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Relational materialism in passive house designs – mundane work and tinkering in Vallastaden’s low energy buildings

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Abstract. Sweden’s new showcase mixed-use neighbourhood of Vallastaden has been designed for social and environmental sustainability, with a specific focus on citizens’ active involvement in the early phases of the planning process, and the built environment has been designed to encourage social interaction between residents. One aspect of the Vallastaden concept is low energy buildings and passive house designs. All buildings are designed to be 25% more energy efficient than the requirements of the Swedish Building Code, and 12 residential buildings have been designed as passive houses. This research project focuses on the planning, construction and management processes, and on the everyday lives of the passive houses’ residents. The paper reports on the initial research conducted with a qualitative approach, including interviews with residents and stakeholders and diaries maintained by residents. Relational materialism is our theoretical approach for analysing empirical material and guiding our understanding of the socio-material as being intertwined in assemblages and how different elements and entities are enacted in everyday life for low energy thermal comfort in passive houses. Our conclusion is that building design and energy system design varies between the different buildings. There are many different passive houses in Vallastaden, which come in different shapes and with multiple relationships between the social and the material. Both residents and professional groups need to work to achieve the desired levels of thermal comfort, and this work includes what seems to be endless tinkering with the different parts of the energy system and buildings. Eventually, different practices become established for mundane management of thermal comfort.

1. Introduction
The vision for Vallastaden in the city of Linköping, Sweden, was to create a new neighbourhood characterised by design multiplicity, social sustainability, resource efficiency, creativity and knowledge. Some of these characteristics have been scrutinised by critics including architects [1], social sustainability critics [2] and housing researchers [3]. The focus on resource efficiency has mainly been centred around the underground infra culvert, stretching 1800 m through Vallastaden and connecting the buildings to the energy infrastructures of the larger urban area of Linköping. Approximately 100 buildings, twelve of which are designed as passive houses, have yet to be explored and analysed in more detail. The current paper sets out to make a contribution to such an exploration and analysis, based on science and technology studies (STS).

The aim of this paper is to describe the passive house designs in Vallastaden as assemblages consisting of human and non-human elements and entities. Our scope focuses on the building envelope and socio-material interactions in the planning, construction and early user phases. The research questions are:
• Which elements and entities were enacted for the passive house designs in the planning and construction phase?
• How are assemblages around thermal comfort formed in the early user phase?
• Who or what are backgrounded or excluded from the assemblages of Vallastaden’s passive houses?

2. Theoretical approach
The research presented in this paper is guided by theoretical ideas found in the interdisciplinary approach of relational materialism [4]. At the core of these ideas are relationships between humans and non-human entities – relationships that are constantly changing and constitute our world. In this state of flux, everything is continuously moving and in the making. The constitution of our world is thus rather a reconstitution in which humans and non-human entities are engaged or unengaged. These ideas can be traced to social studies of technology as presented by John Law and Ann-Marie Mol [4], and to the philosophy of Deleuze and Guattari [5], later developed as assemblage theory by DeLanda [6,7]. Concepts such as enactments of entities and elements, mundane work and tinkering [8] are used to make sense of the many different “doings” in relation to the assemblage. Humans and non-humans are enacted, re-enacted, or dismissed as the relationships are formed and reformed. Assemblage is, however, not an entirely accurate translation of the French agencement, referring to “[…] the action of matching or fitting together a set of components (agencer), as well as to the result of such an action: an ensemble of parts that mesh together well” [7, p. 10]. Agencement captures both the continuous ongoing processes and the always temporary products in a state of movement.

To exemplify assemblage theory and establish a connection to the topic of this paper, we draw on the entities and elements of a residential building. The socio-material elements are constituted by the land and the masterplan for the development, construction materials, planners, builders, infrastructure for transportation, electricity, heating, waste, optical fibres for telecommunications, flows of media for electricity, heating and communication, residents, building caretakers, etc. The designs of the various elements and their shapes and appearances make certain enactments possible. What holds elements and entities together, or tears them apart, depends on the “doings”, or the tinkering carried out in the present. The assemblage of thermal comfort is, in the case of Vallastaden, an enactment of the district heating system, a combined heat and power plant located in another part of the city, the infrastructure for central heating in the building, the media transferring heat from the plant to the residential units, and thermostats that will be used by residents to manage the ambient temperature and thermal comfort. In passive house designs, the building envelope – including the wall structure, insulation, windows and doors – is even more crucial for residents’ thermal comfort, which we address in this paper.

3. Method and data collection
This paper presents the early phase of the research project focusing on a case study of passive houses in the Vallastaden neighbourhood. First, a pilot study was conducted including a couple of passive house residents. The householders were interviewed in our work to develop an interview guide, and they were also a test group for a diary collection app called PODD [9]. PODD was developed using the concept of time geography, allowing householders to keep diaries of their household activities involving household devices and relating their use to possible changes in indoor thermal comfort. When all the households in the pilot study had tested the app, a follow-up interview was conducted in order to evaluate the app itself and the general experience of keeping a diary in this way. Secondly, interviews were held with residents in Vallastaden. To get in touch with the target group we were dependent to some extent on personal contacts, but we also left invitations to take part in the study in mailboxes. Alongside the empirical fieldwork in Vallastaden, we also carried out a minor, non-comprehensive document study using the Mediaarkivet database which includes design journals such as Arkitektur, Arkitekten and Rum, as well as other journals including articles about passive houses in Vallastaden. These texts were used to provide more detailed descriptions of the different buildings.
4. The assemblage of passive houses in Vallastaden

In our analysis of the passive houses in Vallastaden, we refer to the theoretical framework and concepts derived from relational materialism, where passive houses are understood as socio-material and assemblages of a variation of concepts, elements and entities.

4.1. Conceptual plan and masterplan

The Vallastaden neighbourhood masterplan process competed with the conventional Swedish urban planning procedures, since the plan was decided on before the land was sold to developers. [3] The conventional procedures are accused of only being open and transparent on the surface, taking citizens’ opinions into account to a superficial extent and only rarely challenging the very few major developers in the Swedish construction market. In this case, the masterplan was an open competition between architects. The submissions were displayed publicly before a jury agreed on the competition entry “Selions”, which was pushed through the local council. Architects played major roles, both as idea generators for the masterplan before the developers entered the scene, and as members of the jury. Other members of the jury were the local councillor of the built environment and the civil servant responsible for urban planning. In this process, several value laden concepts and spatial features were enacted in this local pocket of alternative urban planning and the construction of buildings in a new neighbourhood.

The concept of “people” was championed early on by the local councillor responsible for the project, who coined the overarching slogan for the project of stepping up ambitions for the city’s built environment: “People build the city” (“Människan bygger staden” in Swedish). “People”, and various similar terms, were then incorporated into various activities and set in relation to the various projects within the formal urban planning process, for example workshops, citizen dialogues, the website “linkopingsbo2016.se” (Linköping citizen 2016, the original year when the first nine blocks and two parks in the neighbourhood would be finished) and social media activities. Green elements were translated both literally as green infrastructure, a river park and an area of allotments for urban gardening, and metaphorically in terms of environmentally conscious decisions and choices. These decisions and choices were related partly to the larger infrastructural construction, such as the underground culvert for district heating, household waste, freshwater pipes and sewage systems, and partly to the Vallastaden quality programme. Quality was a third element enacted in various forms and combinations, including quality in terms of urban planning, architecture and other building design elements, such as passive house designs for low energy housing and communal spaces at the centre of each block and on some rooftops. Quality was also presented as the guiding principle for the urban planning processes and the finished products of the built environment.

In the passive house concept, all three elements – people, green and quality – come together, since passive houses are marketed as high quality buildings that require craftsmanship and careful planning and execution in their construction. The concept is said to save resources in terms of energy for heating, and to be a people-centred design for healthy indoor environments. Some have suggested renaming the concept “active houses”, since the thermal comfort is largely depending on body heat and activities performed by residents. When people carry out their daily household work and take part in indoor leisure activities, they – together with the construction of the building – “make” the house function. Passive house residents are also expected to “tinker” with the white and brown goods, as well as the building envelope, eventually figuring out when and how different household activities can create a comfortable indoor environment. For example, if only one household member is at home, it might be a good idea to do the laundry since using white goods will generate excess heat and help heat the housing unit. However, if residents plan to hold a party at home and invite other people, heating from household appliances is undesirable. Airing homes should also be planned in relation to passive house designs, in both the summer and the winter. With careful planning of building positioning with regard to solar radiation, wind and natural shading, passive houses are said to be even more resource efficient and environmentally sustainable.

4.2. Passive house designs?
In the land sale process, developers were encouraged by the local council to plan for passive house designs. Passive house design was among the 17 quality criteria developers could include in their bid for land, but turned out to be among the least popular for developers to include. Still, around 100 units were planned as passive houses in the first nine blocks inaugurated as Vallastaden in 2017. The assemblage of Vallastaden’s passive houses shows signs of messiness, as the assemblage theory suggests. For example, four terraced rental houses built by the local public housing company and developer Stångåstaden to designs by Kjellgren Kaminsky Architecture have been described in print and online as passive houses [9, 10, 11]. The energy performance was stated to be 39 kWh/m² per year [11], and the design was described by the architect as “an ordinary terraced house achieving passive house requirements, FEBY” [9]. The architect described the process for building permits as rigorous, with the detailed list of requirements being checked by the masterplan architects. [12] One year after tenants moved in, Stångåstaden claimed it was a misunderstanding that these houses had been built with passive designs. [13] Previous studies of the planning process for buildings in Vallastaden show how different software programs had considerable influence over how the calculations for passive houses in Vallastaden were produced. [14] When different energy consultants were hired at different phases of the planning process and they used different software, the calculated energy performance differed, creating insecurity within the group of consultants, developers and architects. The more advanced software indicated that improvements to the insulation of the external walls, roofs and windows were needed, which compromised the design aesthetics. Another compromise discussed at these meetings involved lowering the figures for air flow, which would result in the calculations “passing” the building permit process but being “unrealistic” according to the ventilation consultant. The architects experimented with the shape of the buildings, partly in order to cut construction costs for the developer, and partly to make the energy calculations fit the passive house requirements: “… it is the world’s most simple house, kind of, well the façade is fibre concrete panels which do not cost a lot […]. But the simplicity makes… since we choose not to have any projecting oriels and other parts, and so then you will have bad values in the energy calculations, so the idea is a very simple house with a compact shape.” [12] This house met the plus-energy house requirements since the developer added photovoltaics for electricity generation on the roof.

Other architects chose to combine timber frames, wooden façades and interior wood designs with a passive house concept, for example the House of Dolphins by combined architect and developer Studio Witte [9, 15]. The House of Dolphins is one of five projects in Vallastaden by Studio Witte, and this particular project includes references to historic Swedish granary buildings, a multipurpose building for storing food and equipment which was also for sleeping in during the summer. This project was described as an exploration of the possibilities and boundaries of cross laminated timber as the main construction material, and Vallastaden was a place where architects could “play” with this material and learn new lessons for future projects. Architect Witte stated that “Vallastaden provided no usual standard measurements to take into consideration, it was just a volume to fill” [15]. The masterplan architects Okidoki defined Vallastaden as a “full-scale laboratory” [1] and, together with an association for wooden buildings, defined the quality criterion “modern wood construction” and developed a timber construction standard for Swedish wooden buildings. The quality criterion “passive house standard” is not mentioned as something that would require similar treatment.

Access to daylight in the densely built neighbourhood was expressed as a matter of concern by various parties [1, 17]. Some assessed the access to sunlight from the individual housing units, while others focused on outdoor spaces in courtyards and between the buildings. One conclusion was that Vallastaden was planned for indoor living, regardless of whether this was in residents’ own homes or in the semi-public buildings in courtyards or on rooftops. Outdoor courtyard spaces were not prioritised in the planning and design [17] – the outdoor spaces were merely transition zones for moving between the buildings. When access to sunlight was subject to Swedish public debate in 2017-2019, the positioning of balconies on some buildings in Vallastaden was cited as an example of bad design. [18] The Swedish National Board of Housing, Building and Planning included Vallastaden in a general assessment of
daylight in new neighbourhoods, and a consultancy assessment by the architectural firm BAU (Byrå för arkitektur och urbanism) concluded that, in comparison to other new neighbourhoods, Vallastaden was relatively acceptable. [19]

One analysis of the variety of designs, heights, shapes of buildings and materials and colours of façades is that this is a superficial variation [20]. Another impression of a varied neighbourhood comes from the small allotments and plots of land for each developer and architect, instead of larger chunks of land to build on. Structural variation has been claimed to be the key to the overarching impression of Vallastaden as varied [1]. Design critics question the city district masterplan in answer to calls for better urban environments. There must be an overall idea for the entire urban area instead of new individual projects “[…] pretending to act in a vacuum for experiments with passive houses, co-construction and public health” [21].

The passive houses in Vallastaden have various construction techniques, designs and ownership, being a “community building venture” (byggemenskap in Swedish) organised by Sami Terbunja in four terraced houses called Villa Saranda by architect Mohammad Al Zoghbi. The inspiration for the designs comes from traditional homes in Lebanon and Albania, and Antoni Gaudi’s Catalan modernism [22, 23]. These concrete houses, with their pastel coloured plaster on the exterior walls, were designed by the developer with reference to the sustainability of housing in locations where there is a potential risk of war, and to the failure to create energy efficient buildings in Sweden during the 1970s and 1980s [23]. The reinforced concrete structures and well-insulated external walls should ensure robust houses, economical operation and, according to Terbunja, a potential to “[…] use all possibilities to recycle, for example heating from humans who move around in the house, or from the oven, cooker or light bulbs.” [23]. The position of Villa Saranda, on the northern shore of the river and with open space to the south, exposes the houses to sunlight throughout the year, and the extensive glazing on the southern sides of the building brings risks of overheating during certain seasons.

Only a few of buildings with passive house designs in Vallastaden have been assessed according to any of the available certifications or standards for passive houses. In Sweden, there are associations and private firms that provide tools and criteria for certifying passive houses. These organisations compete and collaborate in the interests of passive houses in Sweden, and include the Swedish Green Building Council (SGBC), the Forum for Energy Efficient Construction (FEBY), the Interest Group for Passive Houses (IGPH) and Lågan, a programme for energy efficient buildings. Lågan compiles information from different certification bodies and compares figures for the 21 Swedish regions. [24] Östergötland, the region in which Vallastaden is located, is in the bottom five when including both residential and commercial buildings and in relation to the number of citizens in the region. The top three regions in Sweden are Värmeland, Västerbotten and Stockholm. The buildings that have qualified for certification are HSB terraced houses (Energisparhus, IGPH), Stångåstaden plusenergy houses (Lågan database, plusenergy house), Stångåstaden terraced houses (Lågan database, passive houses) and Vallastaden School (Miljöbyggnad, SGBC Silver).

4.3. Early user phases

Residents to move into the Vallastaden homes from summer 2017. A passive house design, with its thick walls and insulation, large windows facing sunny directions and reliable ventilation and energy systems, promises stable indoor temperatures and a comfortable climate. Even though none of the interviewed householders knew what a passive house is, or that they were living in one, they all recognised their houses as passive houses when they were informed about the concept. The respondents enjoy the innovative thinking associated with Vallastaden as a whole, where there is a great focus on community, diversity, variety and development. They enjoy the social and aesthetic atmosphere of the neighbourhood, and share their thoughts about the future in a way which suggests that they intend to stay in Vallastaden, but perhaps in a different apartment or another part of the neighbourhood.

The householders have a generally positive attitude towards their homes. At the same time, they are clear that several entities which had a certain purpose in the design and/or building phases have not been enacted as expected, thereby disturbing the assemblage of the homes. The householders gave several
examples of solutions to improve the assemblage, which our theoretical approach refers to as tinkering. We will give two clear examples of disordered assemblages. The first is when the idea of solar-heated apartments reaches a tipping point and becomes a problem rather than a solution. The second example is when a householder does not fit into the pre-decided norm for the apartment, or when the norm of a home does not live up to expectations. Both examples provide multiple examples of tinkering, some of which will be presented here.

4.4. Tinkering with large windows

Windows are a common theme when it comes to indoor temperature. The windows are a two-edged sword, with some describing the pleasures of natural light, an impression of a larger, airier home, and views that change with the seasons. Others talk about the problem of neighbours and passers-by seeing in, and about how extreme outdoor temperatures – which are experienced in Sweden, just as in the rest of Europe – lead to a tipping point whereby the passive house is unable to maintain a comfortable indoor climate, which householders have to achieve in other ways. All the householders have tried covering their windows to limit the sunlight. Some have managed to bring their apartments down to temperature that is not normal, but is at least better than with direct sunlight. For those who have not managed to cover their windows properly, the ceiling height and the large windows have been the main problem since there is no safe way to install curtain rails. One householder explained: ‘Speaking of being too hot. That is really the only problem over the year when we say, like: ‘What are we supposed to do?’ Maybe it would help if we covered the windows with something... We haven’t tried it yet, because getting something up is a bit of a project... We tried a blanket... We tried to hook it to the window, but I don’t remember if it helped...’ At the same time, all the respondents saw covering the windows as a necessary but unfortunate action, since the positive aspects mentioned earlier disappear. One alternative to covering the windows would have been to open them. Unfortunately, due to the narrow construction of Vallastaden, some of the houses are so close to each other that fire ladders have not been installed. To occupants from trying to escape through the windows in the event of a fire, the handles have been removed and the windows cannot be opened. In some apartments, the only way to ventilate them is to open the balcony door, which is unusually large. This not pleasant, according to respondents living on the first floor. They say that it feels a little unsafe, and that it removes the feeling of privacy in their home. However, it is the only way to cool the apartment if they are unable or unwilling to cover the windows.

4.5. Norms – enhancements of assemblages or endless tinkering?

In the planning and construction phase of Vallastaden, innovative thinking has been a reoccurring theme. As mentioned before, this can be seen in examples such as the infra culvert, the selion-based planning, and the multiplicity of house exteriors and interiors. The interiors feature smart technology to reduce energy use and change energy use behaviour. This means that a certain norm of use is expected from the designer as well as from the builder. When users do not live up to these norms, the entities do not work or are not used as expected. There are multiple examples of tinkering, and a few are presented here.

The first norm-breaking, and therefore assemblage-disturbing, behaviour is users working irregular hours. Some smart electric entities are designed for typical, normative working hours, meaning that users spend a certain time pattern at home. When residents work irregular hours, there is often no pattern, or at least not the same pattern. In some apartments, underfloor heating is installed in the bathroom, and is connected to a device that can be used to set the time for the floor to be heated. This is a convenient solution if residents visit the bathroom in a regular pattern. However, the device cannot be set to different hours on different days following a schedule. The only way is to re-adjust the time the day before. This is a time-consuming form of tinkering, and instead householders have set the heating to come on for several consecutive hours in the morning and the evening, increasing the chance of a warm floor when visiting the bathroom. One respondent says that sometimes it is warm and sometimes it is not, and she feels like this kind of device is not optimised for her household routines.
Some households do have devices which can be used flexibly. One example is the ventilation, which can be adjusted according to whether a single person is or several people are at home. This kind of device is not a problem when it comes to irregular patterns.

The previous section discussed norms expected from humans, while this section touches upon expected norms in terms of the home. Here, experiences of an unstable energy system and physical planning which did not live up to floor planning expectations are exemplified. The indoor climate is experienced as being stable overall, as long as it is not too hot or too cold outside, as described previously. However, the outside temperature is not the only causal factor. One householder explained that he did not have any kind of access to control the ventilation system. Some nights, he had woken up to a temperature of 13°C caused by an intense cold airflow from the ventilation. Since he did not have access to the ventilation controls, his solution was to cover the outlet with blankets. When the temperature in the apartment went in the opposite direction, due to hot airflow, he had to sleep with an open balcony door. In contrast to weather conditions, where extreme weather can be predicted (or is at least linked with the seasons), householders who experience this kind of problem cannot plan in advance. They can never tell if they will experience a comfortable, cold or hot night.

Some entities are experienced as being poorly planned, installed and finished due to time limitations in the construction phase. One example is a badly planned and built bathroom, where a glass wall was attached with too little sealant, therefore coming loose and crashing to the floor. Another example is a luxurious kitchen plan which did not match the final outcome. The householders have also spoken about similar problems which they do not see as the result of time limitations, but of new, bold and creative planning which happens to contribute problems, such as the high ceiling, which makes it very hard to install lamps, curtain rails, etc. Also, the architects planned open spaces such as shared balconies, but the householders felt they had a lack of privacy and the balconies were therefore divided up retrospectively.

As seen in the two previous sections, an assemblage can be presented as a home. Homes and assemblages are composed and held together by enactments between humans and non-humans. In this text, tinkering takes place as people enact, re-enact and dismiss enactments with new, smart and innovative residents. The tinkering seems to aim to build, create and maintain a… well, a home!

5. Conclusions
Passive house designs were enacted in the conceptual plan for Vallastaden, where these designs would have a connection to each of the key concepts of Vallastaden: people, green and quality. While some of the other features of Vallastaden have been more developed in the subsequent plans, for example in the masterplan, passive houses are only mentioned as one of the 17 quality criteria in the land sale process. Plus-energy house designs were also included in these criteria.

District heating as the main heating source in buildings is generally a requirement in the entire Linköping area, including in Vallastaden and for the passive houses, which means that the major energy system is never a question. Alternative energy sources for heating are always backgrounded in Linköping. The developer and owner of the district heating system in Vallastaden, Tekniska Verken, often features prominently in various articles about Vallastaden. Passive houses are normally considered to be robust to seasonal changes and sudden changes in weather, which would mean that the external heat source is less important. In this case, residents felt vulnerable in their homes since they could not rely on the building envelope to protect them from the outdoor conditions. Residents felt dependent on the district heating system, which they did not trust due to several failures during the early user phase (2017-2019).

In the empirical material for this paper, the work of architects is enacted and foregrounded, for example as members of the jury to decide on the masterplan and as spokespersons for the different buildings constructed in Vallastaden. Developers, technical consultants and builders were seldom foregrounded in the presentations of Vallastaden’s buildings, even though they play a major part in the construction of buildings – especially passive houses, where craftsmanship and the details of the building processes are even more important than in conventional buildings.
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