees'." (i20)

Many of the subcontractors who were invited to deliver to the project declined initially on the basis that they did not accept the specifications they were asked to deliver. Thus, they were reluctant to deliver the solutions that were specified and provide guarantees for their function in the finished state. Simply put, they did not believe in the concept. The novelty of these solutions and the number of unknowns they represent compared to the tried and true represented an enormous friction among the main contractor, consulting engineers, and risk-averse subcontractors.

"We had made lots of calculations beforehand. The market didn't believe us; no one did. When I ran procurement, they didn't believe me that it would work. That people were going to freeze and sweat and that system [the low energy HVAC] wouldn't work. The biggest contractor didn't want to come along at all because they thought it wasn't going to work." (i11)

This is unsurprising from the point of view of a domestication framework as these "calculations" were fruit of a learning process for the project team of which the subcontractors in question were never a part. It was a general admission among many of the respondents that the overlap between the design phase, with its ardent focus on interdisciplinary workshops and collaboration, went astonishingly well, but when the execution phase and construction of the building ensued, things were allowed to fall into the pattern of a conventional building project. Here, subcontractors were purchased for the project at a late stage, some with the impression that it would be a business-as-usual type of project. This led them astray in their own initial design work on PH Kjørbo, causing the need for order changes and extra work to get the project back in line with the original design.

"It was well coordinated, very well coordinated, at least up until and including the pre-project. However, from the detailing phase of the project, we learned that we drove away a bit, in the traditional fashion, but we weren't actually finished... completely finished that is. When the pre-project was over, it was over because there was a date set. And it's been a lesson for us; we can't let go of the collaboration too early and let the specialists drive away individually. We were not finished." (i14)

The last stages of the project lacked the same kind of comprehensive oversight that was characteristic of the design phase:

"In the transition from the design and pre-project phase into the detailing phase, we stopped having a process manager, and we transitioned to a more traditional construction process in which the contractor usually sits with the technical project manager handling the technical specialists" (i15). The other role for which the process manager still could have proved useful was "communicating with the subcontractors [...and explaining to them] what they were in on. That was kind of the weak link here" (i15).

Eventually, the problems produced could not be handled sufficiently in time, and several errors had already been produced. This could have been because of a lack of subcontractors' comprehension of the project or, as some respondents also suspected, a lack of energy-related competence due to a lack of experience. After all, the exceptional scope of the project would require capabilities to deliver above and beyond a conventional market situation - an impossible task without the relevant experience. At any rate, it is evident that little space was provided in the project to allow subcontractors to domesticate the concept of PH Kjørbo at this point as they had not been given any insight into the underlying premises of the design. They were completely incapable of grasping the project.

Another contributing factor that made these challenges even more difficult to resolve after they were discovered was the contractual frameworks that were employed in the relationship between contractor and subcontractor.

“What I experienced maybe was that [the main contractor who] purchased their technical subcontractors, that is, on electric, piping, and ventilation and the like, was that I don’t think those actors which were purchased really got what kind of building, what kind of project they were in on here, was my feeling. [The main contractor] was on the ball, absolutely, but they purchased their suppliers in a little... in a kind of traditional manner, in a fixed price contract with them. I don’t think that was very fortunate. I don’t think the technical subcontractors realised that this was a special project that had some quite unusual goals.” (i18)

In this technical consultant’s opinion, this lack of understanding of the project’s greater goals led them to “make quick solutions, and not optimal solutions, in some systems.” However, under a fixed price, turnkey type contract framework, the supply side would have to deliver according to specifications a solution the function of which they would be able to guarantee. If the actual cost of the project is underestimated at that point, any extra cost will reduce the supplier’s profit. Quite clearly, the lack of knowledge could have made some subcontractors underestimate their costs going into this project. Subsequently realising their error, subcontractors were dis-incentivised by the fixed price contract framework from changing their stance towards a project that was already underway. A continued unwillingness to change their position endured even after clear cases of the project goals had been made. In spite of the special circumstance of the project, putting the cheapest solution in place in the shortest possible time can be argued, from a market logic standpoint, to be a perfectly reasonable way to proceed given the contractual framework, especially when combined with an absence of an understanding of the project’s realities.

Furthermore, the technical consulting engineers for each specialist area, who were previously integral to the project design, were finally “delivered” to the subcontractors, meaning they were removed from the project design and pre-project team and placed below their relevant subcontractors in the detailing/execution phase. This created integrity issues for the consulting engineers, who now were placed between a rock and a hard place: beneath the subcontractors in the chain of command but, due to their extensive expertise in the design and their closeness to the project and the contractor, ill-suited for carrying anyone’s water. This ostensibly constituted of a loyalty conflict when discussions about the inevitable order changes ensued between the main contractor and the subcontractors, to whom the consulting engineers were expected to defer in their delivered capacity.

This was especially evident for one of the electrical consulting engineers, here referring to the electrical systems installation, perhaps the specialised domain that was most poorly detailed when subcontractors began its design: “The setting was thus that it was us who made the demand specification for the building owner, and which was the foundation for the electrical contract. Later on, we were directly subordinated the [electrical] subcontractor. And the reality is that not all contractors are as specifically competent on lighting and control which was in demand on this project.” (i12)

This resulted in the necessity of much coordination between the contractor and the user group (subcontractors) of the tenant. As we have seen, fixed price turnkey contracts make it difficult to carry out order changes after the fact because the prices (i.e., suppliers’ profits) are fixed. Demanding changes to be made in the design increases the cost of the project for the subcontractor. However, when design had already been drawn and procurement processes initiated, order changes were needed for the project to get back onto the track from which it had departed. As the consulting engineer bluntly stated: “It’s hard to make gold out of stone. [...] I was placed in a position which could be perceived by others as if I was wearing several different hats at once. The turnkey contract model is demanding because suppliers are out after their money rather than creating new solutions. It’s cheaper to put in place old and familiar solutions.” (i12)

5.4 A case for a different contract framework when piloting

Contractual frameworks prove important for the possible execution of a project in the end as they determine the various aspects of cost and profit. In the case of the main contractor, it was engaged by the building owner in what is called a cost-plus contract, in which a set cost is provided in addition to an extra fee. This is, traditionally speaking, a better contract for innovation cases because the added fee alleviates some of the risk averseness that would arise in the face of uncertainty. The main contractor identified risks on its part and had to issue some reservations to the owner concerning project delivery. As a project manager said, "It's about getting to the bottom of it all with a building cost that's OK. Because, we'd love to take the risk, but we will have to price that risk, and then stuff gets expensive" (i20). The overall contract regime thus ended up looking something like this:

"The HVAC entrepreneur made reservations towards us [the general contractor], we had reservations with [the building owner], and [the building owner] was left with the risk [...] They paid us the cost plus a small fee, which incentivised our reaching some agreements about certain target goals in the project, instead of us ending up with a fee, on top of a fee, on top of a fee, due to someone saying no, I'm uncertain about that solution, therefore I'll estimate in a fee. And we'll estimate in a fee, and then it gets really expensive. In this way this is a good way to test new solutions. [The building owner] was willing to take the risk, but they weren't willing to pay us for taking the risk." (i20)

In this sense, the main contractor was engaged in a collaborative contract framework with the building owner. Lower down in the "food chain," however, the subcontractors were more or less engaged in fixed price, turnkey contracts with the main contractor. It was suggested by several informants that some of the issues that arose during the execution phase due to poor detailing (as well as the added cost of re-ordering) may have been avoided had the subcontractors entered into a collaborative contract framework earlier. An earlier placement of knowledgeable consulting engineers at subcontractors end, although pricey, could have been exploited to the subcontractors' benefit instead of becoming for them simply a bearer of bad tidings.

"Of course, they may have felt we were going into the unknown and taking a larger risk than they were willing to. It may be they would have felt that they were more comfortable also with a kind of collaborative contract in a way to get to the finish line. However, we didn't do that this time. [...] They were handled with turnkey contracting. And then they made their reservations, delivered functions according to spec". (i20)

For instance, finally solving the ventilation issue, the HVAC supplier was allowed a reservation regarding the function of their delivery even though it was delivered according to specifications. A project engineer stated, "That enabled them to deliver what we in fact asked them to. If not, it would have in a way... what would the price have been if they were to be held accountable for that?" (i20). Apparently, this was a case where the contractor took the risk and trusted the supplier to deliver to specification even without the guarantee.

The choice of fixed price contracts with elements of collaboration could be one way to address the higher than usual amount of uncertainty in projects such as this and allow social learning to occur lower down the food chain. As proven by the PH Kjørbo project, handing out fixed cost contracts to junior contractors with little experience could become expensive as well. The extensive planning and design phases in the remaining project likely provided an important foundation for social learning and domesticating the concept, thus providing the necessary basis for the realisation of the project. The alternative for disallowing for subcontractors to learn about such out of the ordinary projects is a higher level of detailing. As the consulting engineer on the electrical side explained:

"We had the impression this could have been done in a different way, [...] a 3420 description [NS 3420 comprises a complete system for describing and calculating construction work, including technical installations] where you've actually kneaded it all out, you've finished it beforehand. Here, you had a performance description where the contractors were supposed to contribute by finishing the design based on

performance. And it's not given that, for instance, the electrical contractor would enter into such a project again based on a fixed price contract if the performance descriptions are unclear. So that's a challenge, making that kind of a building with fixed price contracting. Maybe it would have been better to have a collaborative contract, for instance." (i12)

As the above respondent iterated, no one likes the “uncertainties” that this allows for, but sometimes “you don’t necessarily know 100% where you’re going either.” A bad combination of not knowing one’s destination and fixed contracts resulted in “a whole heap of additions and order changes” (i12). The time for learning in a fixed contract is never.

Finally, as one technical project manager with the contractor explained, in the construction business “it gets expensive when you let loose a junior too early, and that’s been done in some areas of execution in this project as well,” but “you can’t use a senior for everything; they need to provide the training on it” (i11). Clearly, senior contractors and other experienced actors have a responsibility for developing their own market of suppliers. Undoubtedly, this is a much better solution than doing all the work for them. As the project manager said, “It’s up to us as a main contractor to make them better” (i11). In a collaborative framework, added cost on paper makes it look less attractive along that one axis, but it can help subcontractors get up to speed early and avoid having to make order changes. The added value of increased energy building competences is one way to incentivise subcontractors and contractors alike for the extra work and lower the long-term cost of these types of frameworks as well. Developing their market for subcontractors is in the interest of main contractors as well and is a value to which an economic value can be attached - albeit indirectly and across a longer time span.

6. Part 2: User acceptance, expectations and negotiations

Eight months after moving into their new house, the team responsible for the running-in period of Powerhouse Kjørbo, composed of representatives from the tenant, the building owner, and relevant contractors, had received a number of complaints by employees regarding building conditions thus far. None of these complaints was fatal; they were mostly comfort issues regarding the lighting system, some slight temperature fluctuations experienced as a slight chill in the first floor areas, and the acoustic quality of the landscape areas. The following will provide a description of the way these issues were experienced by the staff working on the running-in phase, the way the complaints were received (and perceived), and the way they were resolved. A subsequent inquiry into the creation of the conditions that led to these issues will be made and how they may have been avoided (in the opinion of experts) by considering some experiences during the design and detailing phases of the building.

6.1 Lights

The first example of the tension created between the user experience and the novel engineering methods in PH Kjørbo was in regard to the lighting system. The issues had arisen from tension between an energy-saving ambition and the produced quality of lighting. The problems were perceived thusly by an engineer in the running-in period:

"I wouldn't say it's not working, but it's limping a bit. [...] It shuts off in a somewhat untimely fashion because it does not detect that there are people in the areas. This is partially due to the placement of sensors and partially perhaps that there are too few sensors in those areas. However, that is, of course, a decision about optimising and reducing energy spending on lights. [...] [T]his needs to be accepted if one has ambitions to use less energy. [...]" (i1)

In terms of results of the energy situation, at the point of inquiry, energy use spent on lighting had been measured at "somewhat above expected levels" (i1). The energy targets continued to guide the running-in period at this point, but there was also an understanding of the tension this caused for the user experience, as explained here by the tenants' electrical consulting engineer, who was working on the lighting system:

"[There has] been much work afterwards with the lighting system in order to achieve close to exact energy consumption of the lights. And this is connected to the number of sensors and the user's experience of the automatic light control. Because the user should not have to experience that the light goes off when they're at their workplace." (i12)

As mentioned, this was considered work in progress, and the goal of the running-in phase was to achieve both energy savings and a problem-free user experience. An office administrator explained how this problem was handled on the technical side:

"There are too few sensors compared to how the lights should switch off. It's supposed to be as little light as defensible, really. And some of the programming is not good enough [...], so now we have taken some measures temporarily. We have increased the intervals for when the lights switch off according to movement so that the employees won't have a situation where it gets dark while they are working." (i3)

A temporary adjustment was made when the system was unable to deliver satisfactory results to avoid interrupting employees while working. After consulting with a lighting professional, it was determined that 45 minutes of inactivity before shut off would be sufficient "as you'd need to get a coffee and move around a bit, and if they don't move around for 45 minutes, they should" (i3). This was most likely a relief for employees as the auto-off setting was set at a rather ambitious seven minutes of inactivity.

Importantly, this measure was only considered a temporary mitigation while troubleshooting was undertaken to redesign the system to achieve the original goals. The understanding of the need for balancing acts during introductions between employees and technical solutions remained apparent because “it should not come at the expense of the working conditions of the employees” (i3). Furthermore, if conditions were not at an acceptable level for employees, one administration officer emphasised,

“...then we can't look at the [energy targets] in that phase because at that point it's more important that people actually get to work. [...] it's about the frustrations of the employees. When you're up at night because you've got a deadline and you're in the middle of something and suddenly there's darkness all around... That creates negative frustration.” (i4)

Abandoning the energy targets was not considered. The attitude was that this was “elementary stuff [that simply] should have been in order” (i4) and that short-comings of these types were to be treated as any other kind of product deficiency. Thus, the problems described by users would simply have to be sorted out, which - as the running-in staffers were well aware - might include order changes in the project. For the sake of time and money, order changes were considered a last resort but possible if energy targets and user requirements were not both achieved. In short, local adjustments were the first line of defence, but adding more sources of light and more sensors was still on the table should these actions become necessary to achieve satisfactory results. Efforts to improve the lighting situation mostly amounted to rearranging the placements of sensors and/or introducing more of them (where the former was the preferred option cost-wise), and the energy ambition was not abandoned at this point.

“Well, now the consulting engineer has been here, a mapping of the zones has been done to see how it's put up, and it shows in this mapping that to make this work optimally with regard to the target of seven minutes before the lights go off, more sensors are needed. At any rate, some of the mountings need repositioning. [...] it's all about fine tuning.” (i3)

The energy account was still guiding the process, and the importance of reaching energy targets regardless of eventual challenges was underscored both in this context and in others. However, given the reluctance by staffers to compromise working conditions and their willingness to issue possibly costly order changes to meet the energy goals, it is obvious that the user experience would not be sacrificed to benefit energy targets.

6.2 Ventilation

There were some issues regarding the ventilation system and the indoor temperature, although at the point of inquiry, the ventilation system was more or less perceived as “working like it should have from day one” (i3). The running-in period started in the spring of an abnormally warm summer that saw temperatures in the thirties for weeks at a time. These are conditions no Norwegian building is equipped to endure for extended periods and that could pose more serious problems for a building aiming for little or no energy spent on cooling. However, the experience at Kjørbo was that the building handled it quite well, and the unusually warm outside temperatures did not cause any discomfort that would not have been considered “normal” in any other conventional building.

“It's a choice we made to set the refrigeration machine to 'off' rather than have the automation control that as well. If we had it set to 'auto', then likely the heat pump would have engaged the cooling mode parts of the summer to keep the temperature within some preset limits. We let it slide along towards slightly higher temperatures when it was really warm outside without it posing any kind of operational problems.” (i1)

This was likely due in part to the performance of the exposed concrete, which had been “fed” colder temperatures all night during these summer days to be able to absorb the worst of the heat during the day. Free cooling, contributed by geothermal reservoirs, also helped to produce comfortable indoor

temperatures without spending extra energy. The temperatures inside PH Kjørbo during the summer of 2014, although within reasonable parameters, were allowed to move a bit more freely (theoretically, at the expense of users) to avoid using power to keep the climate constant. For the users, this did not have any practical significance for comfort level. The facility manager explained,

“For instance, those people in [another building of comparable type] that is this international company with lots of foreigners who are used to working in office buildings with air conditioning and where it’s 22.2 degrees everywhere all year—you won’t find that here. However, that wasn’t the deal here either. If they [the employees] have between 20 and 25 degrees, they have no reason to complain. And there aren’t any buildings in Norway [...] that are designed to cope with 30 degrees. When you get those periods several days in a row [...] it gets warmer.” (i8)

In this case, temperatures were allowed to wander slightly within a comfort zone defined as less constant than in conventional buildings, and this did not produce complaints on the part of the users (in fact, sentiments more often leaned in the opposite direction). Once the summer waned and the outdoor temperatures decreased, however, a few complaints appeared, mainly regarding chilly temperatures on the first floor areas. However, what constituted a rightful claim to complaint could, according to some, be subject to debate:

“[Temperatures] have been within the defined limits. There is an assumption in the project—but of course, there are some who think that it’s cold when it’s 22 degrees. Then, the message is, put on some clothes. There is no point walking around half-naked if you’re cold when it’s 22 degrees. [...] If there’s an agreement to stay above 21 degrees, then don’t even think about commenting. Then you need to do something else if you’re cold.” (i1)

Arguably, this is a fair comment if expectations among users have been accommodated to the facts of the nature of the ventilation system. Speaking in terms of domestication, it involves the cognitive aspect and what one has been able to learn about the building. Regardless, this particular challenge, in which some users “felt it was a little cold” (i3) in the first floor areas, was easily solved by a slight temperature increase in those areas. Consulting the energy account, the running-in team found there was plenty of room for it: “After the air temperature was increased by, I think it was one or two degrees, I think it happened in August, then it was fine” (i3). Furthermore, this was the type of problem that was well handled by addressing the cognitive aspect of the domestication process. As an engineer working on the running-in phase said, “Users need to be taken on board and provided information about the premise of how things are supposed to work” (i1). The facility manager noted about temperature fluctuations in general,

“[...] if you [as a facility manager] are hands on, and you explain and you manage and you’re up front, then the tenant understands that ‘OK, now it gets warmer, but the facility manager has done all he can so it doesn’t get any warmer than this’. And then you get acceptance. You raise the threshold. [...], and with a continuous dialogue [...], you get acceptance if you are up front and talk instead of just squeezing [energy savings] as hard as you can and saying ‘can’t do anything about it’. Then you won’t be able to reach out to them [the users]. However, if you’re up front, you can get it done.” (i8)

Many of these quotes about temperatures touch upon a topic that is more fundamental to user experiences, namely, expectation. Much of what has made PH Kjørbo a successful experience is that effort has been spent on cognitive aspects: users have been informed and educated that PH Kjørbo is an extremely energy-stingy building. In talking about user expectations, the viability of making a habit of conveying the buildings’ expectations by its users is proven.

“What’s special about this [is] striking a point of balance for the users afterwards, [which means] that the users need to be informed that they are sitting in an environmentally friendly building [...] we’ve been required by something called man 4 in the BREEAM, we have to make a manual and we have to set up information meetings.” (i11)

This means that to achieve BREEAM certification, the engineering phase was required to produce a user manual for the new inhabitants, which the building owner was then responsible for conveying to its tenants. The manual, a 40-page leaflet that was distributed to all of the employees after move-in day, has a comprehensive chapter on the building's various technical solutions. It explains the premises on which the systems are designed and the extent of user involvement allowed for in addition to simple practical guidelines of how user involvement affects the overall energy strategy of the building:

"In every office space and meeting room towards the façade there are windows which may be opened. Opening up windows will not conflict with remaining ventilation or the shading devices on the exterior. Windows are opened and closed manually and must always be closed upon the conclusion of the work day. Opening a window when there is a heating demand will lead to increased energy consumption." (Entra, 2014:27)

It also explains how the temperatures in offices are affected by the use of doors (closing the door more or less cuts the office off from the central ventilation, and there is a policy to always leave doors open when leaving the office). Explanations discuss every detail of the practical aspects of the building, such as how the power outlets function (the red ones are presence activated, and the black ones are always on), how light switches in various common areas are operated, and so on. Finally, it contains other chapters containing what one might call more "regular" work space information, such as fire escape routes and emergency routines, and an introduction to the public transport available in the surrounding area ("how to get to work"). Thus, energy-related advice is bundled together with other generally useful information regarding the workspace, incentivised by one point towards a BREEAM certification. As such, this was a useful way of conveying the practical aspect of the specifics of PH Kjørbo. This is likely a good way of broaching the topic of expectations with the users provided it is also disseminated in a helpful context, such as an information meeting, three of which were provided for the employees at PH Kjørbo. A technical advisor with the building owner explained the gainfulness of this approach:

"We've had quite a bit about what it is like in new, modern, energy-stingy buildings, and then we've receive complaints on the indoor temperature or whatever. And they know... they don't understand the concept, what kind of building they have just moved into. [...] [I]n quite a few of these buildings, we've had information meetings, and it's been positive for the tenants because many of the complaints go away." (i18)

Thus, the running-in period at PH Kjørbo helped to balance the energy account with user expectations and social learning. Although amending the technical issues that were perceived as negative in this case was both affordable and easy (increasing the temperature by one degree), in general, relying only on the latitude provided by the technical installations will deny any project a large part of its tool box for coping with domestication and user acceptance.

6.3 Acoustics

Turning to the final issue of this section, accepting the acoustic conditions in some parts of the building reportedly required a little good will on the part of the users. As the exposed concrete was covered by baffles to soundproof the locales, a decent level of dampening was achieved. In most areas, the use of baffles provided results within the limits of standards, but this was more difficult in the landscape areas (which also have their own standards). The requirement of exposed concrete providing thermal capacity created a certain tension between reaching energy goals and providing what was experienced as optimal user conditions. As the acoustician explained, "Exposed concrete was a precondition for the project, and clearly every acoustician will tear at their hair when hearing about such things because exposed concrete is something we do not want, especially in the ceiling. Then it's hard to achieve good conditions" (i6).

As was explained, in a traditional building, the solution usually reached for soundproofing is the so-called system ceiling, which is "simple and affordable and creates good conditions" (i6). This would have

solved the issue of acoustics thoroughly, but, as admitted by the acoustician, other considerations were of greater importance in this case. Therefore, negotiations with the perceived user experience once again entered into the project. Measurements were made at the previous offices to obtain a sense of what users were used to. It turned out that the previous conditions were very good: "They were extremely silent and quiet, so it's most likely quite a transition for many to move in here." However, "when we set our goals here, we thought perhaps that we needed to allow for a bit more [noise] but that the working conditions still should be good" (i6). For the new conditions, a reverberation time of 0.8 seconds was allowed, which for the most part was achieved in offices and meeting rooms. This would place the results for these areas just within the minimum requirement (level C) of an earlier version of the relevant standard (NS81-75, 2008 - the choice for the earlier version as opposed to the 2012 version was made possible as the project was classified as rehabilitation). However, keeping within the limits of standards but this close to their edges would be an unusual experience for many users. After acousticians had negotiated their solutions within the framework of the standard requirements, it became necessary to convey the premise of this solution to the users to obtain their acceptance of the new conditions. Some in the project considered the requirements extreme, to which the acoustician responded, "There is nothing extreme with minimum requirements" (i6). The remainder of this issue would emanate largely from the landscape areas that feature in PH Kjørbo. Here, people moving around and making conversation can be disturbing to others. This situation is further exacerbated by the fact that the walkways around the landscapes are baffle-free to showcase the exposed concrete to visitors and thus are a crucial part of the design of the building - a thoroughly symbolic aspect of the design of PH Kjørbo. A benefit of introducing the acoustic issue early in the project was that planning between acousticians and architects actually resulted in the design of the plan solution itself minimising traffic in the landscape areas. A provision was introduced that had little to do with soundproofing per se but rather involved a relational shift that contributed to the prevention of noise arising in the first place:

"When you are sitting in a landscape, it's a benefit not to be disturbed by those walking around the premises [...], and that's also... when we worked together a lot with the architects here... it's that if you're headed to a meeting room, you don't have to walk through the entire landscape, you can get to all the meeting rooms here without walking through the landscape." (i6)

Reducing the amount of absorbents was deemed "a calculated risk" by the acoustician. There were also tales of heavy usage of noise-cancelling headphones and quiet keyboards around the landscape - all practical provisions to address unwanted noise. Finally, the running-in team continued to work to improve soundproofing and to find additional crooks and crannies to place more absorbents, such as on patches of dry wall along the interior façade - albeit not on the exposed concrete. This was another practical provision. On a cognitive level, however, office landscape acoustic issues all have the defining characteristic of being landscape issues and not necessarily issues specific to PH Kjørbo. In combination with this, ample opportunities are provided to escape in case one needs to get away from noise (or one is planning to create noise) in the form of silent areas, both free-to-use and bookable variants:

"No, it's everywhere. There simply isn't anything special about this; they're typical landscape problems. Not everyone can handle it, and also it's a little... if anybody has a need to sit and concentrate a lot [...] there are options to seclude oneself if you need concentration and work without interruption." (i6)

Respondents mentioned the benefits of sitting in landscape mode, including the fact that discussions and talking shop were just a conversation away, which is the "give of the take" in all office landscapes. Additionally, with a provision of a closed office ratio of approximately 20%/80%, according to the accounts gathered here, those in need of silence should have their needs covered. Again, as the minimum requirements were achieved, discontent could largely be accounted for by users' previous experiences with mostly system ceiling solutions. The acoustician displayed some academic interest in this: "Of course, I think it should have been dampened more. But this is as bad as it can be allowed; this

is the minimum requirement, as I said, and maybe it's all right to experience what that is too, the minimum requirement. What it cannot be worse than" (i6).

6.4 Out of the ordinary?

Concerning these three issues together, the end use experience has been slightly different from that of a conventional office building. Practical provisions, habit changes and technical improvements were employed at this stage by users and running-in engineers alike. It was equally useful to address the cognitive aspects of use and to achieve an understanding with users about the symbolic relevance of the lack of soundproofing in walkways or helping users to understand the design behind the exposed concrete (a cognitive exercise). These issues notwithstanding, the experience so far is that all these issues - however PH Kjørbo-specific in shape and form - do not necessarily pose greater problems for the new tenants than other instances of moving the office into a new building:

"[...] usually you make an inspection before you start paying rent, and at that time [the conditions are] supposed to be reasonably decent; you're supposed to be able to move in. [...] However, then it's never 100%, and you can't just say no, then we're not moving in, because you can move in, you can live with them doing adjustments here and some things there. And that process has been somewhat smoother here. There've been challenges here too, I'm not saying that, but that's related to other stuff. And at least nothing more, that it hasn't." (i4)

In any case of moving into a new building there is work left to do and details that are discovered out of place. Consequently, visits will be made every couple of days by contractors who will intrude on the workspace to implement improvements. This is to be expected as the purpose of an adjustment inevitably arises from someone's discovery of its necessity. For many of these adjustments to be discovered, an attempt must first be made at normal use conditions.

"What's been challenging here has mostly to do with lights and acoustics. However, that's got a lot to do with the concept. So in the other areas, those things are in place. We haven't had things here that haven't [actually] worked, as was the case in other buildings we've had rehabilitated." (i3)

This was the situation in the view of the office manager, an individual who was placed rather centrally in every move this particular tenant made and who was likely to have grounds for making comparisons. The verdict was clear: the move they had just made went far better than any of the previous ones. This view was seconded by a colleague:

"When we moved in 2008, we experienced sitting there in 2011, and there were still deficiencies after the take-over three years later, and things took time. Ventilation was never optimal, and we see this in other leases [our company] has made too, often when you move and even if it's been refurbished or even if the building is new, there's a period of adjustment after moving in." (i4)

Including all the statements of this type would be outside the scope of this report, a clear testimonial to the merits of the building. Does this mean that the building itself should get all the credit? It is true that forward and relational thinking has resulted in a high-performance building in many respects, but the practical aspects of the domestication process are an insufficient explanation for the success described. As we have seen, user involvement has been necessary and has been addressed on more levels than the practical.

6.5 The sum of experience

As we have seen so far, when certain aspects of building use differ from users' previous experiences, antipathies can arise. This situation obviously calls for improving those conditions that are unappreciated, but a balance can also be struck by addressing cognitive and symbolic aspects of

building use and enrolling users in the overall project goals. As mentioned in relation to the landscape environment, in the case of PH Kjørbo, there are “gives” that can be identified for many of the “takes.” What we could call the relational aspects of the building that are characteristic of the conceptualisation and design of PH Kjørbo are also relevant for understanding the “experience phase” of the building:

“In regard to the noise issue, I would like to say that there is another thing about noise because one issue is the noise made by people and how the noise carries when someone talks, but the ventilation noise is non-existent. And you only notice that once it’s gone [...]. And it’s incredibly nice. I feel it has this stress-reducing effect. So climate wise, environmentally wise, in regard to how the building works, I feel it’s a healthier building.” (i7)

In summary, doing things differently can create novel problems, which, as they are experienced, may produce user frustration. However, there is a possible in-road to handling such issues in a running-in phase that aims for and facilitates an adequate domestication of the building. Some problems are difficult to eliminate completely due to necessities inherent in the environmental design. However, taking into account the experience of Kjørbo as a whole, some “old” problems that we may not consider because we have become so used to them are now gone. In the case of one respondent, this is considered a huge reward:

“In general, I think it’s a very good building. You can say there’s a bit more noise here than in our previous building, it was soundproofed a lot there, but in return the air quality there was a lot worse. So even though the temperature here may feel a bit cold sometimes, the air quality is way better, so the head stays clear for more of the day. And that is a huge difference.” (i7)

The words “in return” are relevant in the above quote. The building has become, relationally speaking, a completely different animal than a conventional building, a shift that is not reducible to its individual parts. Thus, the entire end use experience becomes something else as well. Paying too much attention to isolated “error incidents” such as above-average noise levels poses a risk of not appreciating what perhaps matters more: the sum of experiences. This last quote presents a case in which, for this person, the increased noise from the exposed concrete is an acceptable deficiency in light of reduced ventilation noise. Experiencing the building as a give-and-take experience that offers benefits that are considered valuable in their own right when spending large amounts of time at the office - inevitably connected as it is with topics such as “work flow efficiency”, “indoor climate,” or “well-being” - provides a good example of an important symbolic aspect of the domestication of PH Kjørbo.

6.6 The user as “data source” for the comfort threshold

The issues recounted so far serve as examples of what can happen when energy requirements offset the possibilities of using tried and true catch-all solutions for coping with well-known problems such as acoustics, ventilation and lighting. It also creates a greater need to balance system performance more accurately with users’ requirements. It requires relational thinking. As such, if the services provided by the technical side of the building are scaled down and minimised to save energy and avoid oversizing, there is a need as well as a potential to roll back performance close to the minimum requirements on the part of the users without causing distress or discomfort. A running-in period is normally concerned with the ideal performance of technical systems, and the partial user focus exhibited in this inquiry belies the actual dimension of the rather small share that involves end user experiences. Despite being a proportionately small part of the running-in period, it is a part that can provide considerable leverage to the rest of the process.

Achieving a balance between the technical aspects of the building and the energy performance goal (no small task in itself) will necessarily be based on a number of measurements achieved by the extensive employment of sensors. However, the only real sensor for the limits of comfort is the user itself. Like the sensors to measure air quality and temperature and levels of activity within the building, the values of

which command everything from when ventilation scales up or down to when lights go on and off, how can the information collected by the user-as-sensor be processed by the running-in team? PH Kjørbo provided an illustration of this. Although the solution could be considered time consuming, it is quite simple.

Administration staff and office managers are part of any office environment and are often known and appreciated for their efforts at streamlining the working day of the rest of their organisation. PH Kjørbo with its tenant is no exception, and this particular branch was fortuitously placed at the centre of the running-in period. One individual (a trained architect) in particular played a crucial part in the project by serving as a connection between users and the engineering side of the project. Arguably, the most important tool that was employed for this job was an office support system that functioned as “a help desk for the office” (i3), where any problem, large or small, could instantly be reported to the office manager by any employee on an electronic form.

“It’s me who’s the connecting link here. I receive registrations in the office management link, and I’ve reported them to the customer service department of [the building owner], but I also report directly to the project. I go straight through to those channels because I’ve been working with those people a lot during the entire project phase.” (i3)

In other words, this person was embedded in the project from the very beginning, even before the contract was signed with the building owner, representing the part of the end users. This gave the end users a person uniquely suited to handle their requests, and a mature channel of communication was established through this individual with all parts of the engineering project at an early phase.

“[i3] was in the user forum [for PH partners] all along, even from before we entered into the contract and almost a year and a half before we moved in. So there were regular user forums with [architects], [main contractor] and [building owner] and discussions about solutions. So it’s been very - as such - from a user perspective, [i3] has direct insight into who does what.” (i4)

Arguably, this had to do with the particular concept being a pilot and would perhaps not be observable in most conventional projects. With regard to the question of whether it was the particular expertise of the tenant, being in the business of engineering consulting/architecture, or the attitude towards the technological setup being particularly malleable, the respondent commented,

“I think it’s a combination because first of all, this is a special building with many special solutions which commands a closer attention from the project concerning both contractor and subcontractors, who have regular meetings to follow up and make sure stuff works and that the energy account is the way it’s supposed to. [...] So I think because of this project, which is a special project, things have been solved a lot quicker.” (i3)

In the early stages of the Powerhouse collaboration, of which Kjørbo would be the first showcase, the definitions that were established during the project phase of Kjørbo and after were very loosely defined: “we realised pretty quickly that the road was being made as we went along, in fact. Because it was all new, and definitions and the like were not in place when the dialogue [about Kjørbo as a Powerhouse] was initiated” (i4). This could have contributed to creating more headroom to include personnel in the early stages of the planning phases of the project; elsewhere they likely would have been considered superfluous and excluded or not invited at all. Regardless, it is evident that the placement of a user representative in such close proximity to the engineering branches of the project was useful for connecting the user side:

“[...] of course, [i3] also had internal user forums [for actual users of PH Kjørbo], but that was with group leaders to get input for the other meetings. Sometimes there were extended user forums [for partners] also, where group leaders [with the tenant] partook. [...] However, otherwise it’s this log, this office management link which serves a sort of help desk, but not for IT stuff; it’s for office operation. [...] So there you can report

a lot of stuff, and it's actually been very helpful that folks here could do that now. Because we can really see, 'Oh, lot's about lights, acoustics.' It shows you what counts, in a way." (i4)

In other words, connecting users to the engineering project through the office manager was a helpful way to inform the running-in team about user requirements. Equally supportive of the entire process was the office link that provided real-time feedback from users about their experiences within the office environment. Conveyed by the office manager, this feedback filled the information need solicited by building operators managing the running-in period about how to balance comfort issues with the energy account and, to use an economic term, the “comfort-elasticity” of the users. Finally, an indication that a problem was resolved was provided when the data link stopped producing reports from users about that particular issue. “It’s going in the right direction because now we’ve had two weeks where I haven’t reported any cases to customer service of the building owner. And that’s actually very good. Not all the cases are closed, but there are things going on there” (i3). A data source for setting a viable comfort threshold had been established; even though issues might not have been resolved, they were experienced by users as “being dealt with.”

7. In lieu of a conclusion: The three qualities of PH Kjørbo

7.1 Quality 1: Good for the bottom line

Just as for its functionality, the building received a lot of praise for its symbolic value from our respondents. One executive with the tenant illustrated this point succinctly when he posited that “this building suits us; it contains a message about us. It displays social responsibility, optimal energy solutions combined with a good aesthetic, and that’s a bull’s eye for us” (i2). Seen from this perspective, the extra investment into a zero emission building made economic sense for this specific tenant. One example in particular pointed towards this particular image effect and how it related to the tenant’s bottom line: A Danish consulting firm went on a visit to find a Norwegian partner and so went shopping at various consulting firms in the area:

“And they went to the main offices of [a main competitor]. [...] And they had been there first and then came down here and they said it was like travelling 30 years into the future in three minutes [...]. And of course, out of all the measurements you can make of [our competitor] and us, [the competitor] is the mastodon, big brother in the play pen, where everything is successful and good results, right? However, the symbolic effect for us in this instance was enormous. So now they want to work with us and not [our competitor].” (i5)

7.2 Quality 2: Showing that it can be done and that it can be done beautifully

But the building was meant to be much more than just a way to attract business for a specific tenant. Several respondents expressed the hope that the markets were affected by what they had accomplished as they had to task market actors considerably to deliver what was requested. As another executive explained, “I don’t know what was sent out to these furniture vendors, but they’ve been pulling their hair because of it. That’s awesome” (i5). Furthermore, the project developed skills and competences with involved companies’ personnel that would provide future advantages over competitors. As we saw in the first part, subcontractors benefited from the project by building their energy related competences as well, even though it was a steep learning curve for some and the added time necessary for learning to occur was a source of conflict.

In this sense PH Kjørbo was more a symbol than anything else finally providing an example of an environmental pledge that actually lived up to its name and represented a confrontation with existing cynical views of environmental ambitions as somehow “vicarious”. Providing the “proof of the pudding,” so to speak, PH Kjørbo would contribute to assuaging such misconceptions.

The new goal after the conclusion of PH Kjørbo was, as an executive stated, to prove the conservative sentiments of the construction business even more wrong “by building another one, this time even more affordable” (i5). This quote directs our attention to the cost of PH Kjørbo. To be able to be the shining example the building had to become more than just functional, it had to become beautiful, too. In fact, much of the blame for the extra cost was considered by our informants to belong to the extensive detailing of the design, such as the arching walls, the aesthetic lighting, and the ribbed walls and baffle-covered ceilings (which also were necessary to improve the acoustics). The technical part of the building was considered to be cheaper than a conventional case. As the project manager stated:

“[...] comparing the Powerhouse with other projects quickly gets problematic. I’d argue that the energy concept doesn’t cost much more, but you can pay 25,000 per square meter for a design building anywhere else. That’s perfectly possible; it’s a choice for the building owner, what qualities to emphasise, how it’ll look, are you willing to pay for that, well then you need to pay for that. The energy concept isn’t what’s made Kjørbo pricier than normal.” (i20)

What he is saying here is that lessening the emphasis on some of the signal effect design aspects of the project would have made it more realisable. In the words of another informant: “if you choose to build a building with the same functionality but without so many design elements, I’d think the price could be reduced considerably” (i6).

It remains to be seen whether high quality design really can be subtracted from future incarnations of the Powerhouse franchise without leaving a dent in the “Tesla effect” that might have had a hand in convincing the occupants to accept slightly reduced temporal and acoustic comfort just for the intangible goal to achieve some emission and energy “0” can be achieved some day in the future. It goes without saying that from a perspective that cares about **architectural quality** this return to business as usual is without doubt a mistake.

7.3 Quality 3: Skilfully weaving a web of occupants, components and architecture

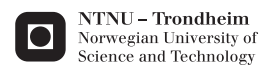
Whether good zero emission office buildings can be created at a lower price by choosing lesser design or not is to be seen in the future. However, this calculation does not account for the extra cost that has accrued in the early design phase and during the carefully orchestrated running in phase. These extra costs are mostly due to the temporal suspension of cost-saving division of labour in favour of collaborative learning. Here, too, a return to business as usual can be expected in which the solutions found at PH Kjørbo are “applied” to other projects. Seen from the socio-technical perspective described in the beginning of this report a building’s performance is the result of relations between all the technologies implemented in the building, the materials and architectural form, and last but not least of the occupants and their actions. With the exception of a short period after the original process manager had left until the occupants have moved in, PH Kjørbo appears to be an example for the skilful weaving together of these very different components to create an original, a beautiful, and not least the well-functioning whole that is more than the sum of its parts.

8. References

- Akrich, M. 1992. "The De-Description of Technological Objects." In *Shaping Technology/Building Society*, edited by Wiebe E. Bijker and John Law, 205–24. MIT Press, Cambridge, MA.
- Akrich, Madeleine. 1995. "User Representations: Practices, Methods and Sociology." In *The Approach of Constructive Technology Assessment*, edited by Arie Rip, TJ Misa, and J. Schot, 167–84. Pinter Publishers, London; New York.
- Berker, Thomas. 2011. "Domesticating Spaces. Socio-Technical Studies and the Built Environment." *Space and Culture* 14 (3).
- Brand, S. 1995. *How Buildings Learn: What Happens After They're Built*. Penguin Books.
- Bye, Robert. 2008. "Lærende Bygninger - Nøkkelferdige Brukere?: Bruk, Brukermedvirkning Og Energieffektivisering I Yrkesbygg." PhD thesis, Norges teknisk-naturvitenskapelige universitet, Det historisk-filosofiske fakultet, Institutt for tverrfaglige kulturstudier.
- Gieryn, Thomas F. 2002. "What Buildings Do." *Theory and Society* 31 (1): 35–74.
<http://links.jstor.org/sici?sici=0304-2421%28200202%2931%3A1%3C35%3AWBD%3E2.0.CO%3B2-M>.
- Hirschman, Albert O. 1970. *Exit, Voice, and Loyalty. Responses to Decline in Firms, Organizations, and States*. Harvard University Press, Harvard.
- Holtan, Knut Sørensen, Knut. 2005. "Domestication. The Enactment of Technology." In *Domestication of Media and Technology*, edited by Thomas Berker, Thomas, Maren Hartmann, Yves Punie, and Katie Ward. London: Open University Press.
- Hughes, Thomas P. 1988. *The Development of Large Technical Systems*. Campus, Frankfurt/New York.
- Law, John. 2000. "Notes on the Theory of the Actor-Network: Ordering, Strategy and Heterogeneity." In *Organizational Studies: Critical Perspectives*, edited by Warwick Organizational Behaviour Staff, 2:853â 868. Routledge, London New York.
- Lie, Merete, and Knut Holtan Sørensen. 1996. *Making Technology Our Own? Domesticating Technology into Everyday Life*. Scandinavian University Press, Oslo.
- Meistad, Torill, and Lillian Strand. 2013. *Powerhouse One - Erfaringer Med å Utarbeide Konseptet for et Nullenergi-Bygg*. 11. Trondheim: Sintef Byggforsk.
- Silverstone, Roger, and Eric Hirsch. 1992. *Consuming Technologies : Media and Information in Domestic Spaces*. Routledge, London.
- Star, Susan Leigh. 2010. "This Is Not a Boundary Object: Reflections on the Origin of a Concept." *Science, Technology & Human Values* 35 (5): 601–17. doi:10.1177/0162243910377624.
- Woolgar, Steven. 1991. "Configuring the User: The Case of Usability Trials." In *A Sociology of Monsters: Essays on Power, Technology and Domination*, edited by John Law, 57–99. Routledge, London.

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