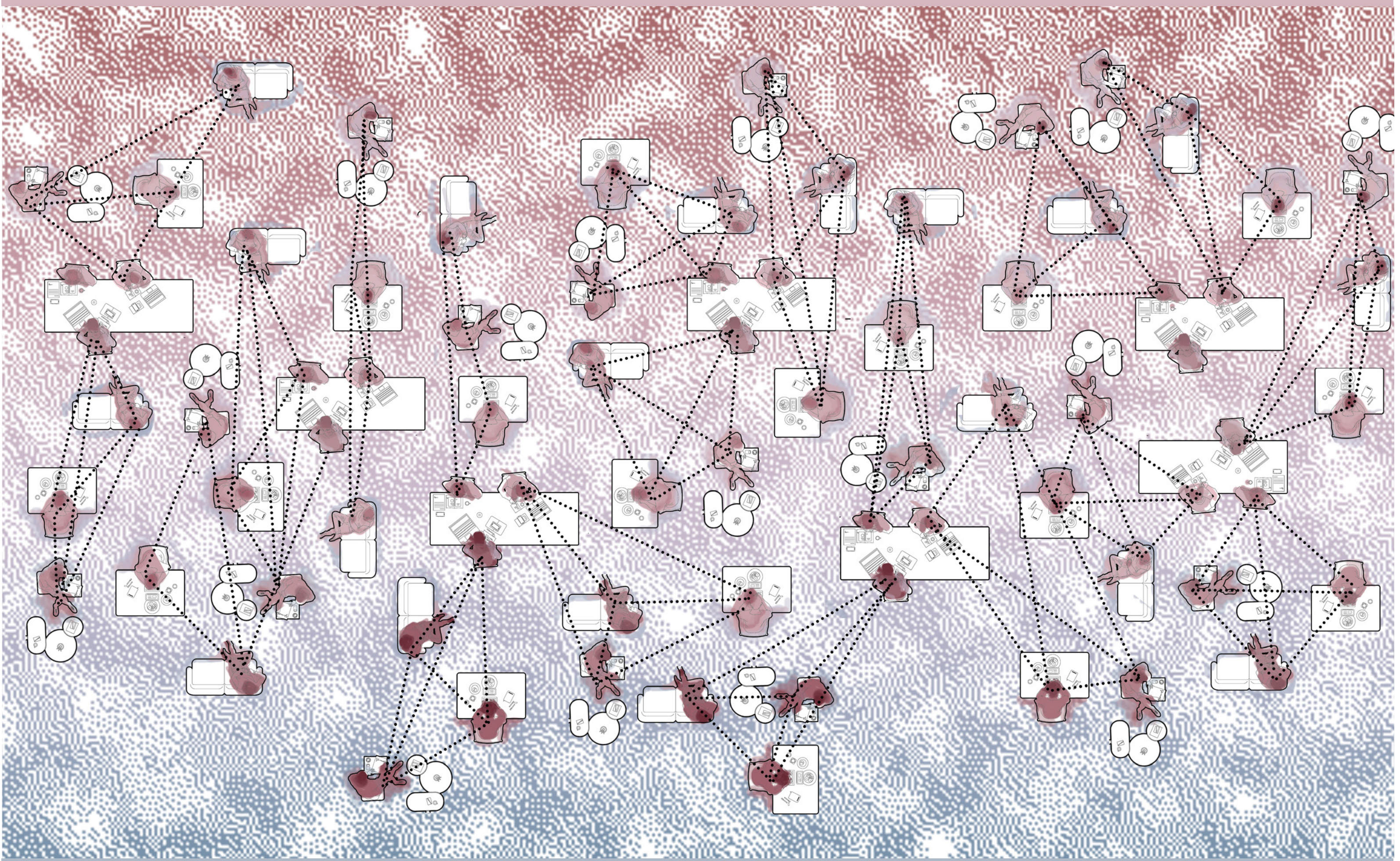
# An office of thermal delight

An open thermodynamic approach to comfort for office retrofit




Sasha Kushnirenko
M.Arch

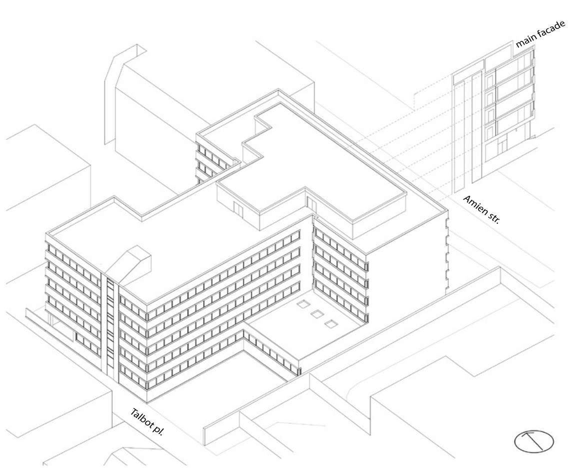

# Reseach Folio

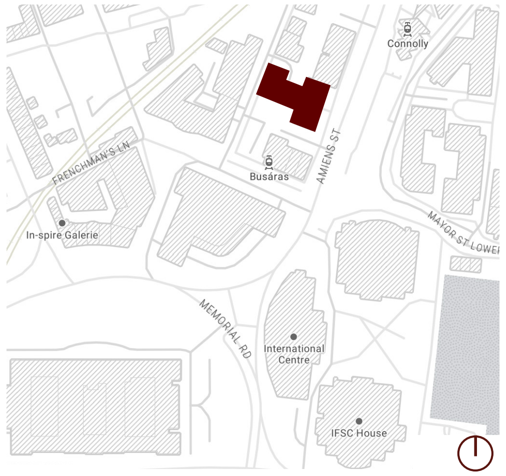
An office for thermal delaight

An open thermodynamic approach to comfort for office retrofit


**Abstract:**

This research project examines the manner in which a 1970s office building can be adapted to engage a sense of what Lisa Heschong describes as 'thermal delight' (Heschong, 1997). By conceiving of the building as an open thermodynamic system, the design proposal re-imagines the internal environment of an office as a set of different thermal milieus by granting heat, as an energetic phenomenon, a greater agency in the composition of space. Through this introduction of thermal heterogeneity into the contemporary workplace, a less deterministic approach to comfort is explored, one which focuses on the diversity of individual experience and makes room for adaptation, 'a process that regularly transforms space and ritually speaks of life' (Knowles, 2012, p43).




Top Left:

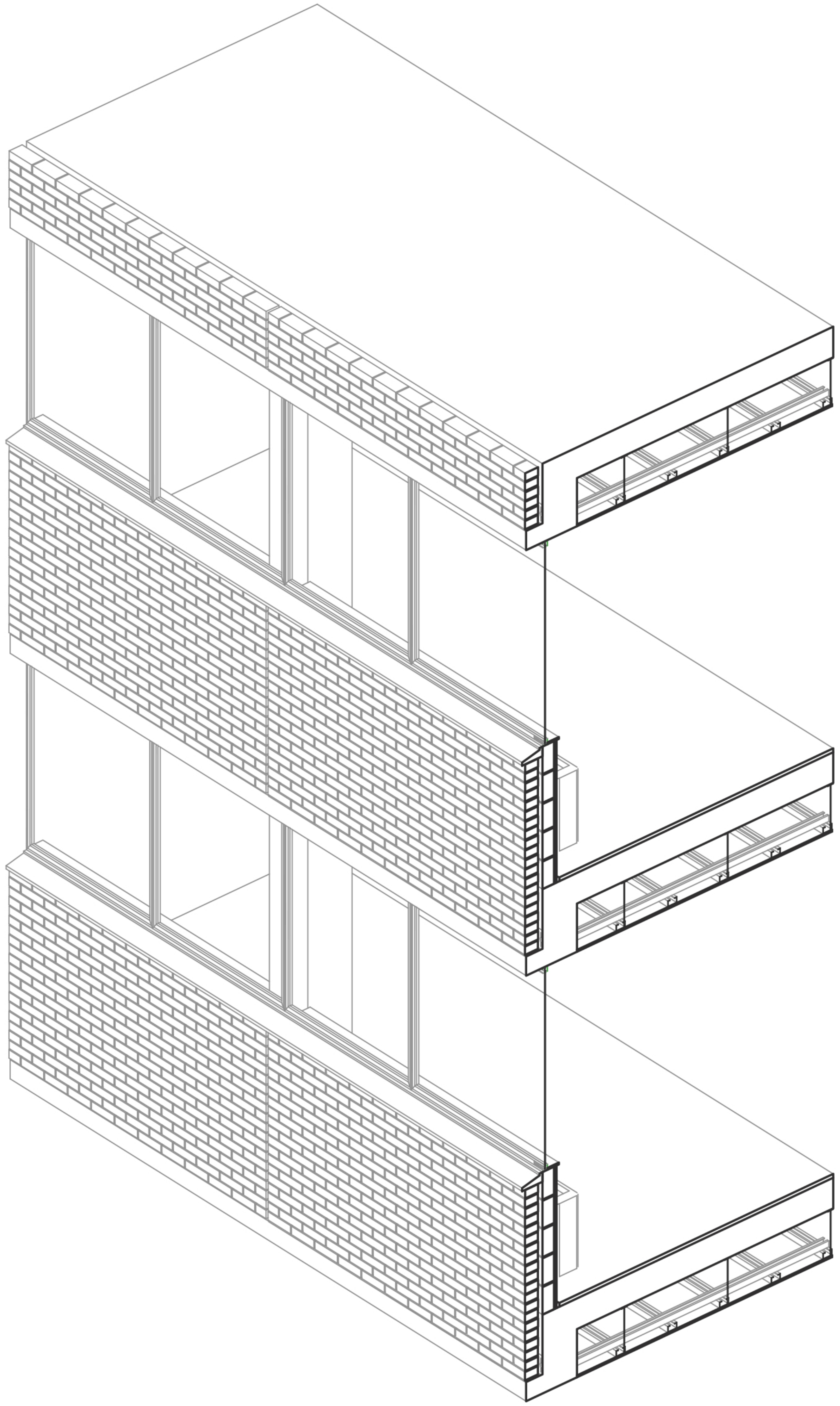
Axonometric of existing building

Top Right:

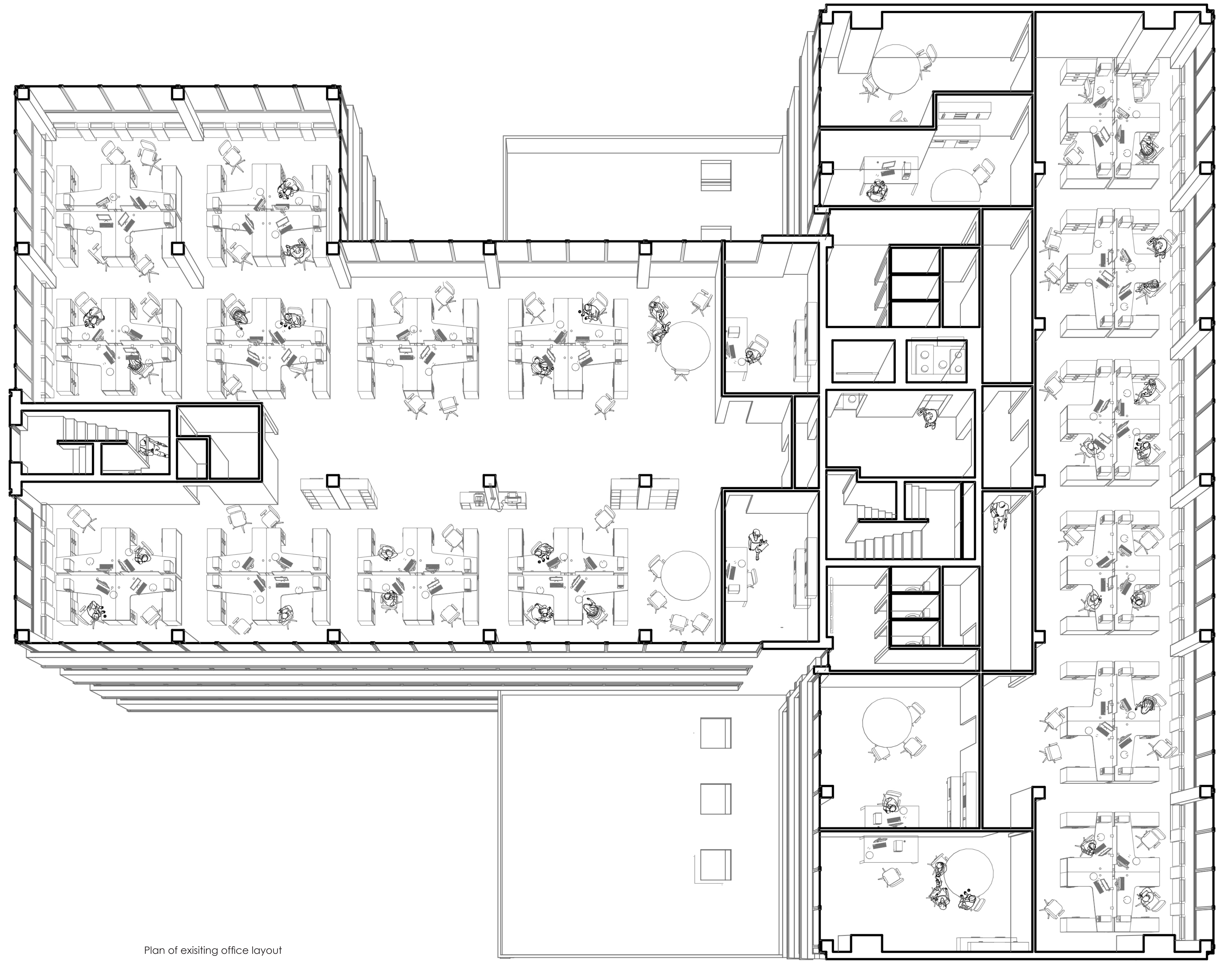
Site Location Map

Bottom:

View of Gandon House from Bus Aras



Existing facade detail axonometric



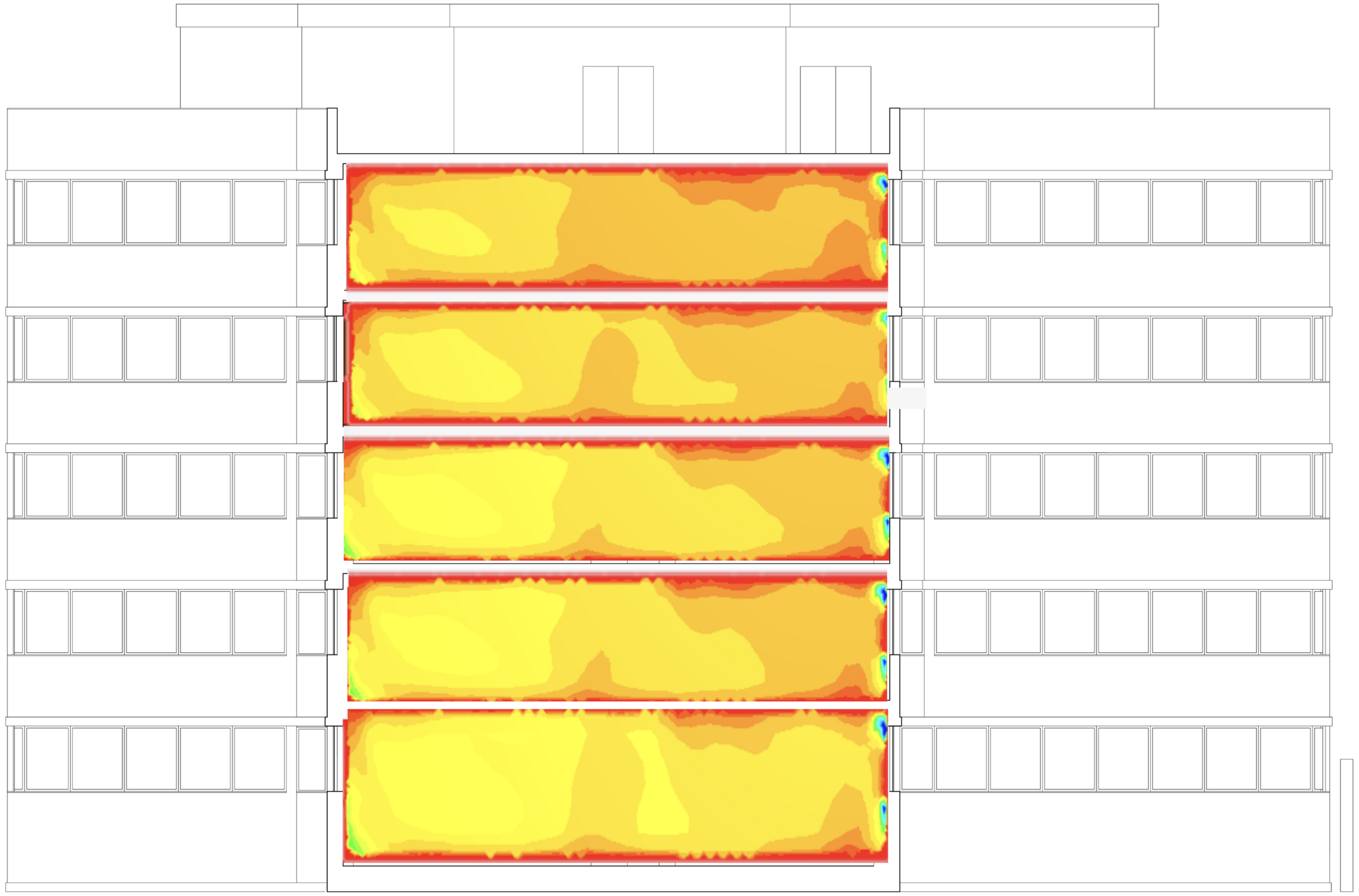
Plan of exisiting office layout

Right :

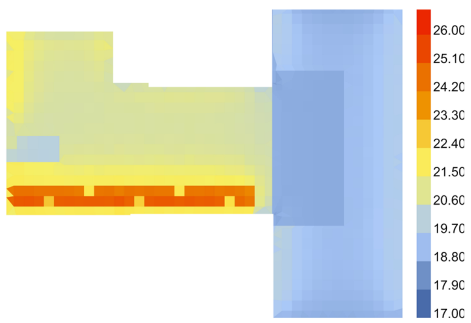
CFD sectional view of heat distribution

Below :

heat distribution maps for various points of the day




Operative Temperature
21 Sep 09:00

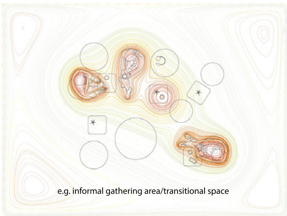



Operative Temperature
21 Sep 11:00

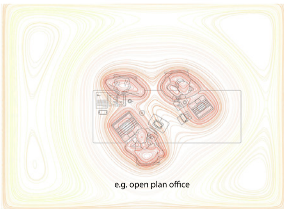

Operative Temperature
21 Sep 13:00


Operative Temperature
21 Sep 15:00

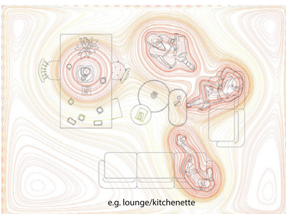

Operative Temperature
21 Sep 17:00



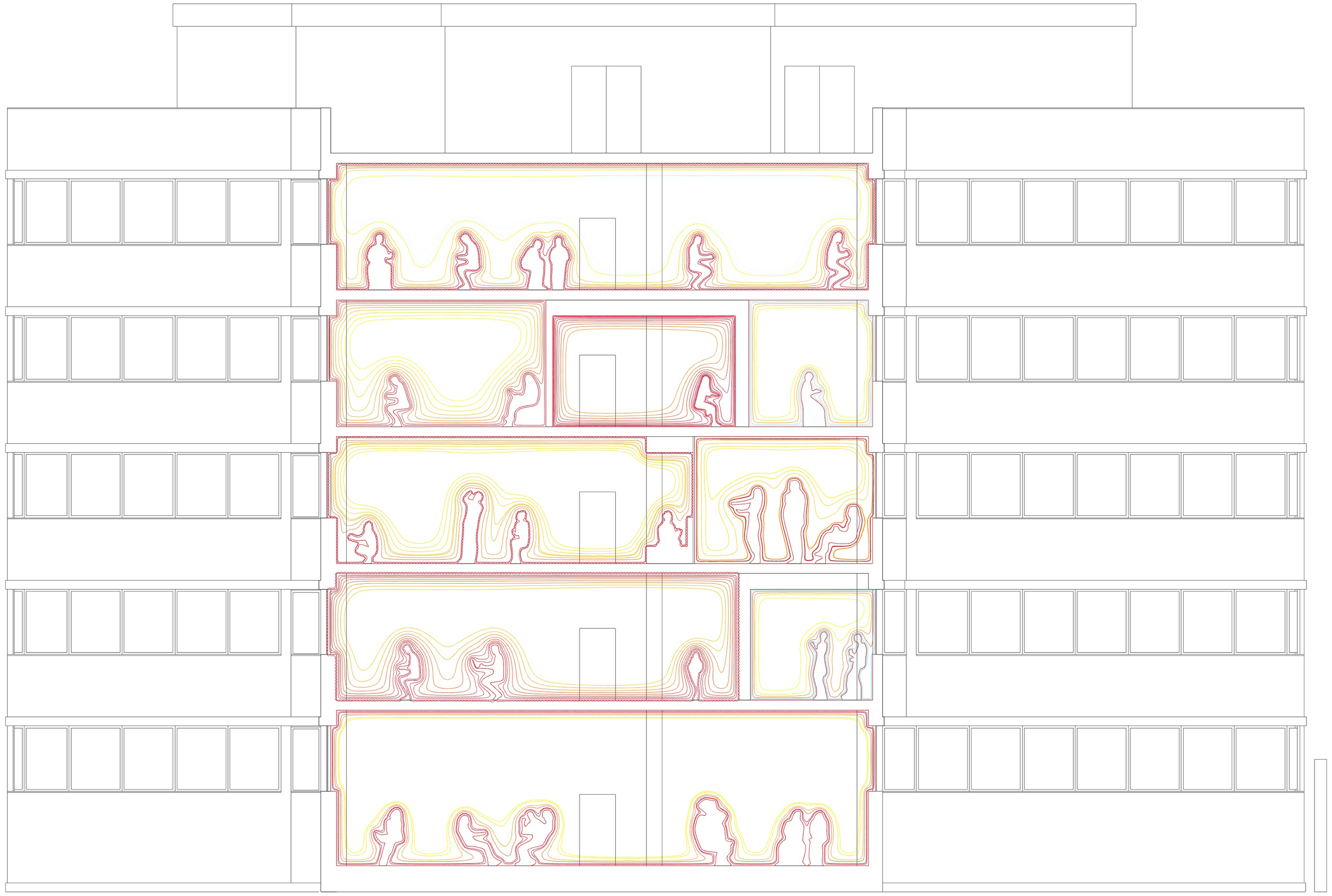

affective zone - collectively controlled

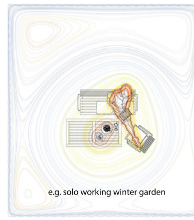



neutral zone - collectively controlled

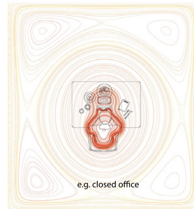



affective zone - collectively controlled

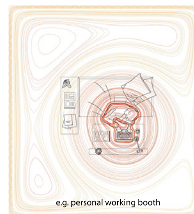





affective zone - individually controlled

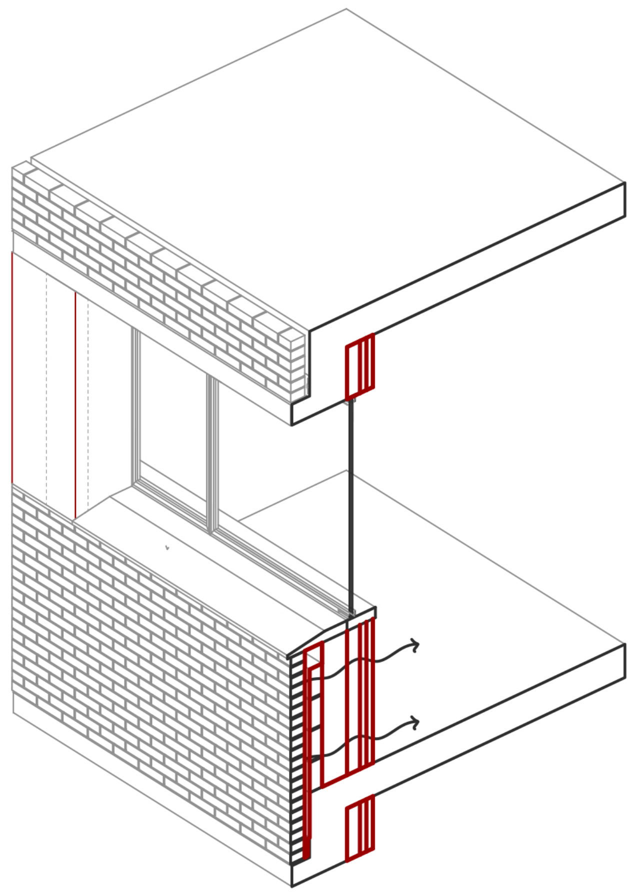


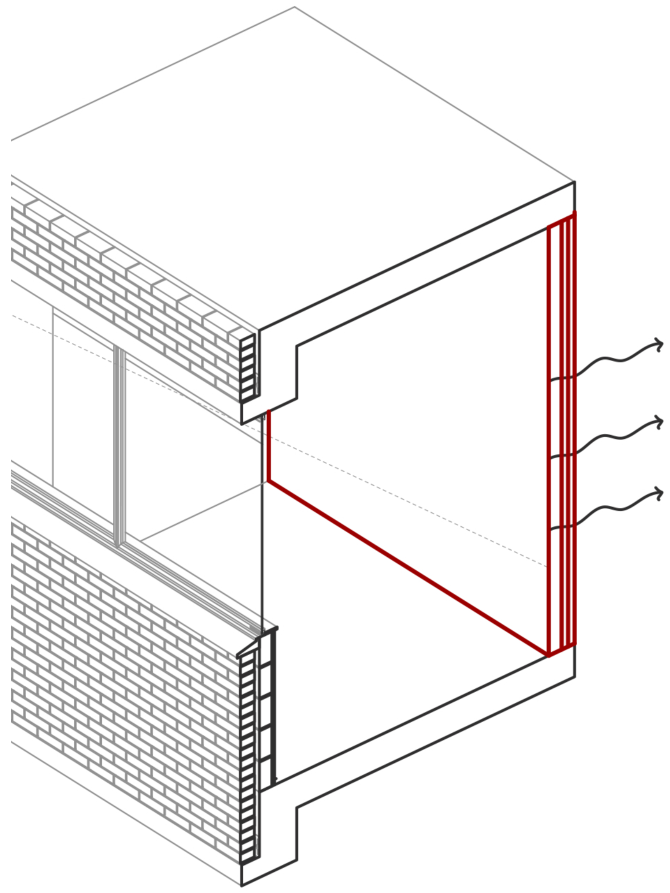

neutral zone - individually controlled




affective zone - individually controlled

Conceptual sketches and spatial arrangments for different thermal zones





Explored alterations to facade:

Top Left:

addition of mass behind existing fabric

Top Right:

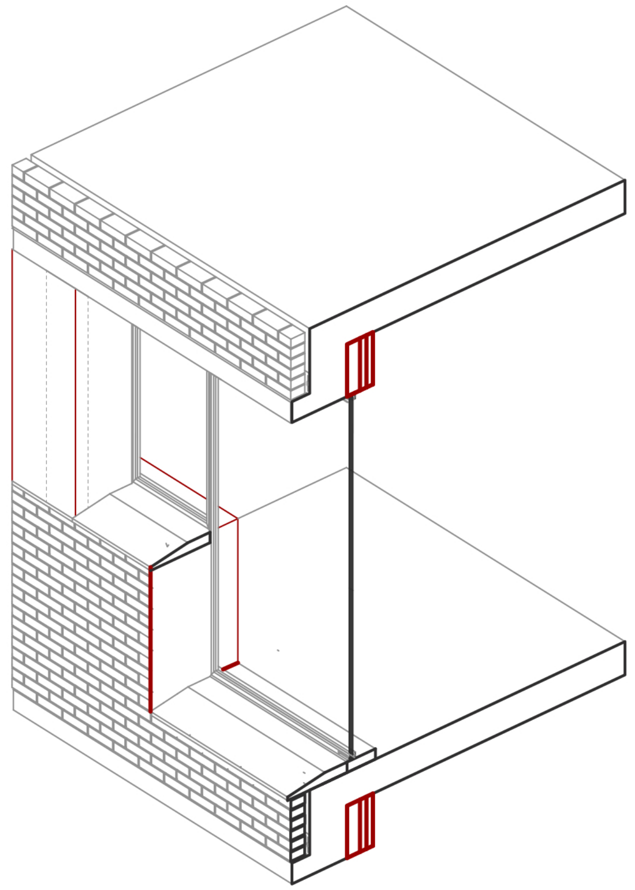
addition of mass away from facade for sunspace

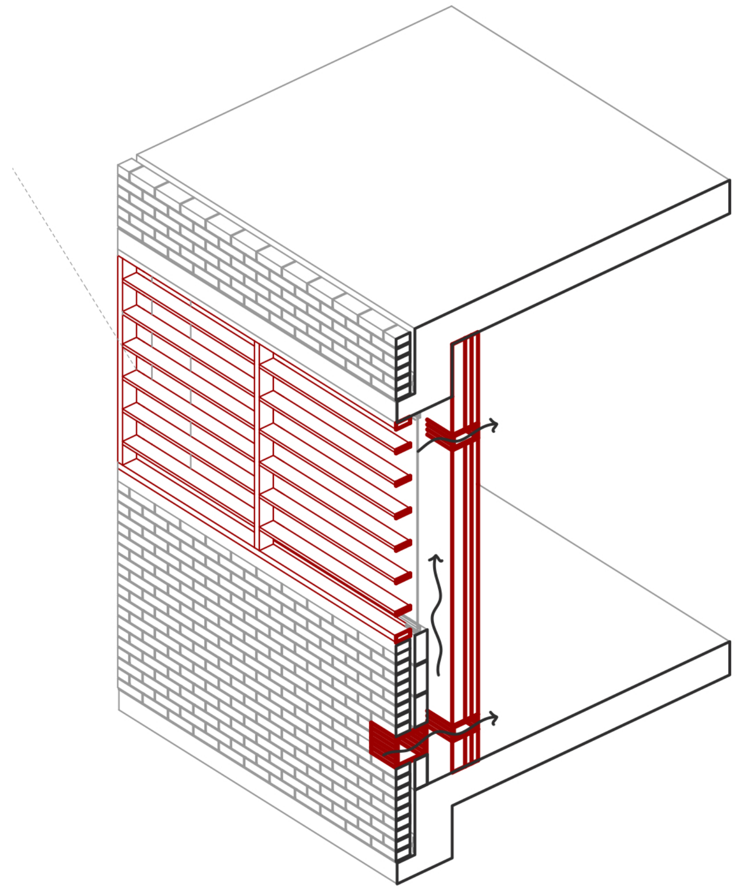
Bottom Left:

Varying window opes

Bottom Right:

Trombe wall



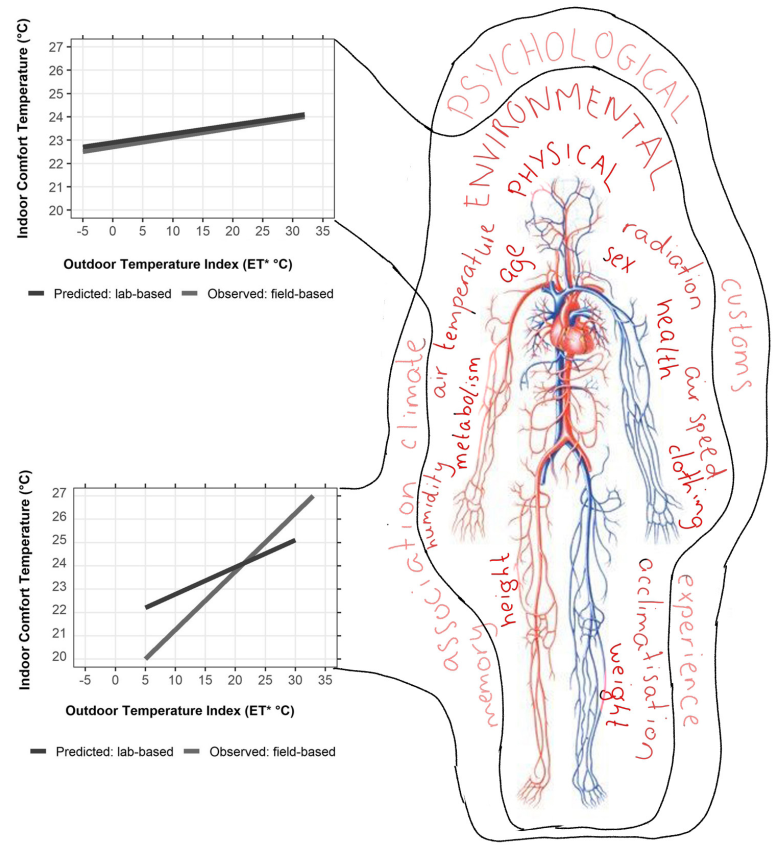


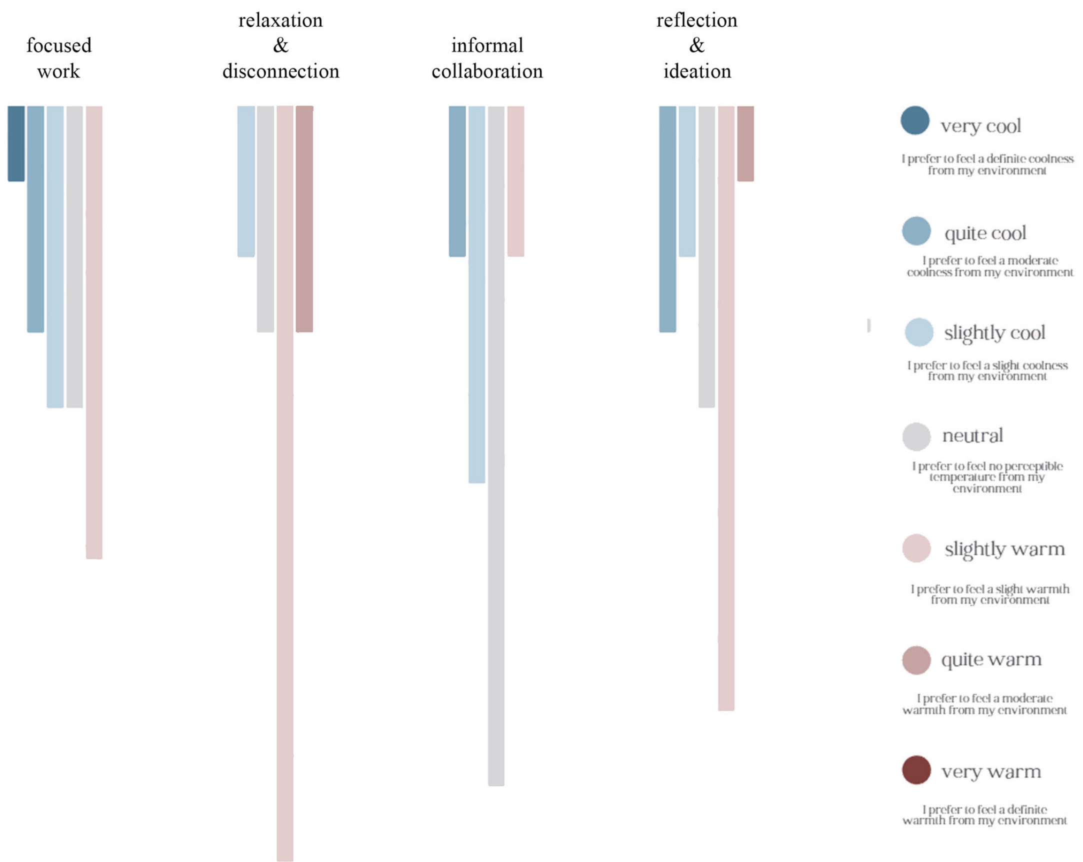
Above:

sketches of inglenooks:

Right:

research of infuences on thermal comfort



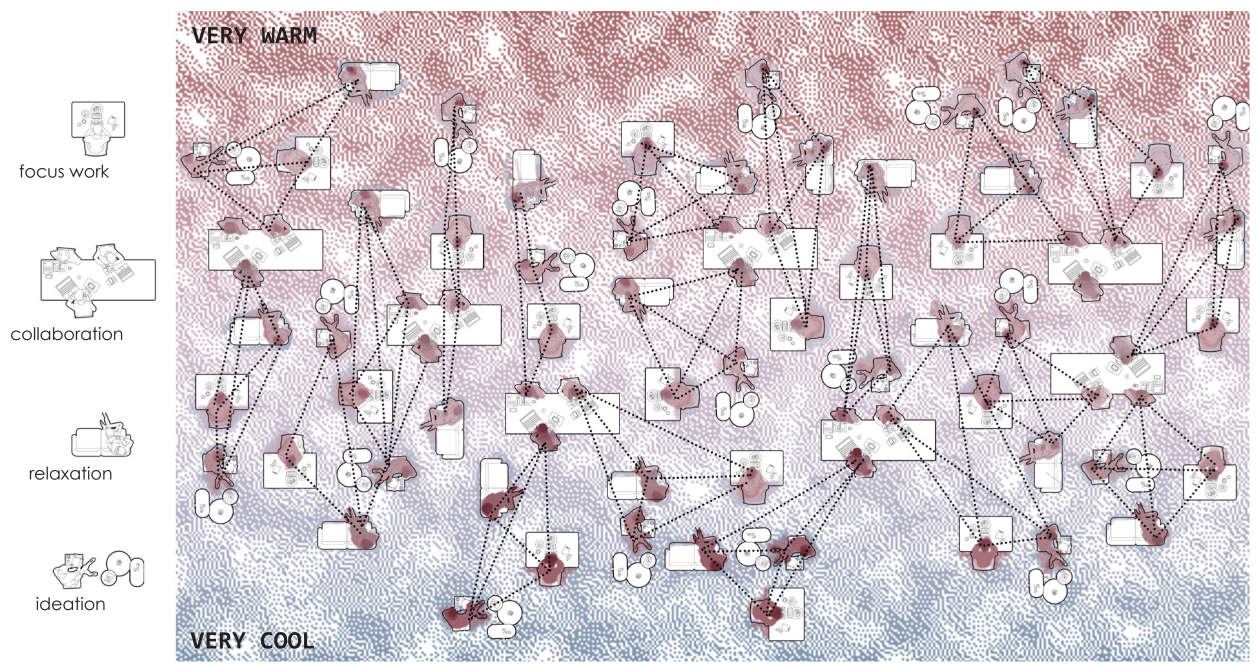



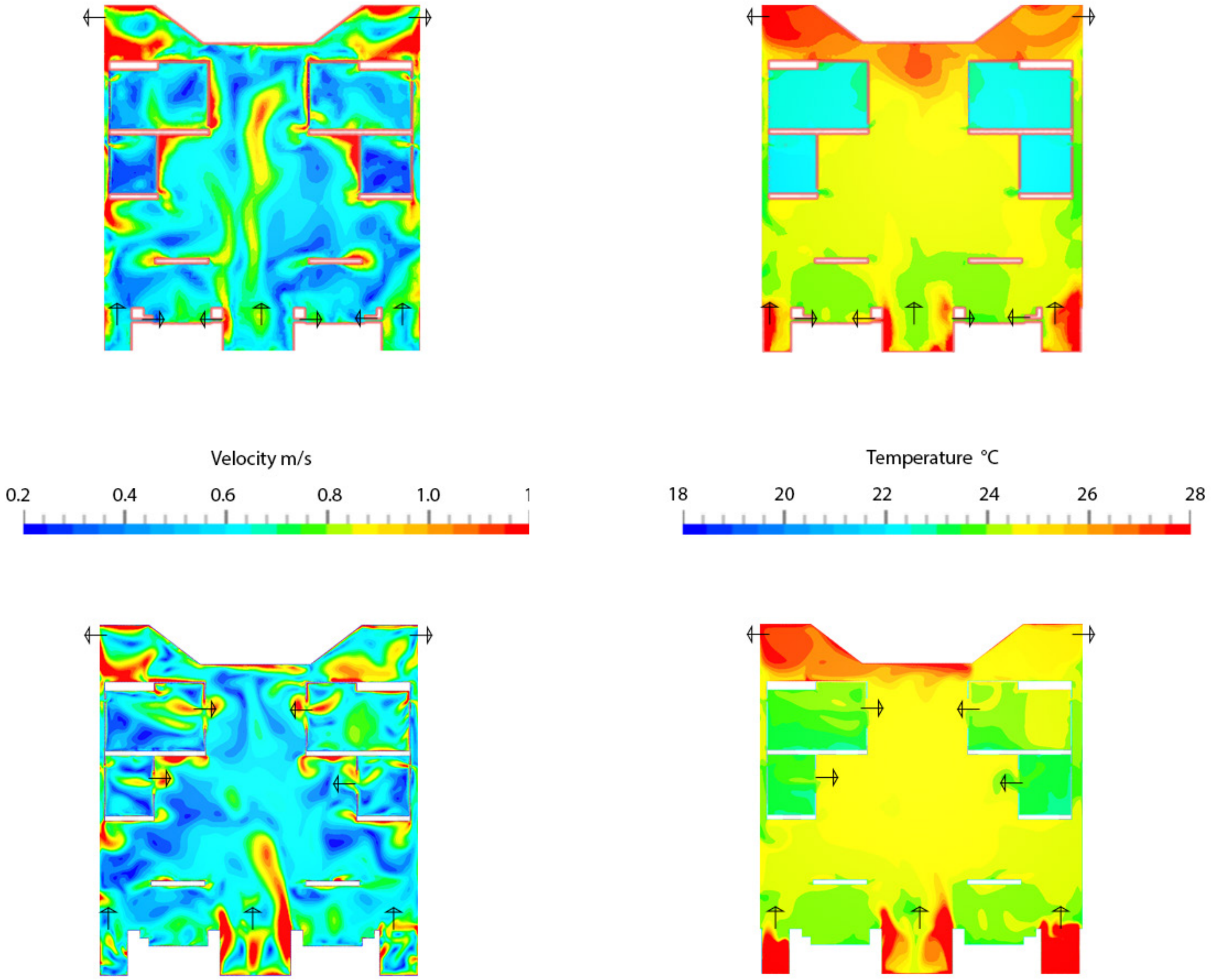

Above :

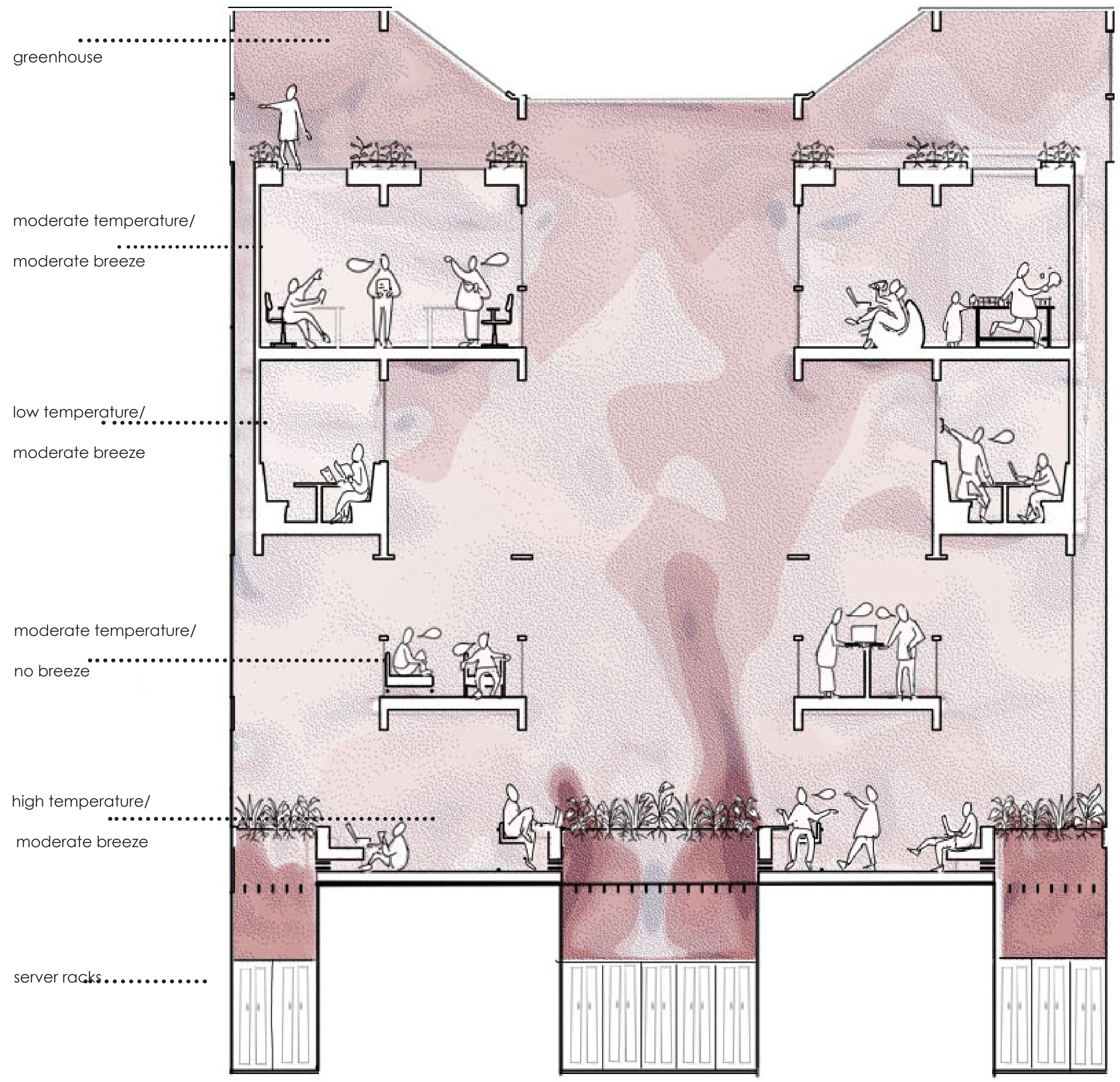
Left: Thermal Perception survey results

Below :

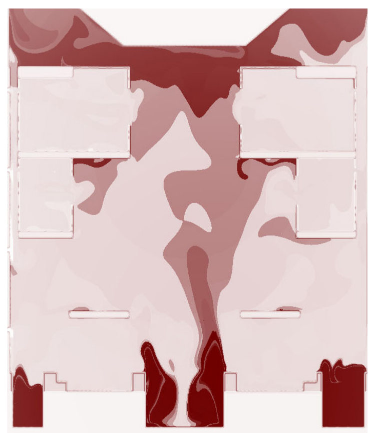
Graphic of respondents' presferences mapped






CFD analysis all windows open vents closed



CFD analysis all windows open vents closed

Above (left column):

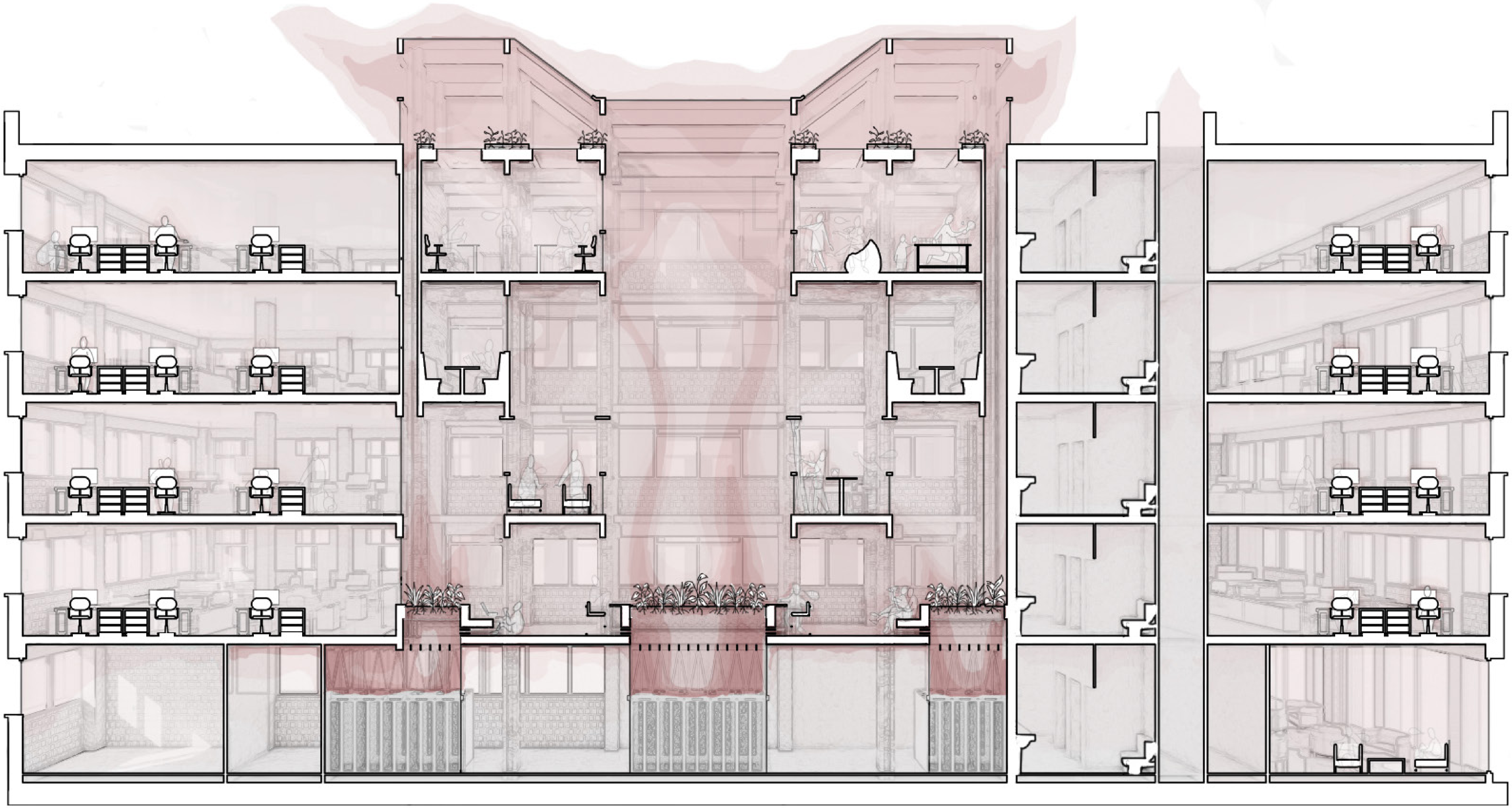
Airflow patterins in attrium with different opening configurations

Above (right column):

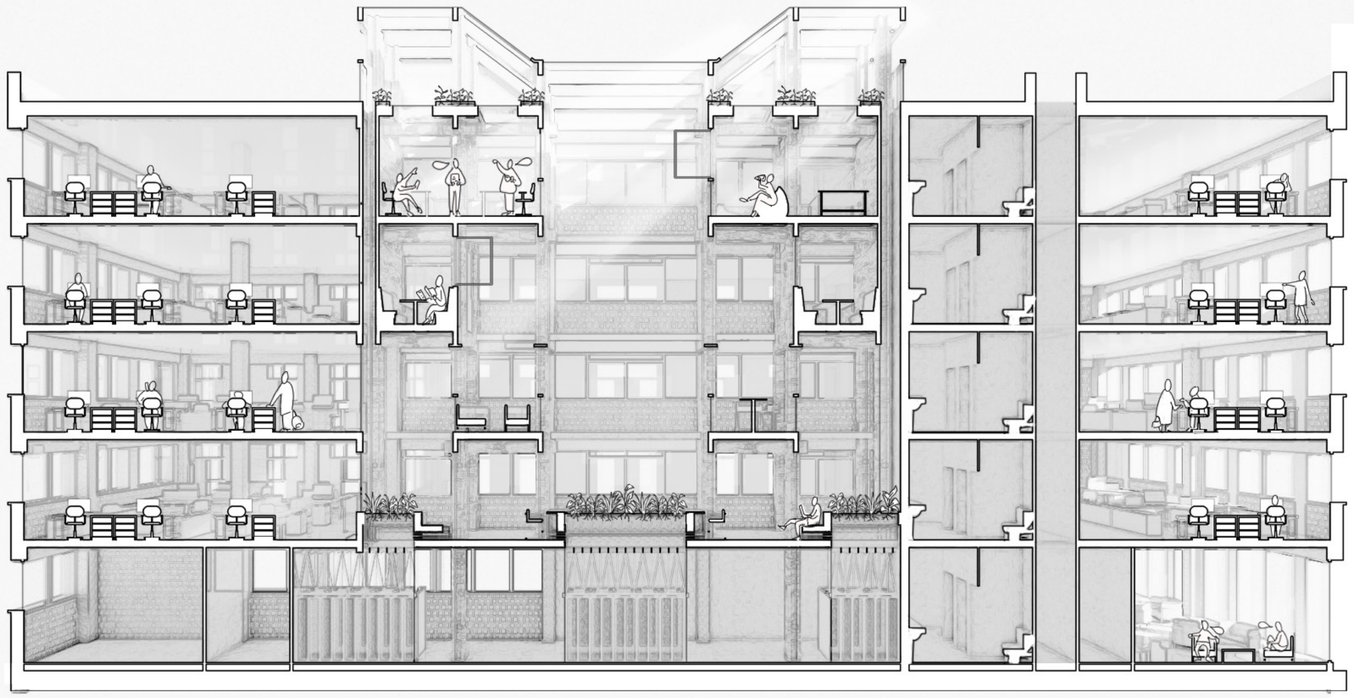
Airflow patterins in attrium with different opening configurations

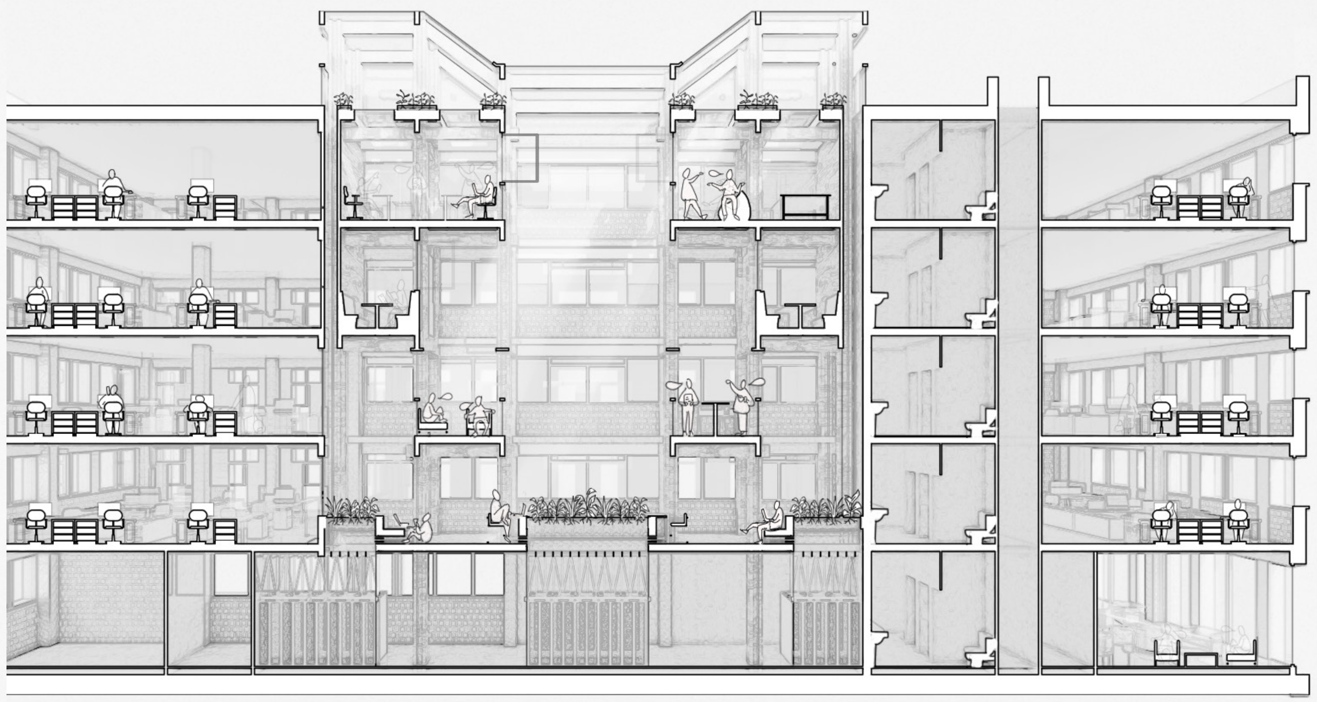
Right:

Layering of heat, air and acitivity in atrium



Above: Inhabted section: translating CFD analysis into design



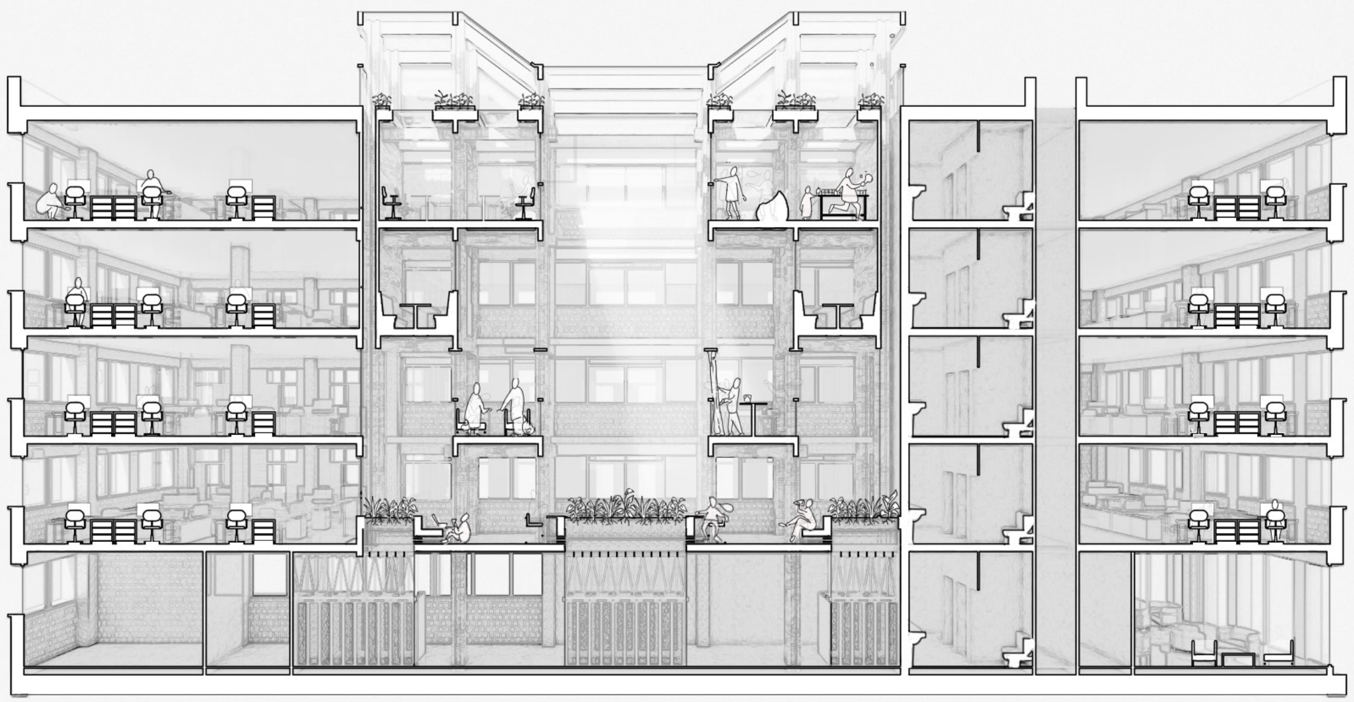


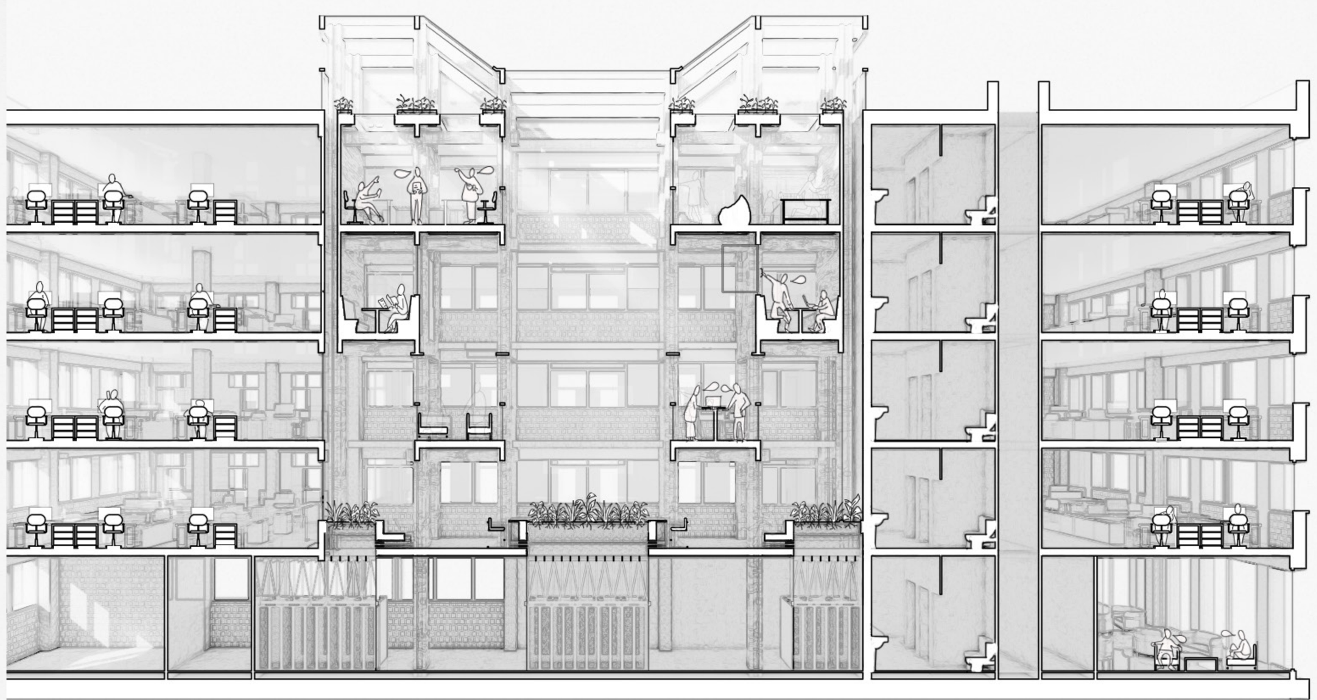
Above: Light study in atrium 9 am - equinox

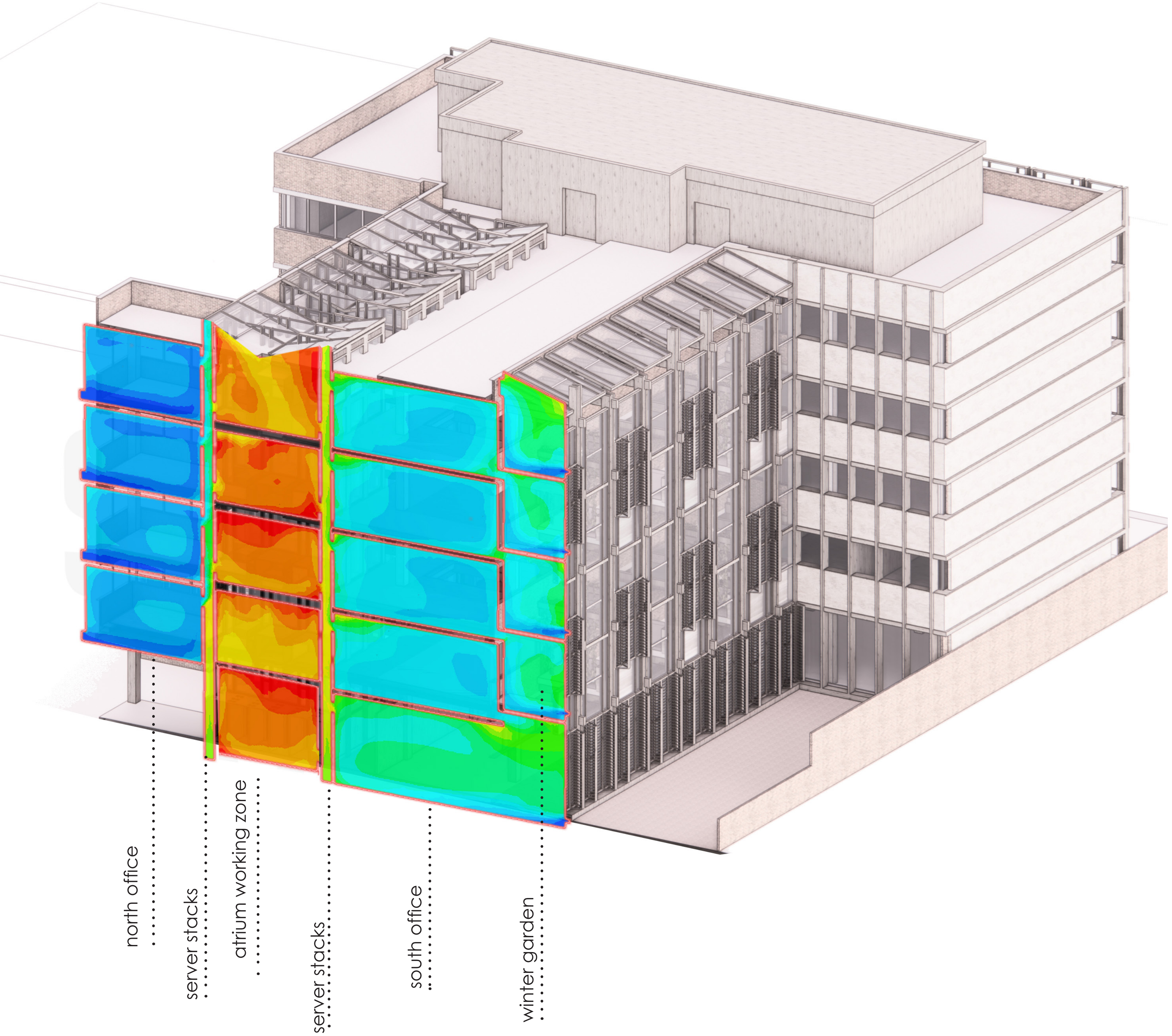
Below: Light study in atrium 1 pm - equinox

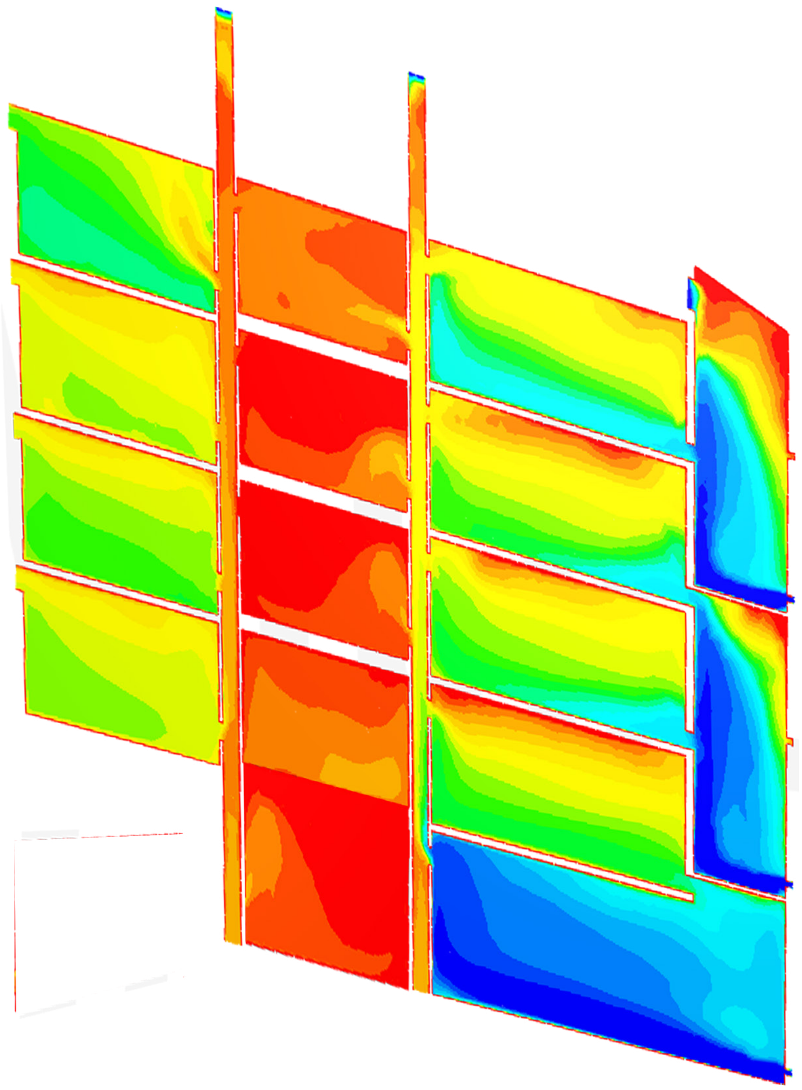
Above: Light study in atrium 11 am - equinox

Below: Light study in atrium 3 pm - equinox





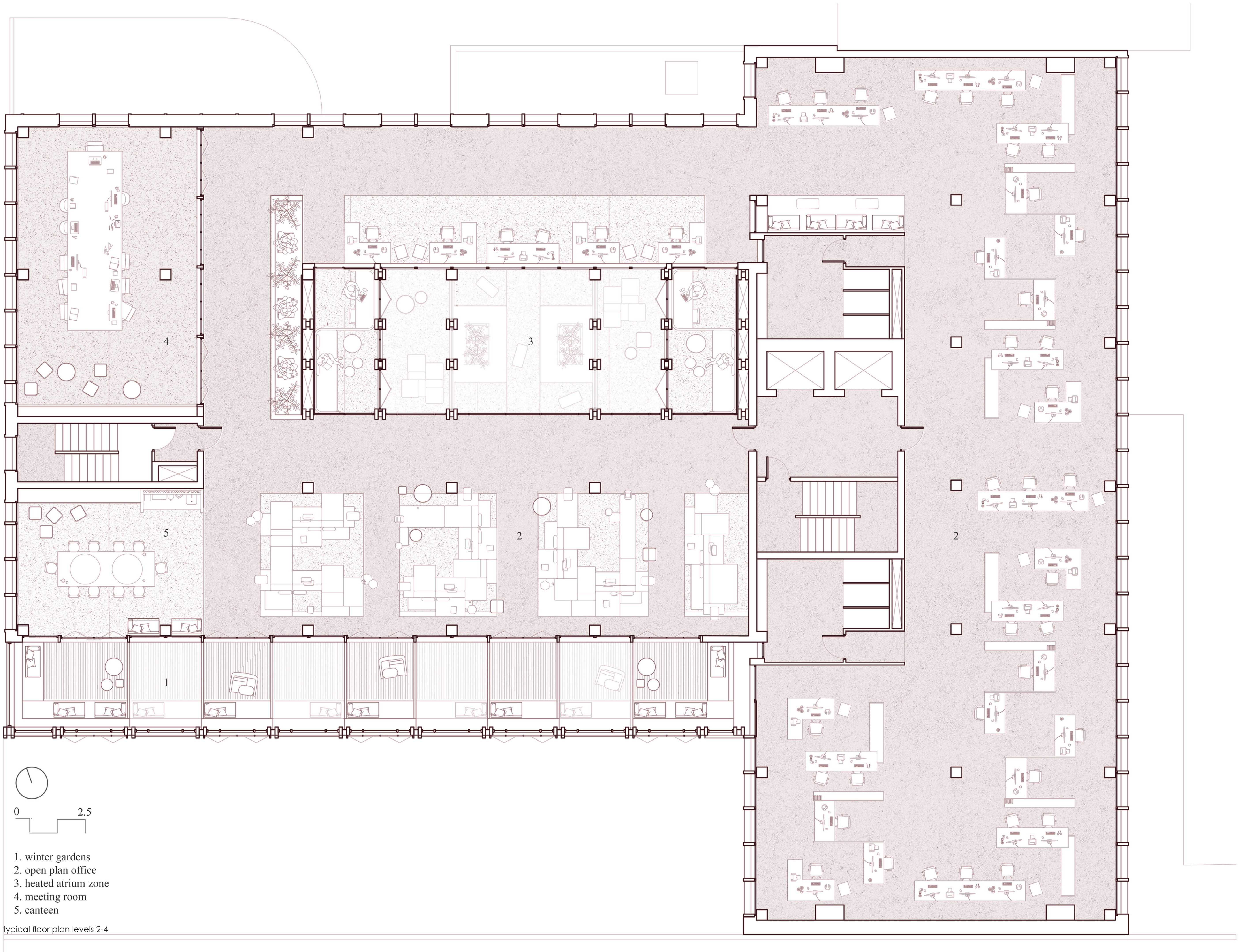


Proposed thermal layering, CFD results overaid on model

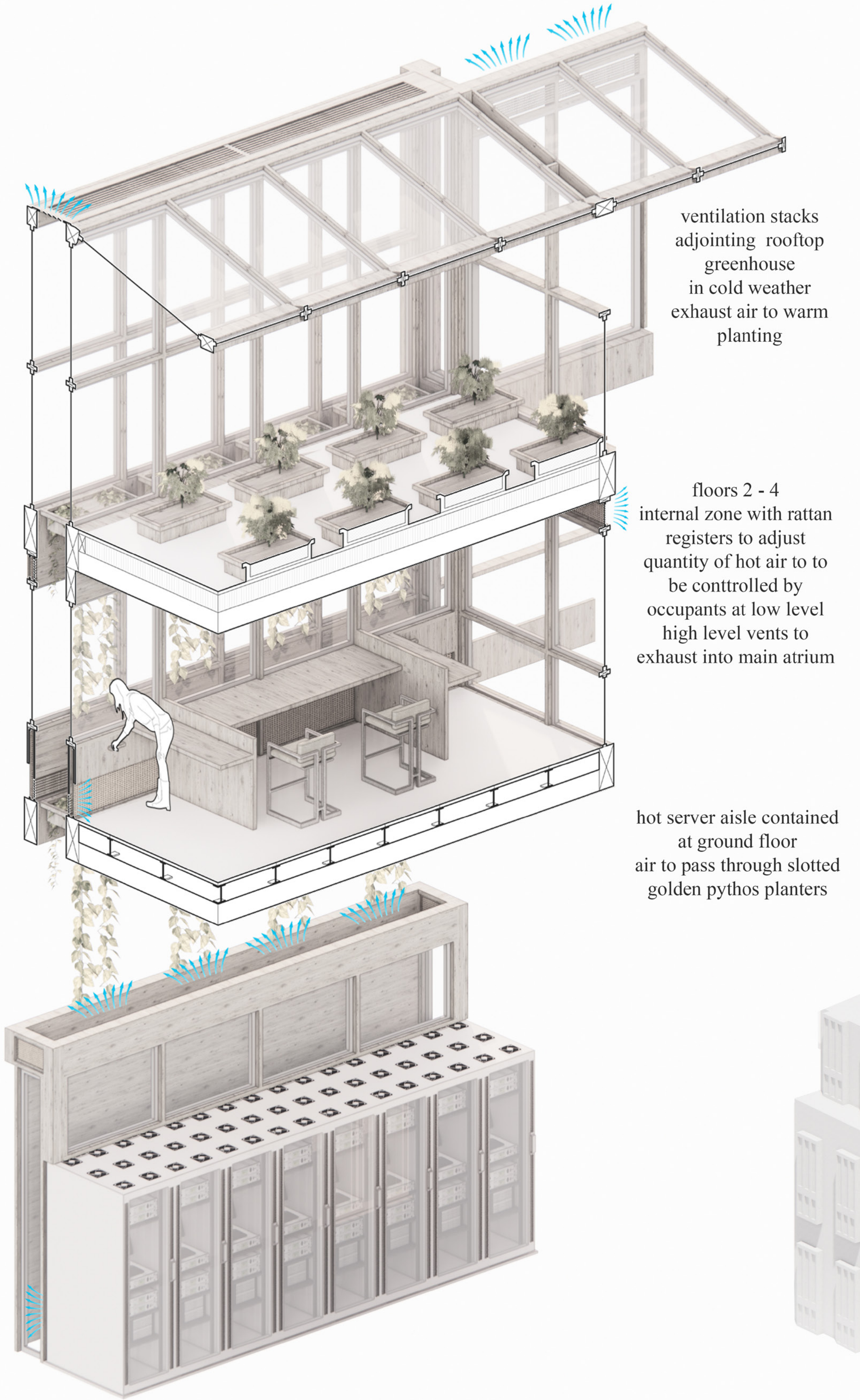
Above: version with double height winter gardens

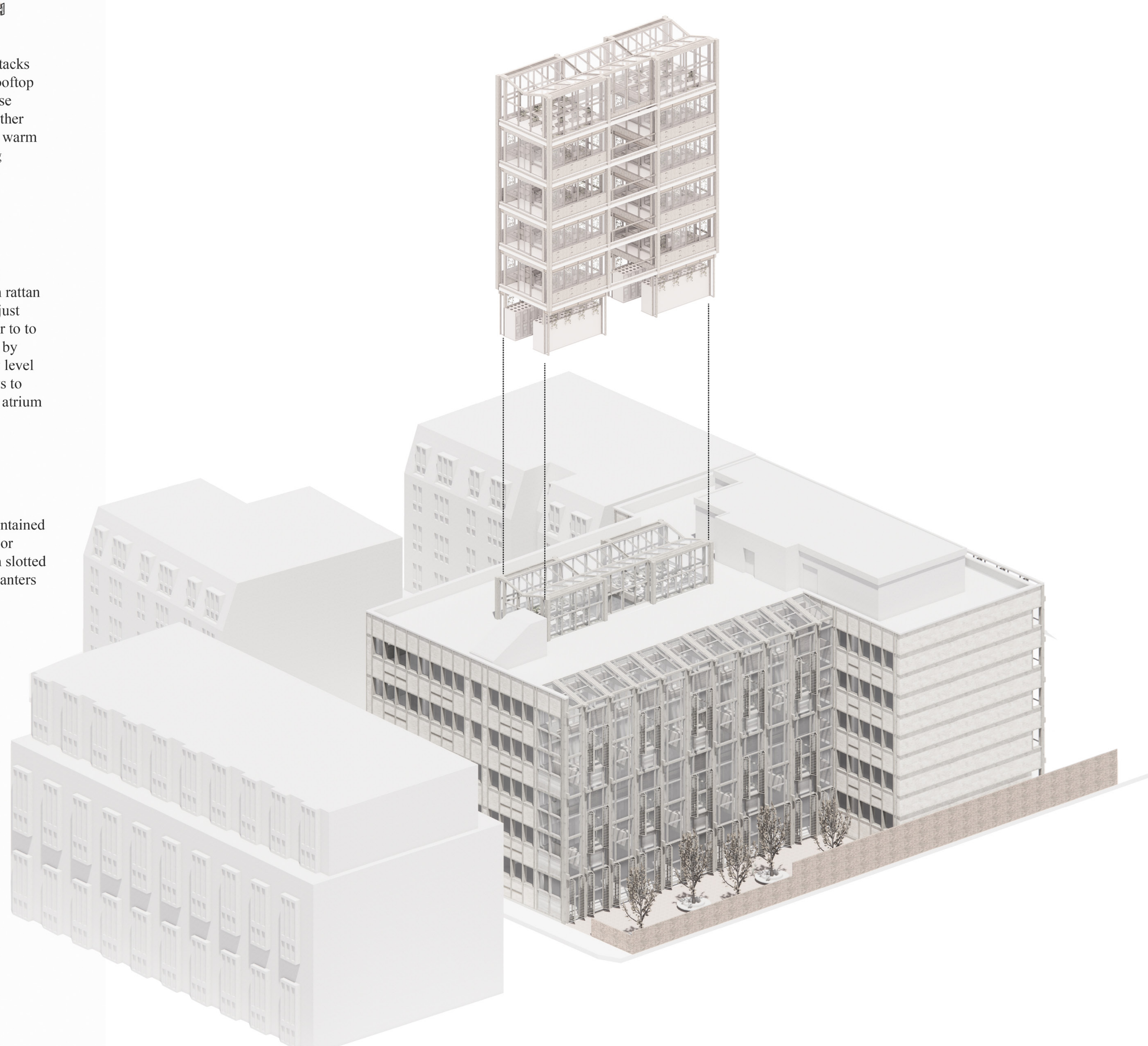
Left: version with single height winter gardes



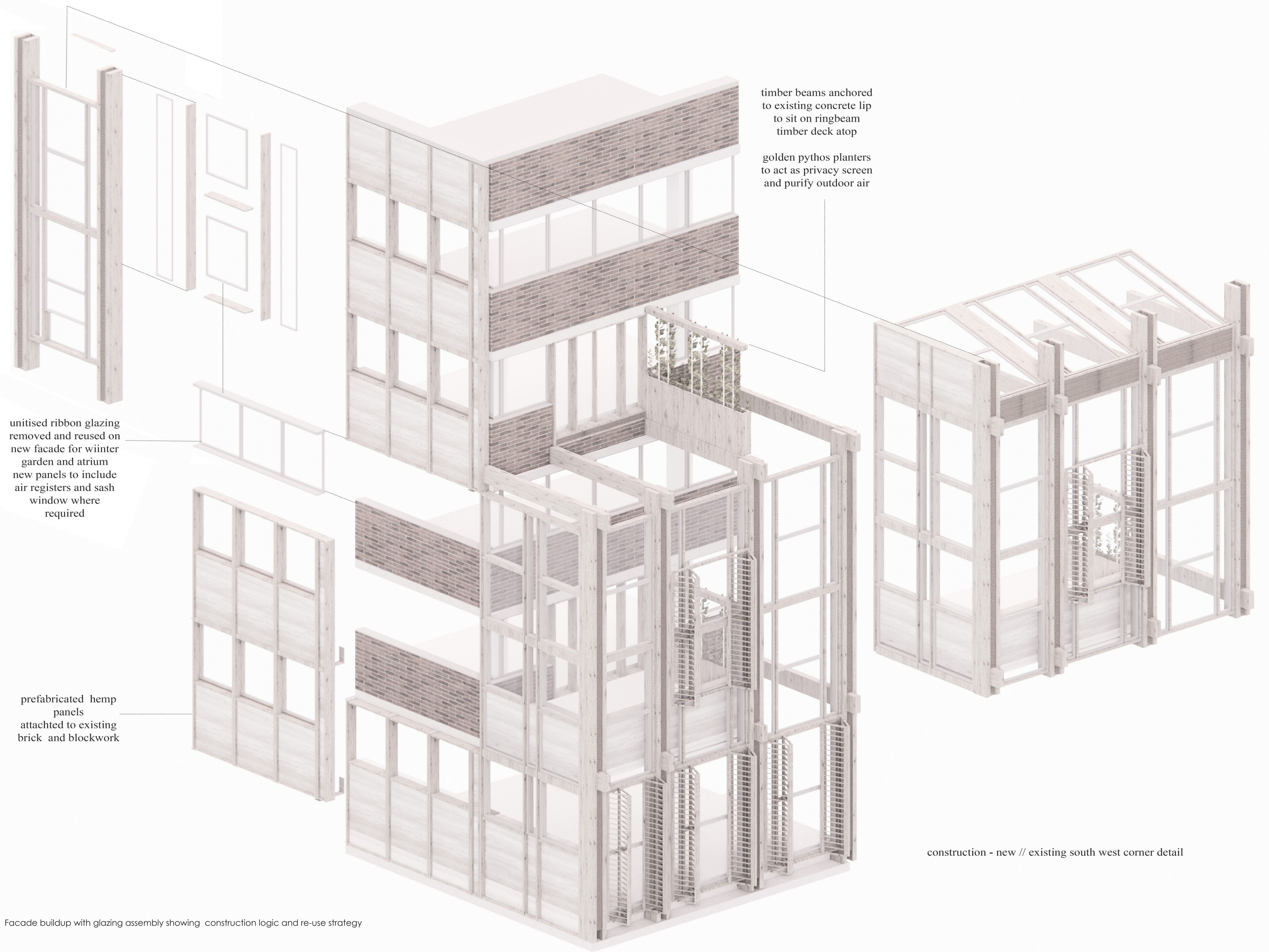

1. winter gardens
2. open plan office
3. heated atrium zone
4. meeting room
5. canteen

typical floor plan levels 2-4



atrium buildup and ventilation strategy




construction - new // existing south west corner detail

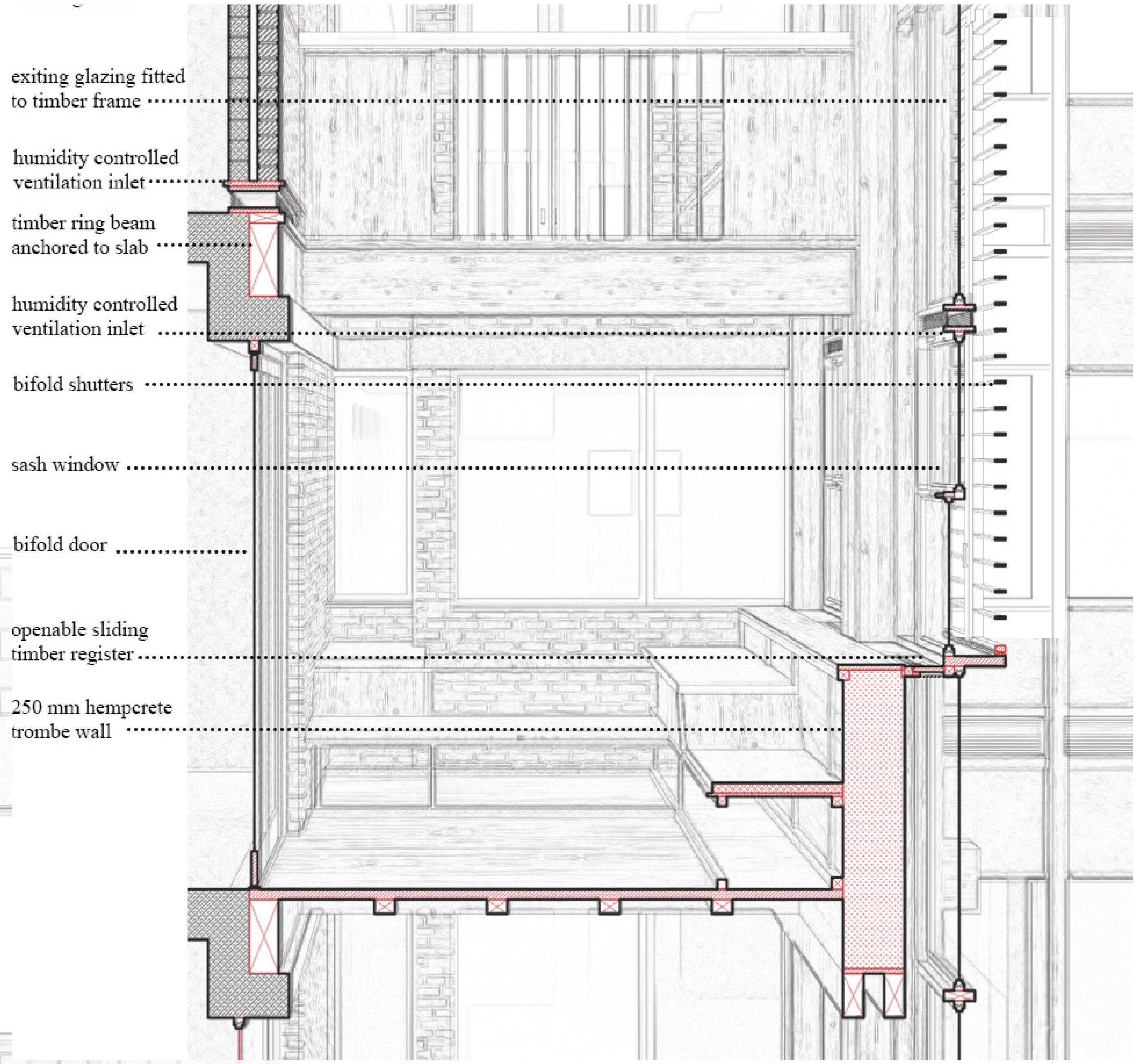
Facade buildup with glazing assembly showing construction logic and re-use strategy north south section showing thermal layering and ventilation

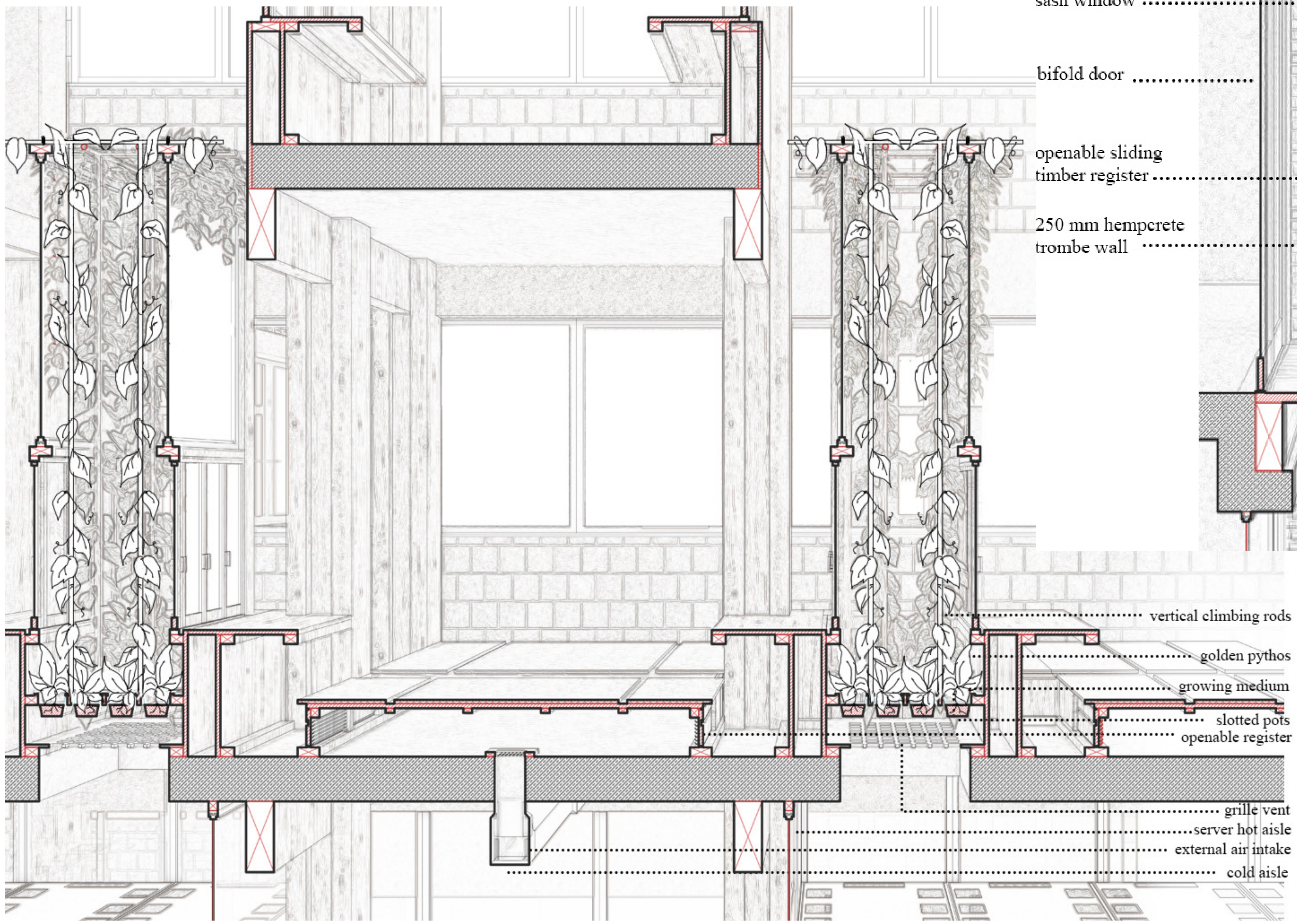
Below:

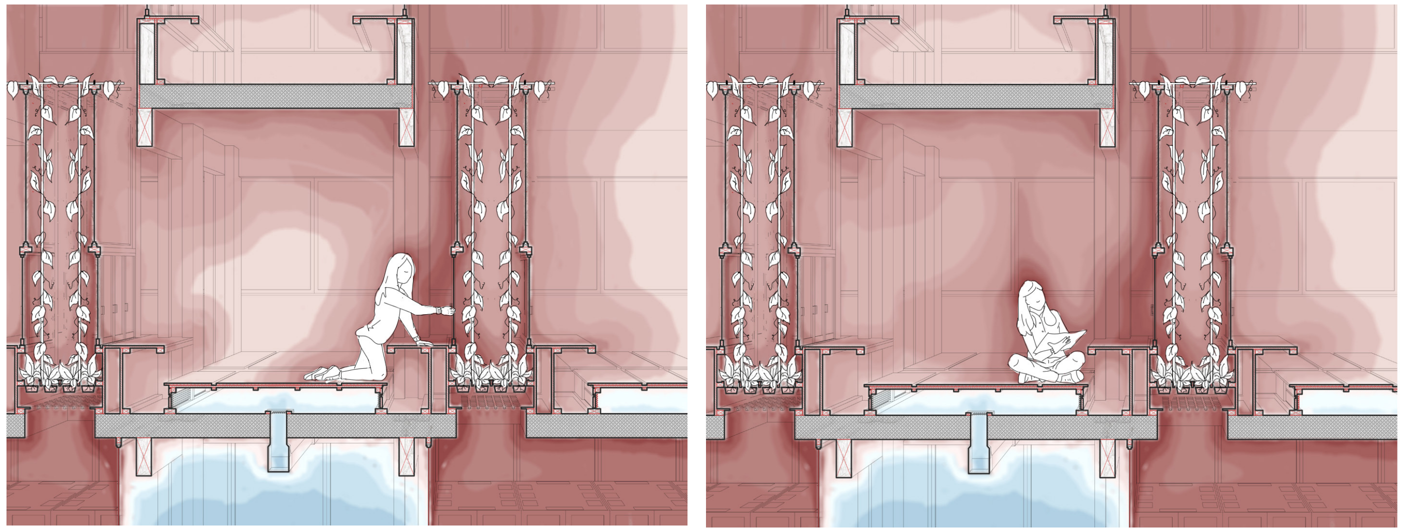
Atrium detail ground floor

Right:

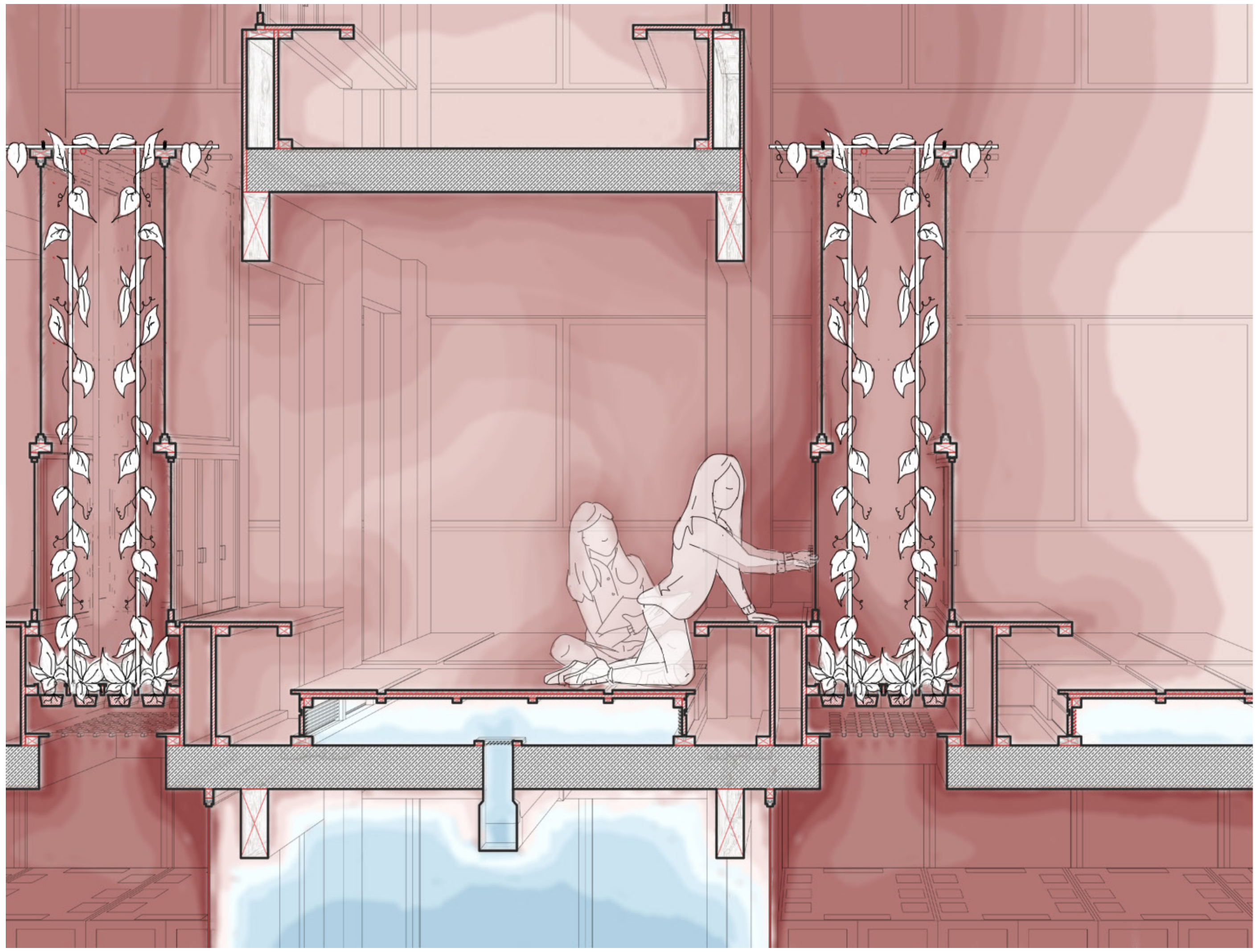
winter garden detail at south east junction



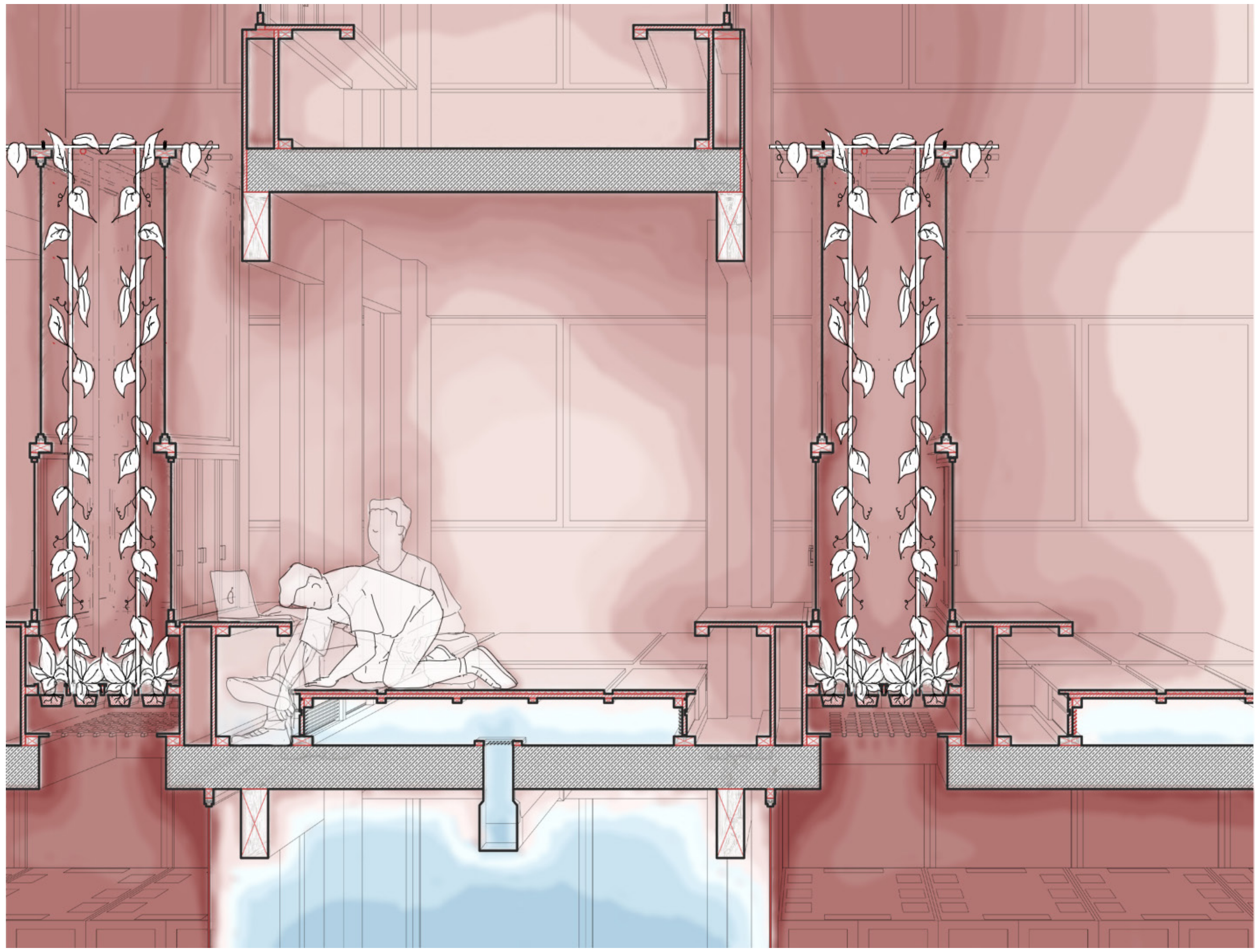


Above : atrium cuppant adjusting for comfort - warmer

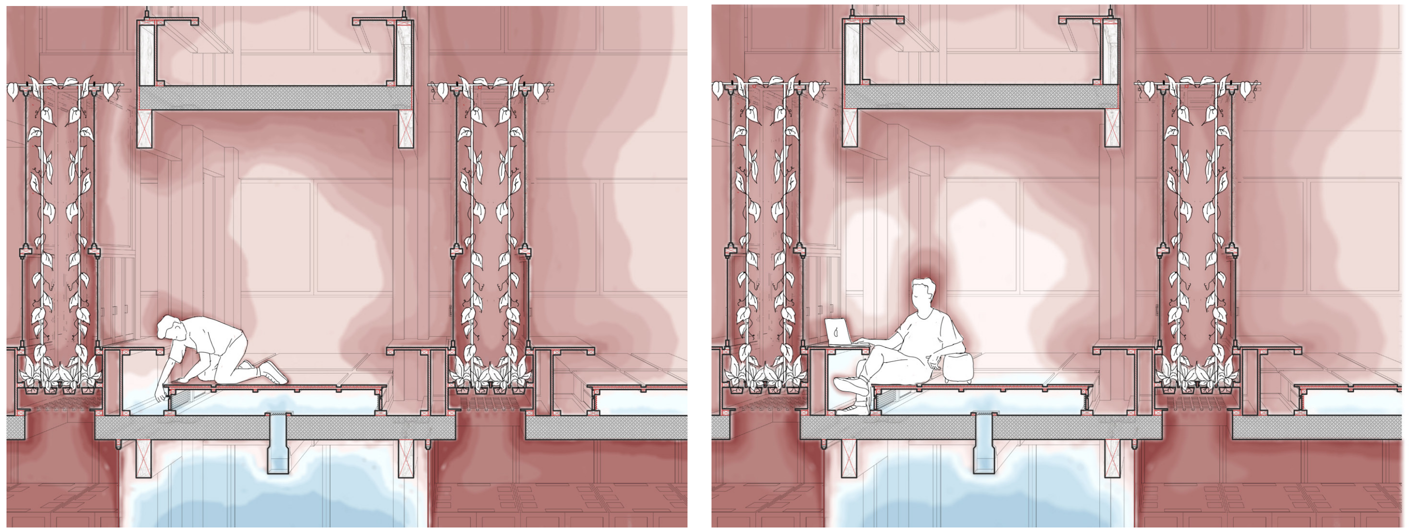


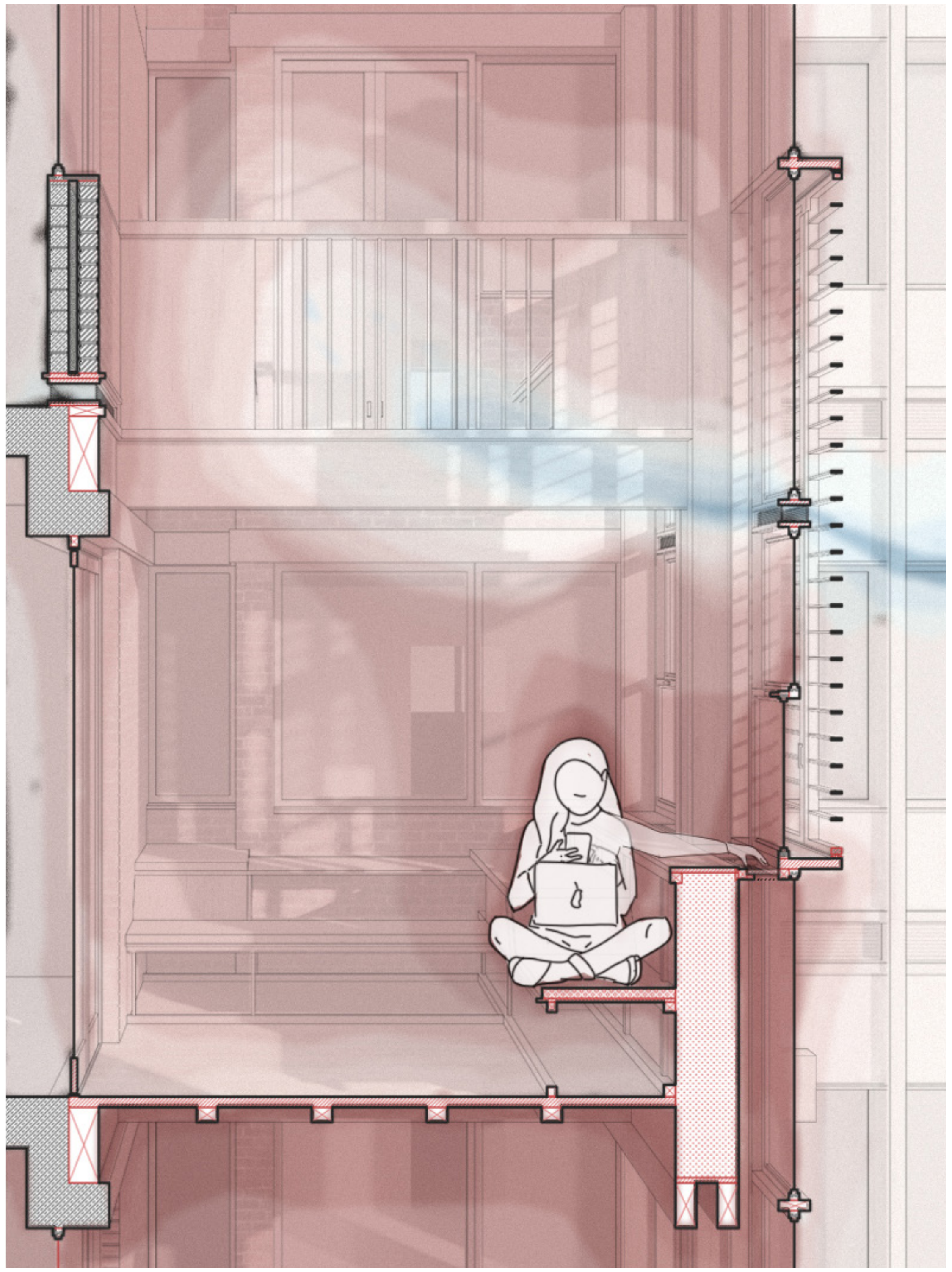
Above: Atrium ocuppant adjusting for comfort - warmer (layered)

Below: atrium ocuppant adjusting for comfort - colder (layered)

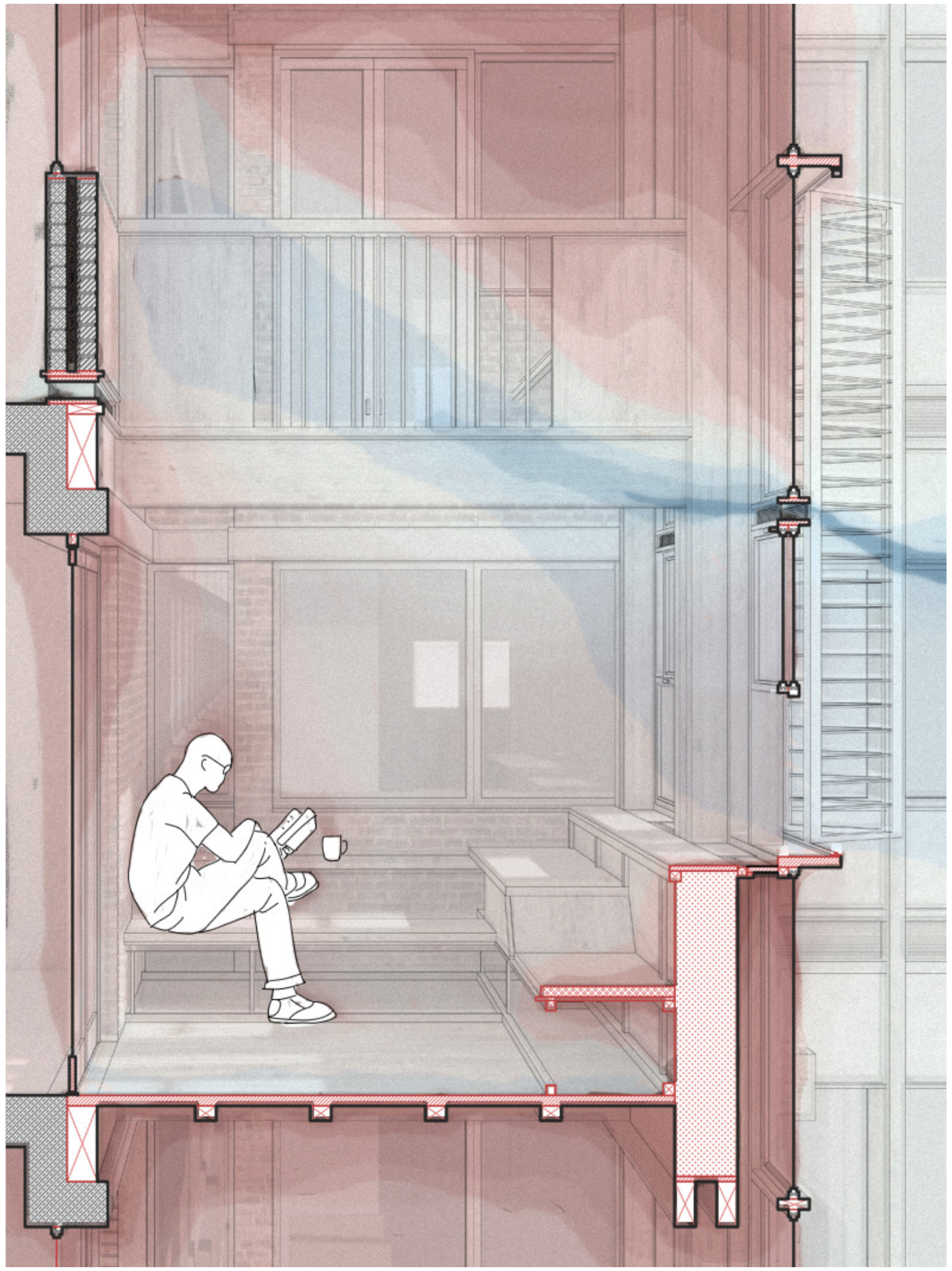


Below: atrium ocuppant adjusting for comfort - colder

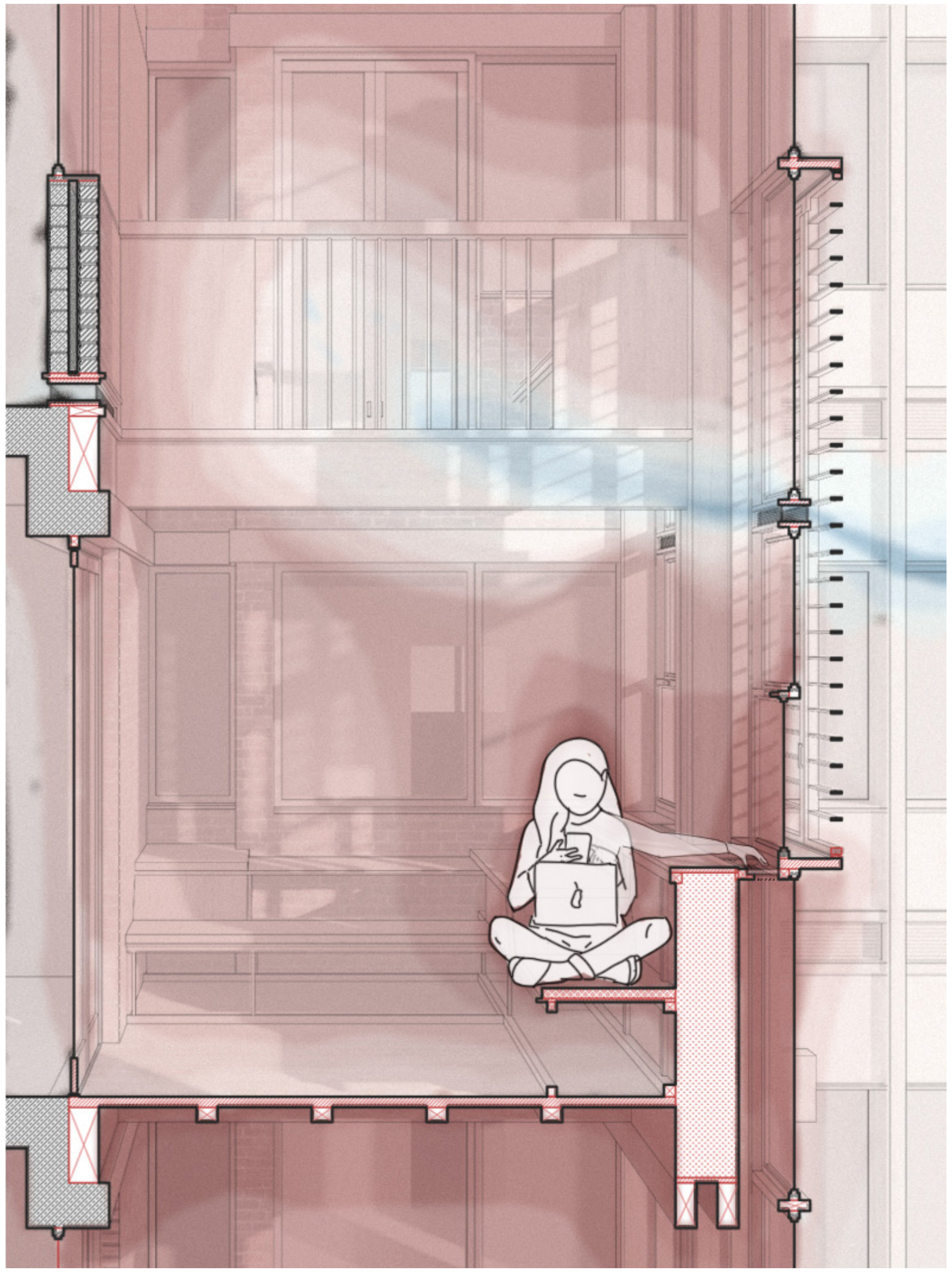




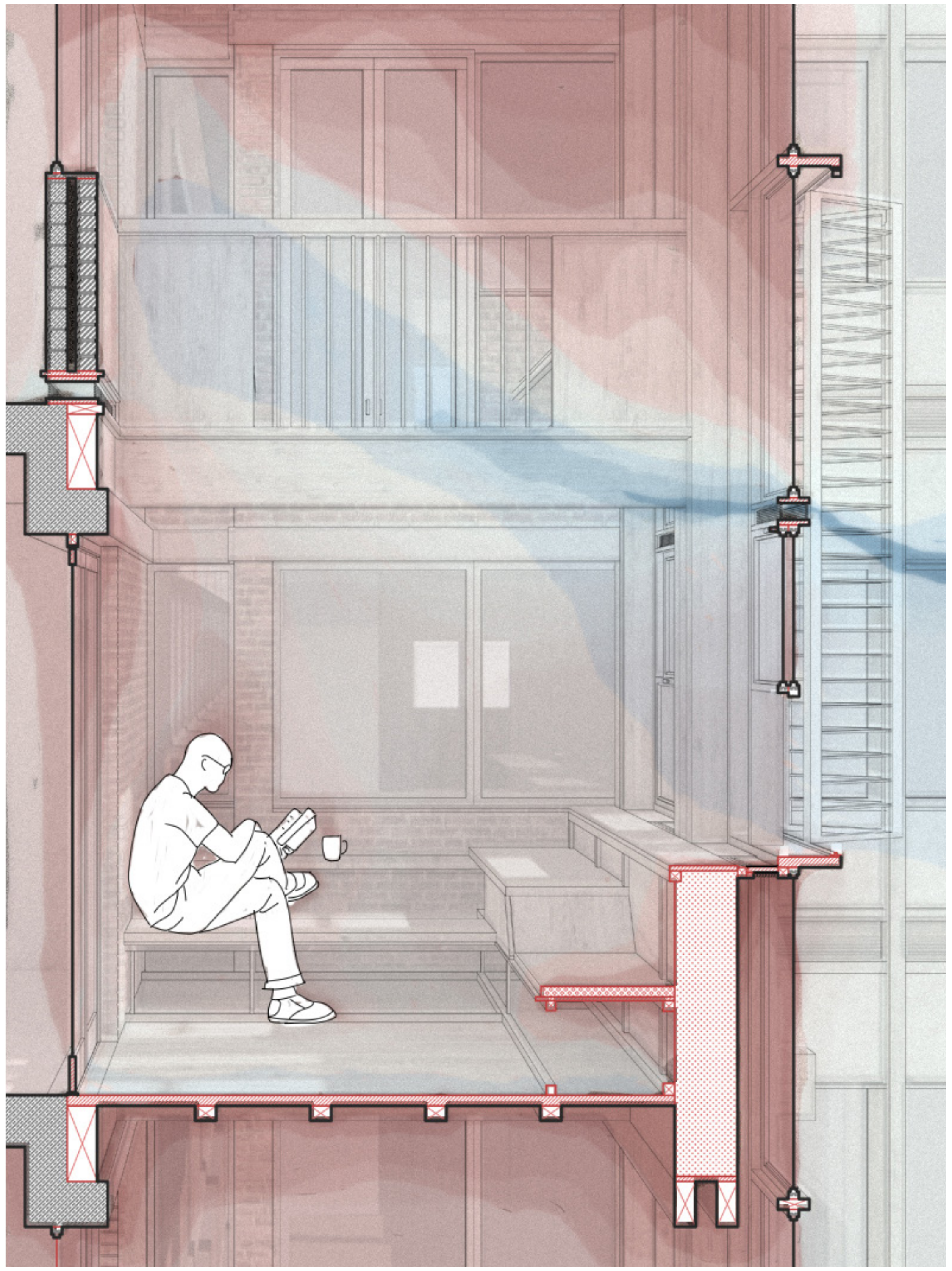
winter garden ocuppant adjusting for comfort - warmer



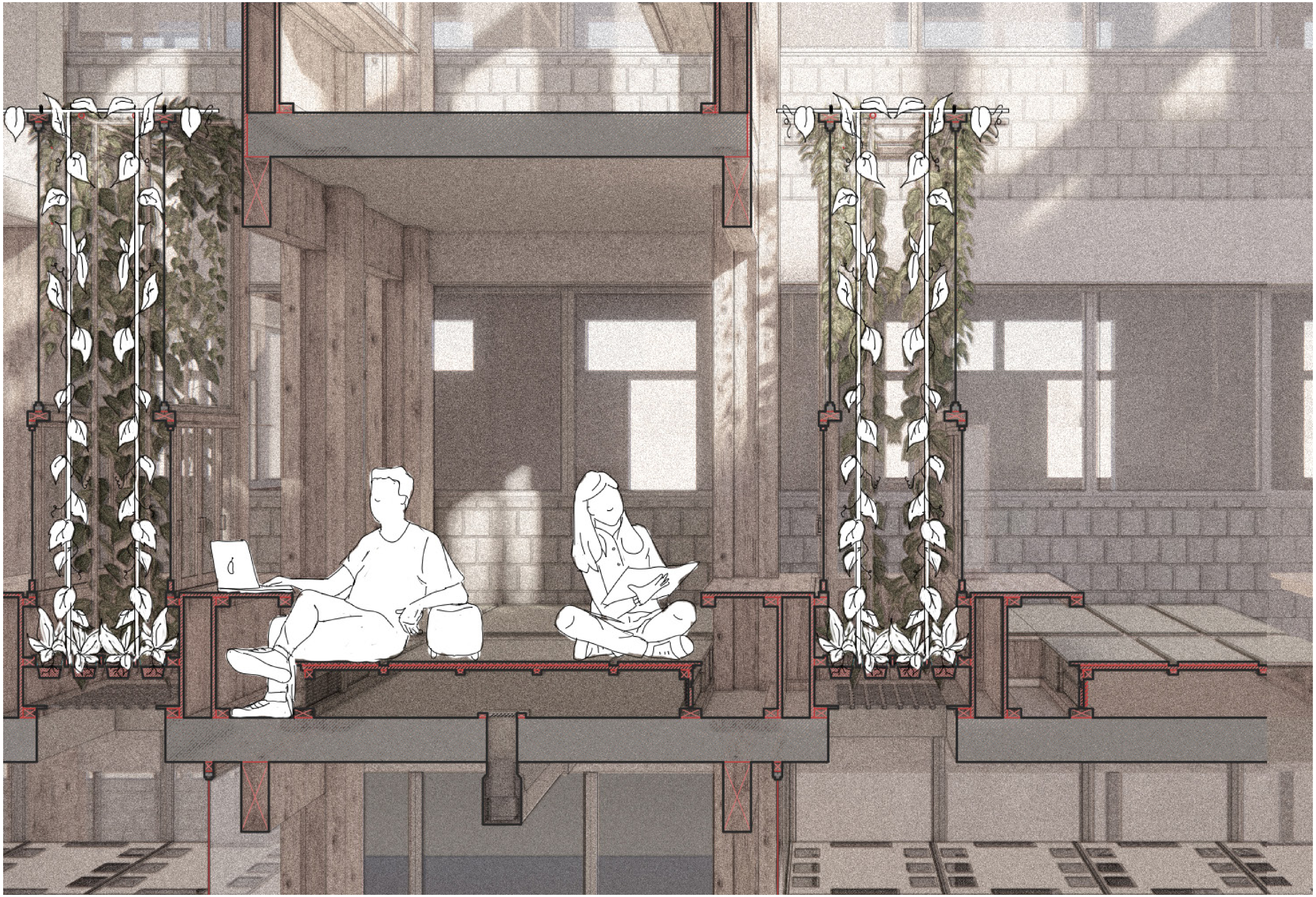
winter garden ocuppant adjusting for comfort - colder



winter garden ocuppant adjusting for comfort - warmer



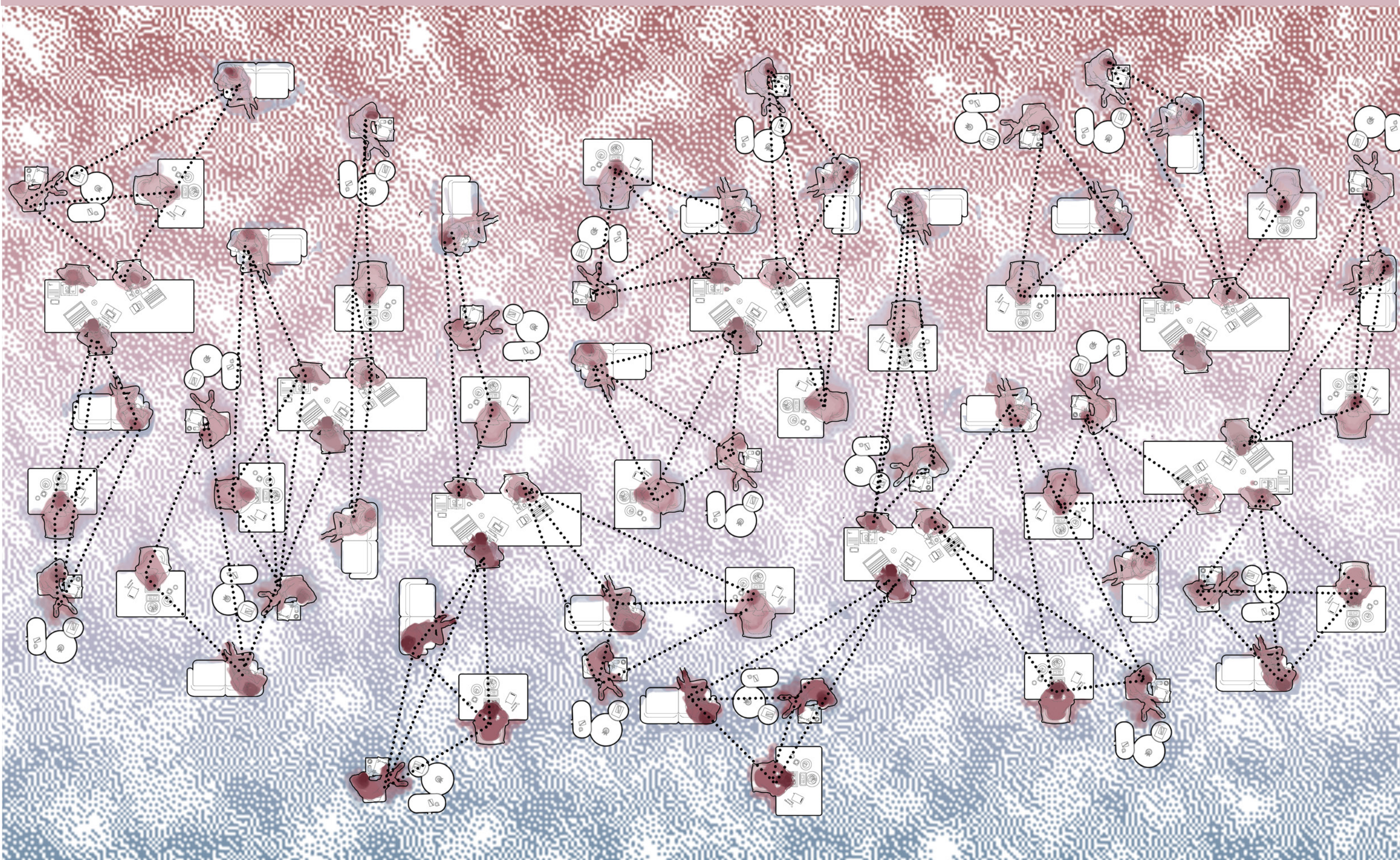
winter garden ocuppant adjusting for comfort - colder



atrium occupants 11 am equinox

# An office of thermal delight

## An open thermodynamic approach to comfort for office retrofit



Sasha Kushnirenko
M.Arch

# An office of thermal delight

## An open thermodynamic approach to comfort for office retrofit

A dissertation submitted to the Technological University Dublin in part fulfilment of the requirements for award of Masters in Architecture

by

Sasha Kushnirenko B.Sc. in Architecture
September 2022/ January 2023

Dublin School of Architecture
Bolton Street,
Dublin 1
Head of School: Conor Norton
Supervisor: Marcin Wojcik and Sarah Sheridan

**Contents:**



**Declaration:**

I hereby certify that the material submitted in this dissertation toward the award of Masters in Architecture is entirely my own work and has not been submitted for assessment other than part-fulfilment of the award named above.

**Signature of candidate:** Sasha Kushnirenko

**Date:** 13.01.2022

**Abstract:**

This research project examines the manner in which a 1970s office building can be adapted to engage a sense of what Lisa Heschong describes as 'thermal delight' (Heschong, 1997). By conceiving of the building as an open thermodynamic system, the design proposal re-imagines the internal environment of an office as a set of different thermal milieus by granting heat, as an energetic phenomenon, a greater agency in the composition of space. Through this introduction of thermal heterogeneity into the contemporary workplace, a less deterministic approach to comfort is explored, one which focuses on the diversity of individual experience and makes room for adaptation, 'a process that regularly transforms space and ritually speaks of life' (Knowles, 2012, p43).

**Introduction:**

At present, the space heating and cooling of office buildings accounts for 23.4% of fuel consumption for non-residential building stock in Ireland, surpassed only by the retail sector at 37.8% (CSO, 2022). With rising concern about fuel security and climate change, as well as the shift in working practices after the COVID 19 pandemic, this work takes these conditions as an opportunity to reconsider how the office can provide an environment that evokes a sense of comfort and enjoyment in its occupants through the redesign of an existing office block. The chosen location of the intervention is Gandon House, which is currently in use as the Office for Social Protections. It is located on Amien St. in Dublin city centre and was constructed in 1972. This building was found to be a suitable testing site for the ideas developed during the research phase due to the underperformance of its existing fabric. The envelope was analysed, and it was discovered that the building is uninsulated and is not ventilated naturally, suggesting the need for its rehabilitation.

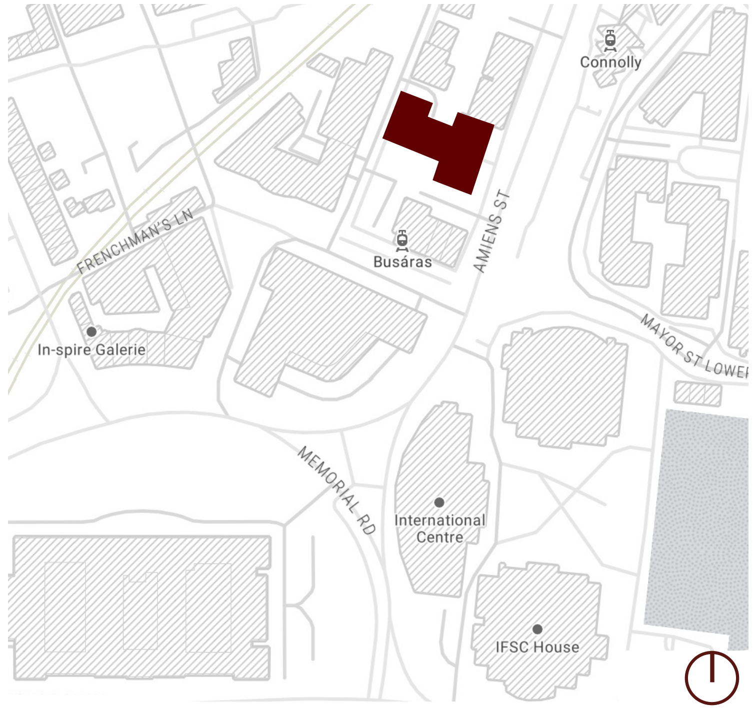
Rather than a sole focus on meeting contemporary thermal performance criteria, the strategies proposed attempt to go beyond standard comfort and energy standards to deliver diverse and pleasing environments for its occupants. Due to the lack of direct access to the current occupants themselves, this proposal is intended to serve as an exploration into the general future of office planning, using data obtained from a self-conducted questionnaire and findings from Leesman, a survey body established to measure and analyse employee workplace satisfaction. Conditions such as poor heat retention and ventilation, overheating and glare, which are sought to be amended in Gandon House are typical for building stock of this period and it is hoped that the approaches tested in this work may inform future retrofit practices in this field.

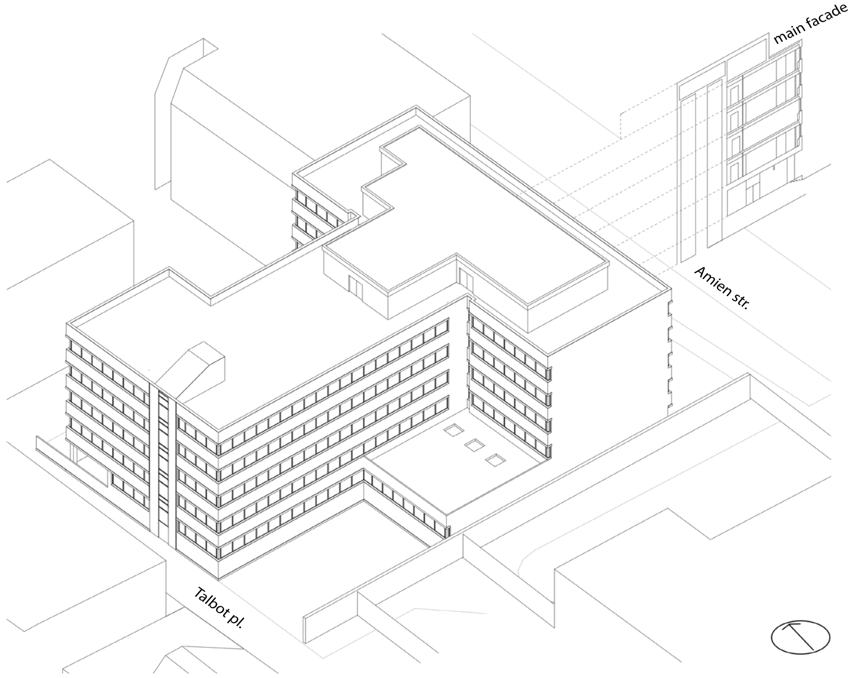
Right - Figure 1:

Site location plan

Below - Figure 2:

View of Gandon House from Bus Aras




Left - Figure 3:

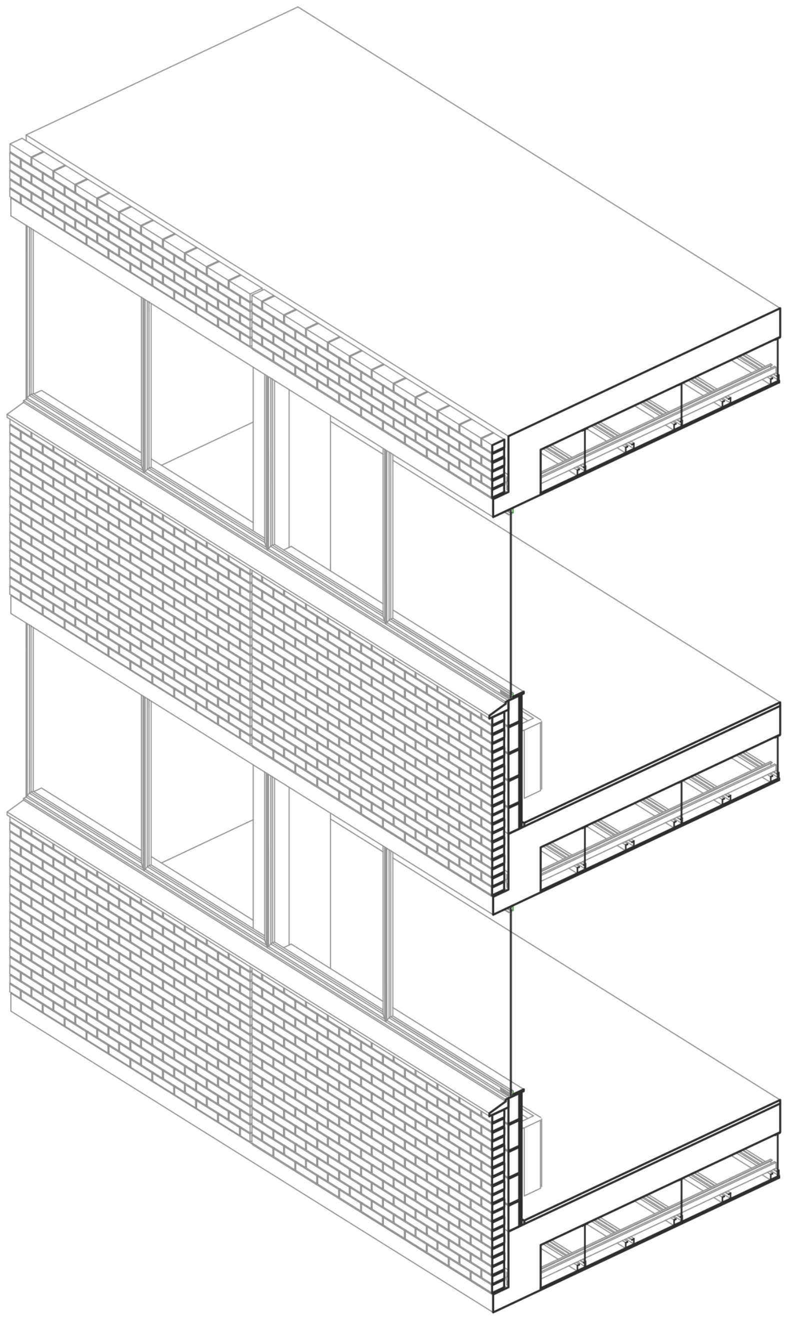
Axonometric of existing building

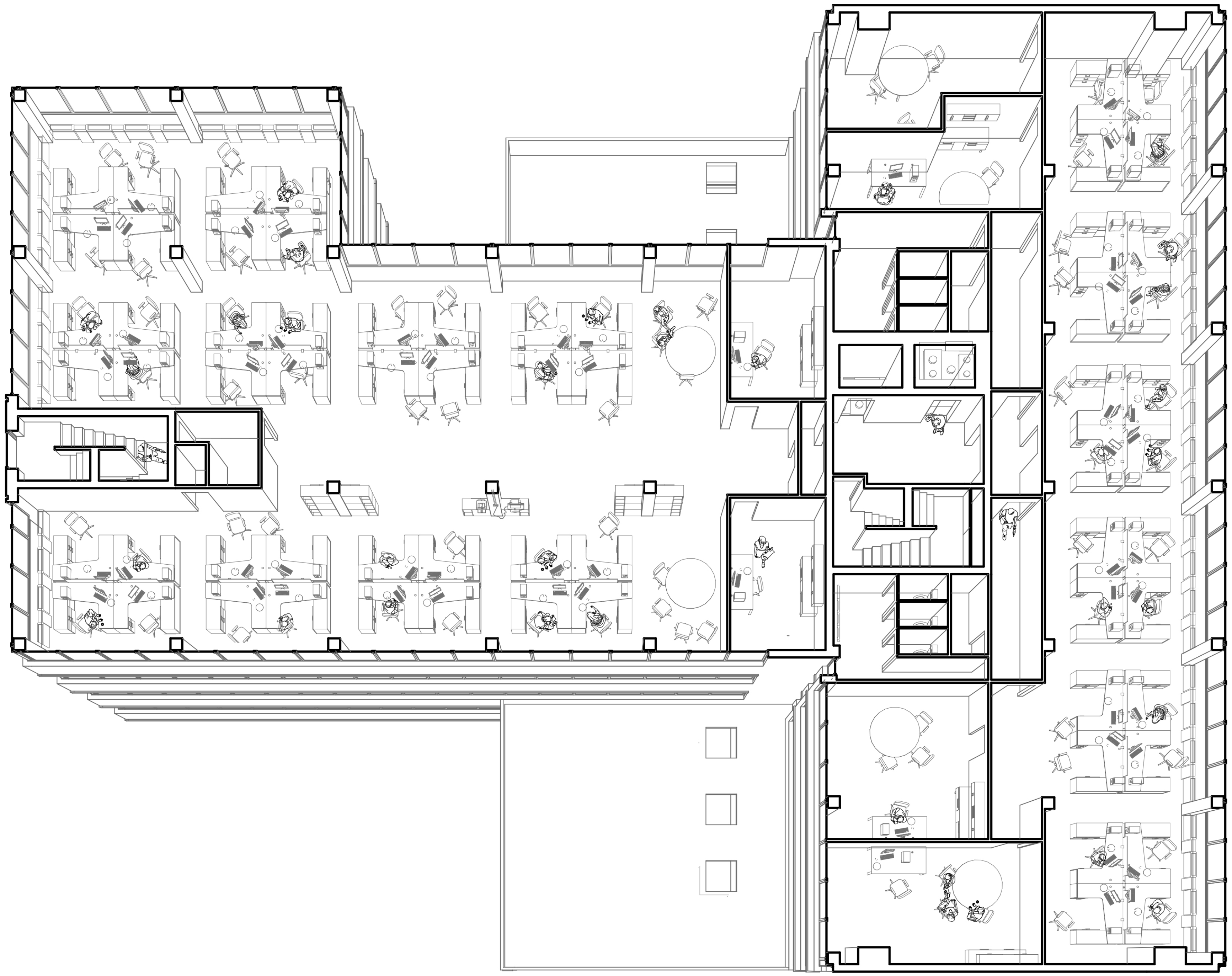
Left Lower - Figure 4:

Detail of existing facade

Below - Figure 5:

Plan of existing layout





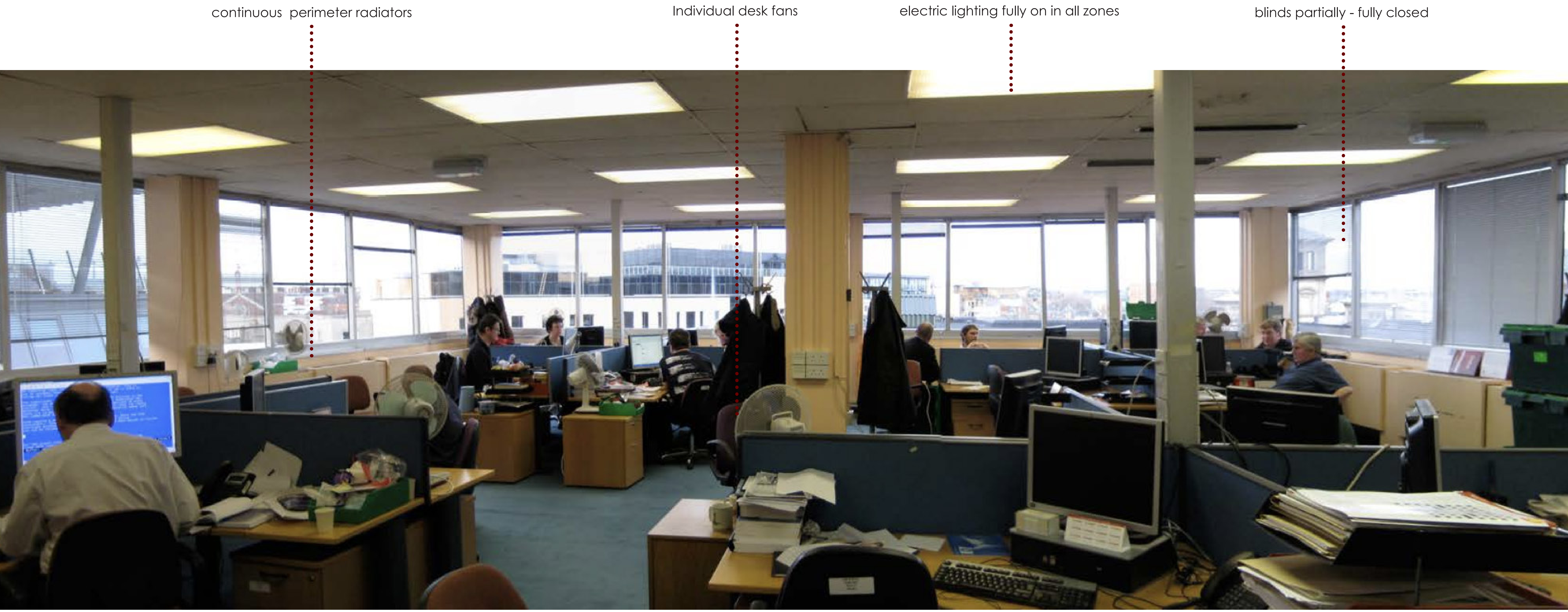



Figure 6:

View of existing working conditions

**Thermodynamics in Architecture:**

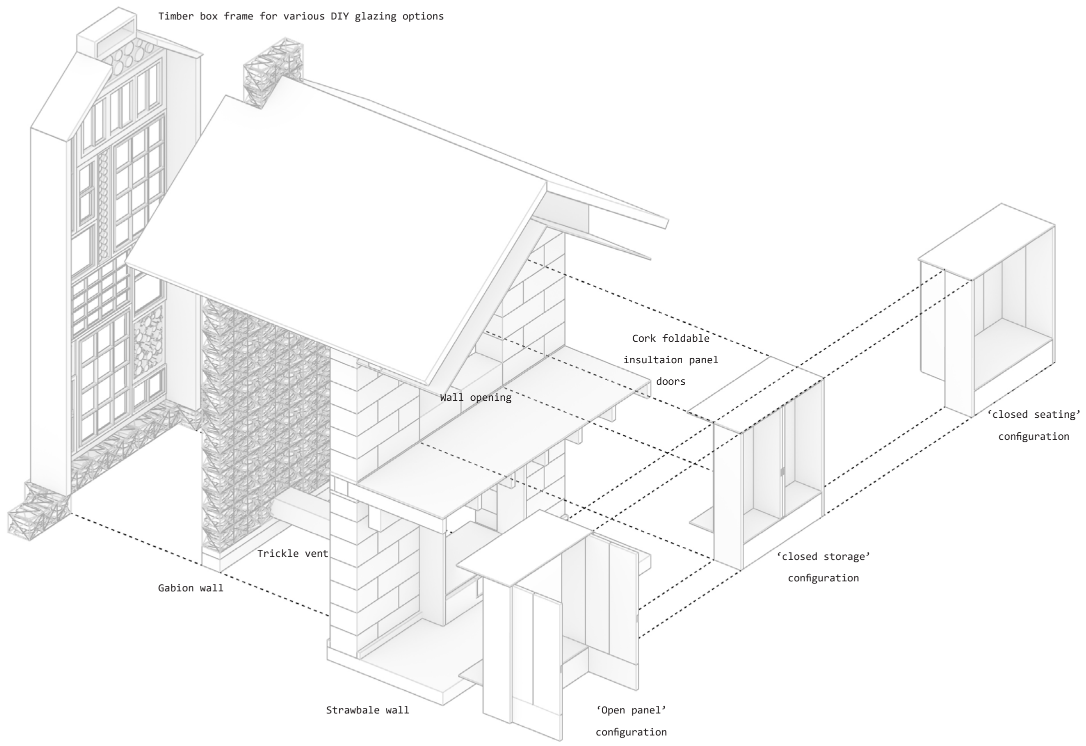
This research project situates itself in the broader field of open-systems dynamics, which in the architectural domain, broadly speaking, aims to reframe the conversation around the production of buildings 'not as sin-gular or fixed bodies, but as complex energy and material systems that have a life span, and exist as part of the environment, and as an iteration of a long series that proceeds by evolutionary development towards an intelligent ecosystem' (Hensel et. al, 2006, p6).

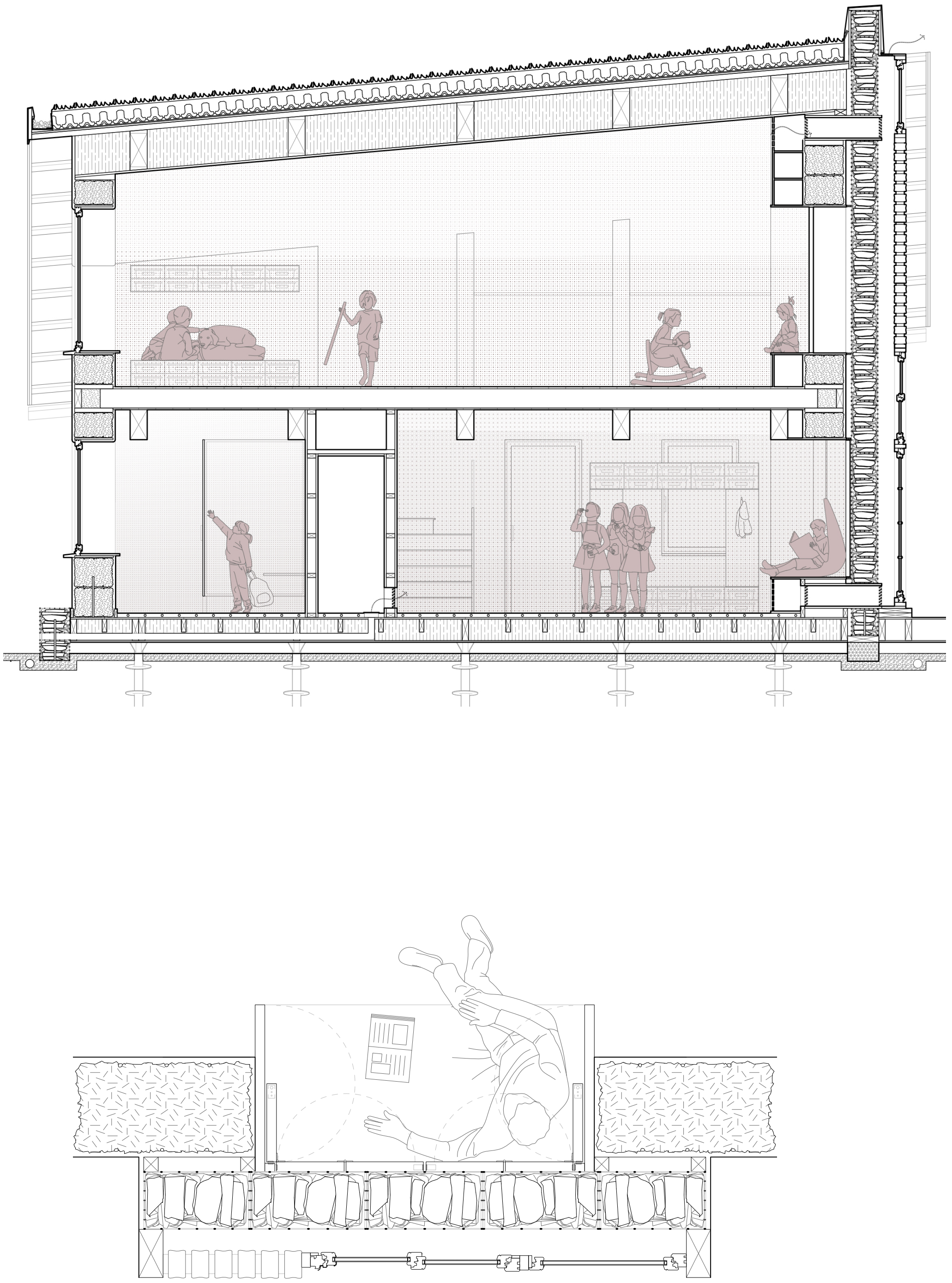
Particularly of interest to this project, are the ways in which thermodynamics have been interpreted in architectural discourse. Luis Fernandez Galiano (2000) examines the divergence in thinking around energy within the discipline that emerged in the 20th century from different perceptions of the first two laws of thermodynamics. He separates them into 'Architectures of the First Principle' and 'Architectures of the Second Principle' which he illustrates using the work of Le Corbusier and Frank Lloyd Wright respectively, through their approaches to solar energy. To Wright, 'the sun is heat more than it is light, a beginning more than a regulator, a factor of change rather than of stability' (Fernández-Galiano & Cariño, 2000, p29) which 'dances in sentient beings' (Ibid, p25). Conversely, Le Corbusier was more concerned with charting and controlling the sun, to ensure that no ray of touches the glass during the warmest hours of the day, 'between the spring equinox and the autumn equinox' (Ibid, p106) through carefully designed brise-soleil that could provide 'a single building for all nations and climates with an internal temperature of 18 degrees' (Ibid). Fernández-Galiano suggests that the latter preoccupation with energetic control gave rise to the heliotechnical, mechanical architecture of energy, 'obsessed with maximizing gains, minimizing losses, and optimizing output' (Ibid) which dominates environmental discourse today. Similar views are articulated by Daniel A. Barber (2016), and Kiel Moe (2014) as they chart the alignment of modern architecture's energetic agenda to wider socio-political ideologies and the development of technologies such as refrigeration. As Peter Reyner-Banham notes, the adoption of such advancements from adjacent industries can be se seen as 'either as the final liberation of architecture from the ballast of structure, or its total subservience to the goads of mechanical service' (Banham, 1969, p265).

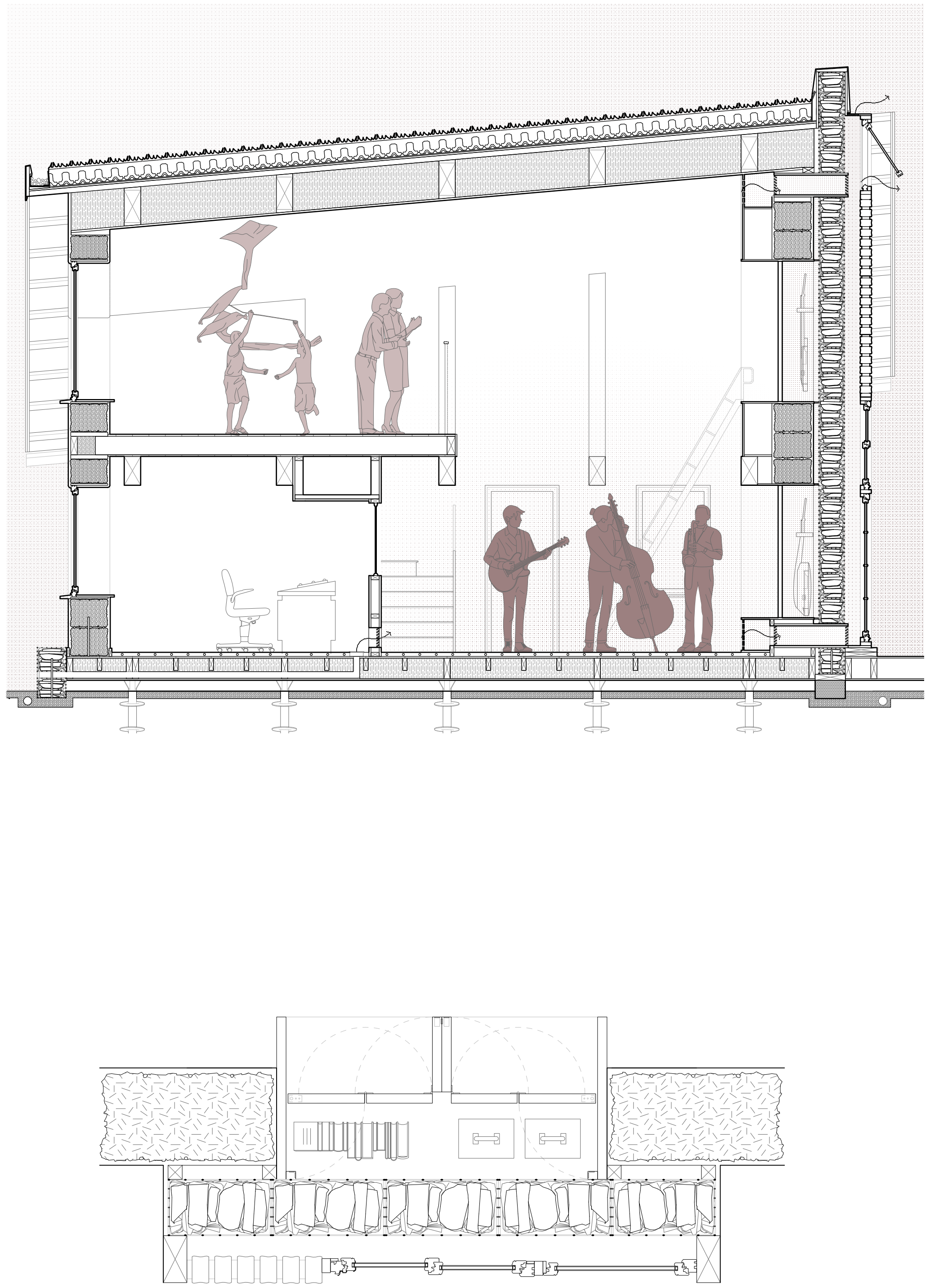
Left - Figure 7:

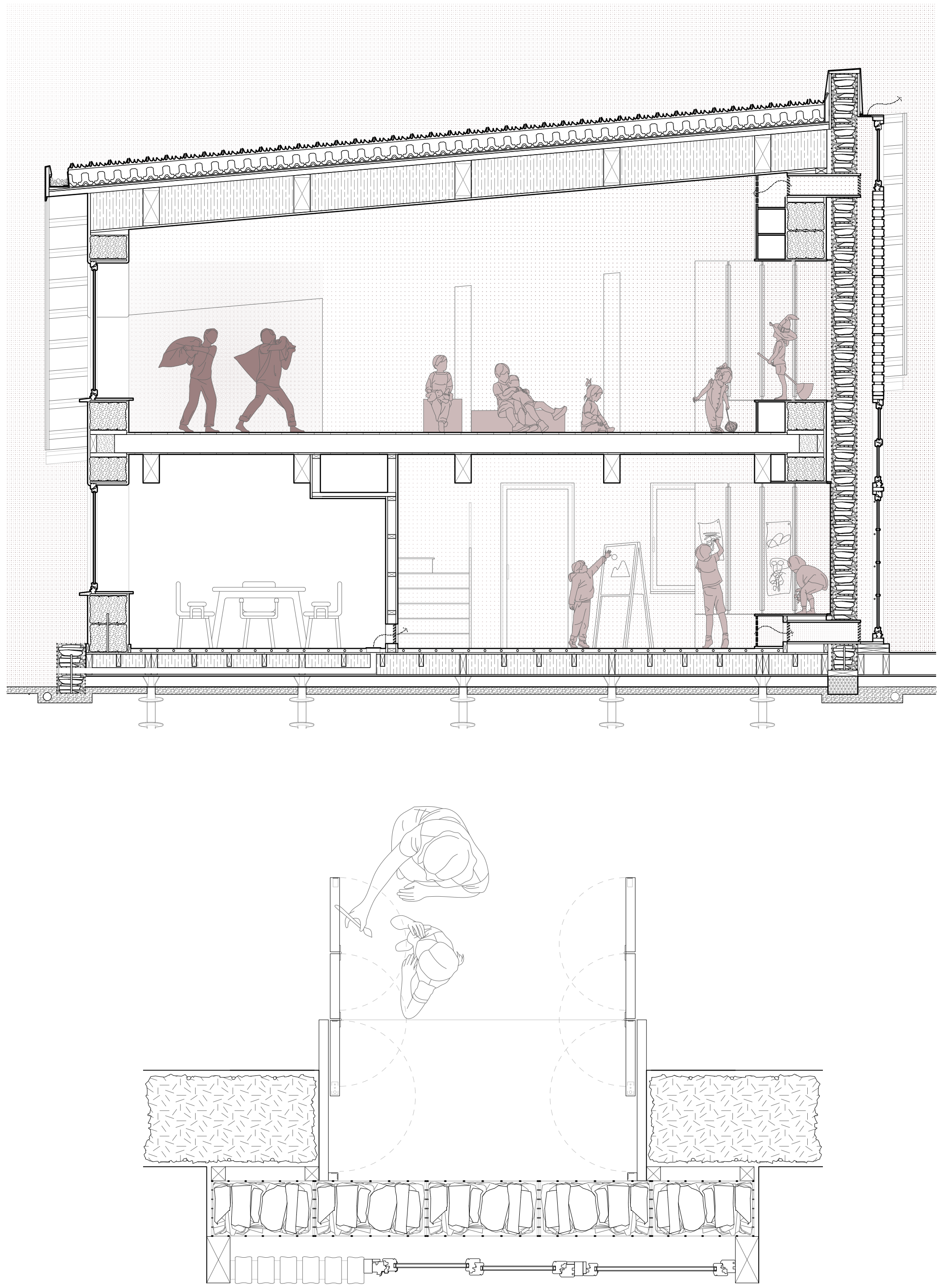
Exploded Axonometric of Trombe Wall

Moe proposes an alternate view of an architecture of energetics, one than shifts the focus from efficiency to 'modulation of various energy scales, forms, and velocities: faster here, slower there, almost paused, or stored, but never ceasing' (Moe, 2013, p233). This modulation encompasses the channelling of flows of energy between the building and it's wider ecological networks rather than isolating the former from the latter.  This idea was explored in an earlier design proposal for a democratic Sudsburry school in a rural setting during the second semester of this master's course. The intervention relied primarily on passive solar design strategies to conceive of the school as an open thermodynamic system which is in constant dialogue with its surroundings. A series of Trombe walls were employed as a means of mediating this dialogue through occupants' interactions with them by integrating useful features such as moveable seating and storage. Snapshots of the imagined occupation were developed through drawing, by presenting scenarios such as 'a sunny winter's day in the art room' or 'an overcast cold day in the cubby room' which depicted the children's activities and their chosen configuration of the wall (see Figures 9,10,11). Through the physical sensation of radiant heat emitted from the stone gabions, the design sought to foster an understanding of the interconnectivity of that human comfort and environment within the children. The design of the Subsburry School in Sligo served as a starting point for a more rigorous study of the way in which architecture can reconceptualise shelter as a human intervention that is embedded within an ecological system and engage with energies that flow through it.









Left - Figure 9:

An overcast cold day in the cubby room - inhabited details

Center - Figure 10:

A  hot sunny day in the music room - inhabited details

Right - Figure 11:

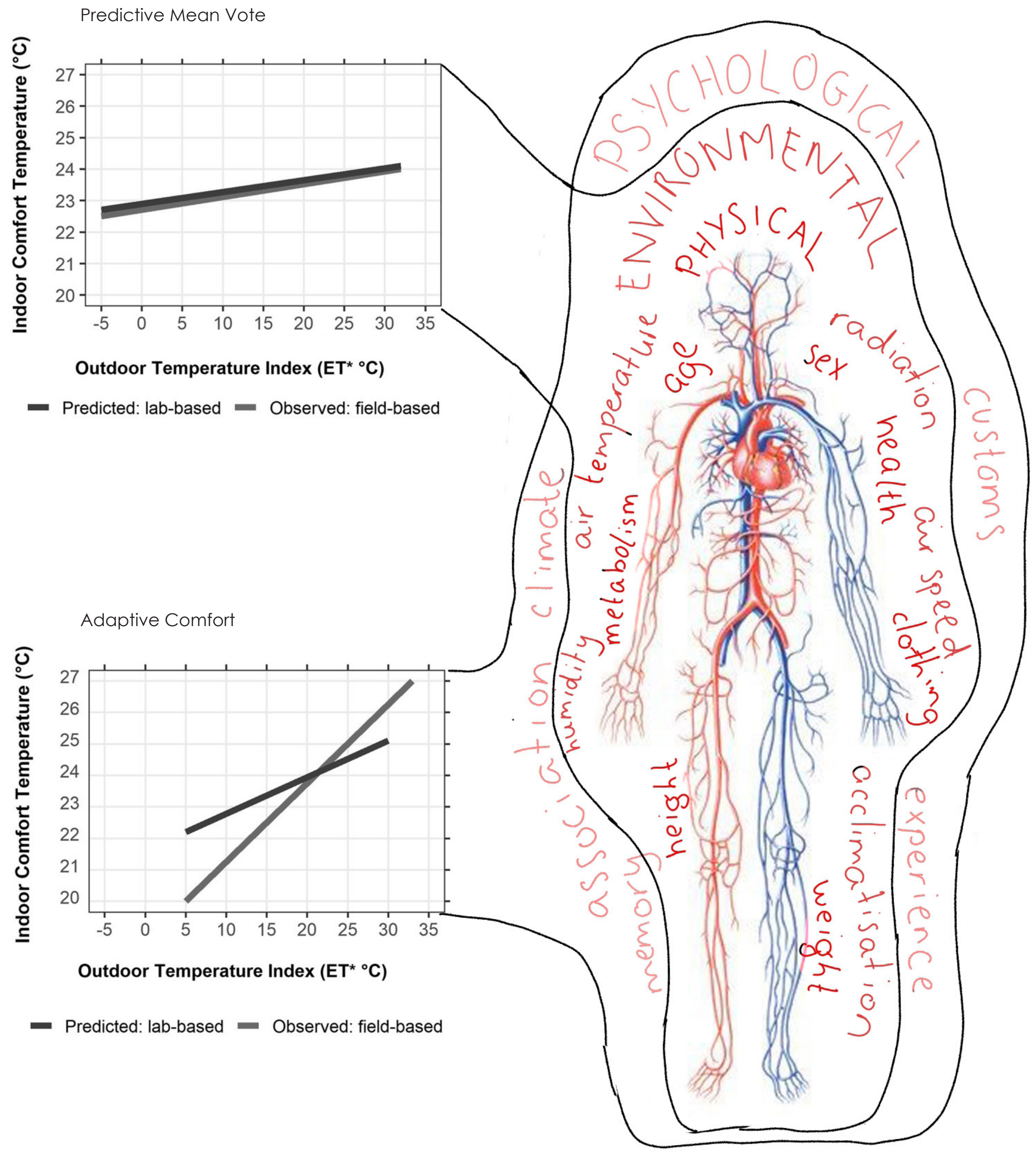
A sunny winter's day in the art room - inhabited details

**Quantifying Comfort:**

Once the full suite of environmental controls became available after Willis Carrier's advancements in air conditioning, the question of what an ideal thermal environment should feel like began to emerge. The notion of comfort as a qualitative phenomenon shifted to a set of conditions which could be rigorously measured and used to predict human thermal responses in a given environment. This was encapsulated by the development of a mathematical model by engineer Povel Fanger in the 1960s called the Predictive Mean Vote. His experiments were carried out in a climate-controlled chamber which reflected the conditions that the new heating and cooling technologies brought to actual inhabited spaces, making the model quite successful in this domain. The oversimplification of dynamic phenomena that characterised the world around a building's sealed interior, however, left to the PMV model unable to deal with scenarios such as natural ventilation. The failure of these predictions when faced with indeterminacy, as well as lack of regard for differences in thermal preference which were observed across various cultures and individuals, served as ground for later investigations such as those done by Humphreys and Nicol, who put forward the adaptive comfort scale. The adaptive comfort scale demonstrated that a broader range of temperatures was perceived as comfortable when individuals had agency over their environment through acts such as opening windows.

**Thermal Delight:**

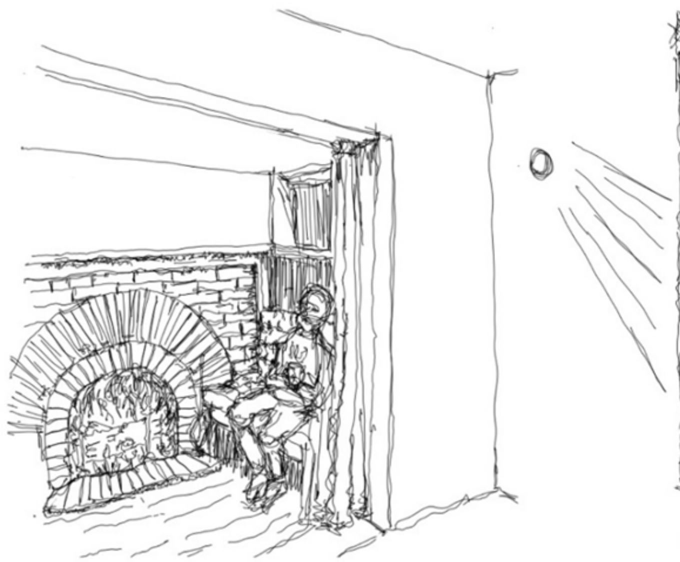
The work of Lisa Heschong proved to be a rich source of commentary on the multitude of nuanced factors which influence thermal perception. She speaks of comfort as largely a qualitative sensation, in which 'thermal information is not differentiated in our memory, but rather is retained as a quality, or underlying tone, which is associated with the whole experience of the place' (Heschong, 1997, p56). The accounts she presents of places with strong thermal presence do not ascribe comfort to specific temperatures, but instead often rely on relationality to construct an impression of constrasting sensation. This phenomenon is perhaps best described by Gregory Bateson's assertion that, 'perception operates only upon difference. All receipt of information is necessarily the receipt of news of difference.' (Bateson, 1979, p29)




Top - Figure 12:

Exploration of factors contributing to different comfort models

The notion of the 'thermal aedicule' (Heschong, 1997, p56) suggests that which makes a little warm nook special is not only its own warmth but the coolness of the surrounding spaces. The inglenook, a small space enclosing a fire, stands out in Heschong's analysis as an excellent example of this relationality at play. The convergence of spatial features such as lowered ceilings, exposed telluric materials, change of threshold denote a space with a character distinct from the main room heighten the sensation of heat felt from the fire itself. The inglenook's revival in the twentieth century by Frank Llyod Wright was met with critique by writers such as Fernández-Galiano, who saw it 'as functionally redundant as it was symbolically indispensible' (Fernández-Galiano & Cariño, 2000, p29) due to Wright's reliance on radiant floor slab systems rather than the fire itself as the dominant heat source. However, Moe suggests that through the use of a thermally active surface, the hearth served 'not as an artifact to repeat, but more as a habit of mind to emulate' (Moe, 2014, p182). These observations about the nature of contributing factors to the warmth of a space, led me to consider how the traditional features of a thermal aedicule could be translated into a contemporary office. Through sketching the traditional inglenook (figure 13) I began to imagine its re-interpretation as an intimate working space which featured a mass wall as a radiant heat source of solar energy (figure 14), but retained the associative warmth evoked by the original feature.





Though, naturally, there are limits to the range of temperatures the human body can tolerate, Heschong argues that the definition of a thermal optimum for indoor temperature leads to the homogenisation of the possible range of environments which humans may inhabit. She notes that this strive for equilibrium disregards the experiential qualities through 'an underlying assumption that the best thermal environment never needs to be noticed' (Heschong,1997, p25). Not only does thermal monotony preclude the possibility heightened and contrasting experiences but it also strips people of agency and motive to engage with to the world around them. but it can be seen to Ralph Knowles proposes that this engagement forms the basis of 'sheltering'. Rather than the static concept of shelter, 'sheltering' denotes that 'we make certain adjustments for comfort in response to changes in the natural environment. We repeat these adjustments in concert with the unique rhythms of weather and climate in our particular setting. This repetition can give rise to rituals that feed our soul. These ritual acts of sheltering help explain who we are and where we are in the world' (Knowles, 2013, p3).

This description of 'sheltering' as human activity unfolding through an alignment to larger ecological patterns, in a broad sense, is akin Tim Inglod's descriptions of 'dwelling'. For Ingold, the act of dwelling in the world implies that 'we do not act upon it or do things to it; rather we move along with it. Our actions do not transform the world, they are part and parcel of the world's transforming itself' (Ingold, 2011, p200). Together, these descriptions of temporal patterns of human activity suggest that life, in a broad sense, develops around a heterogeneous assemblage of thermal experiences.

Left - Figure 13:

Sketch of traditional inglenook

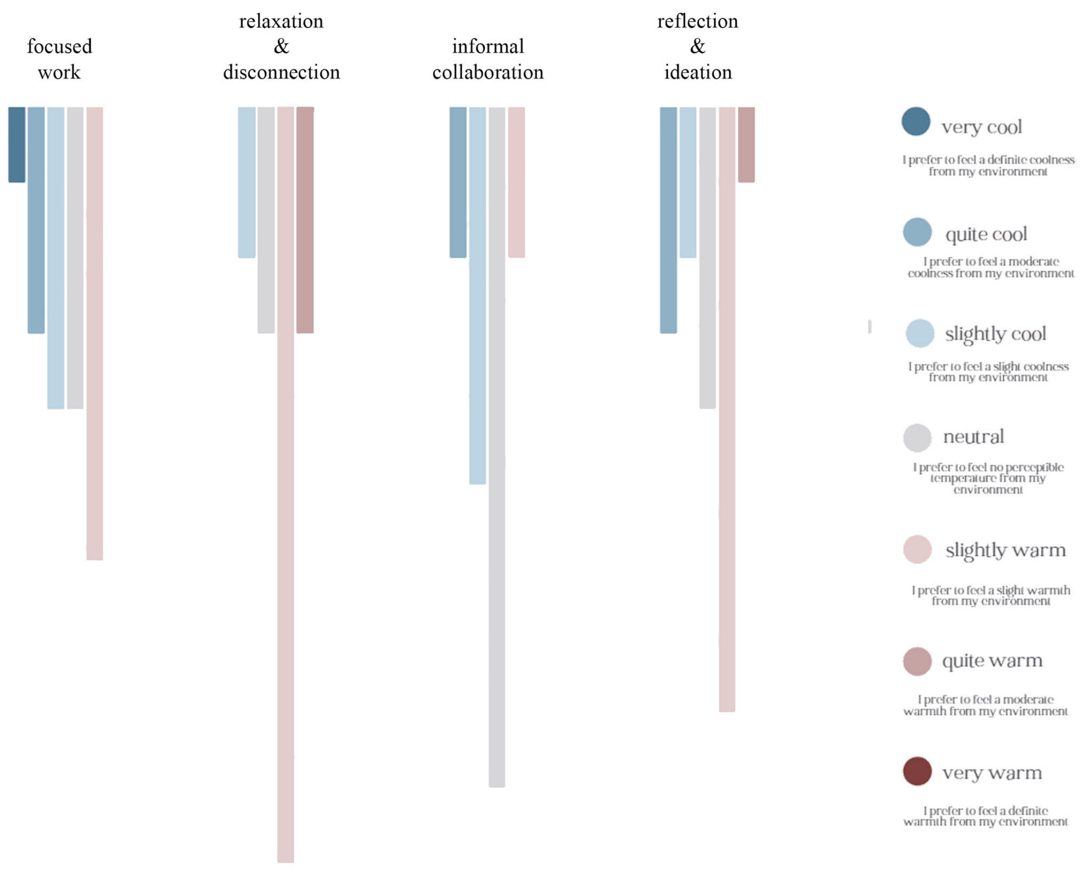
RIght - Figure 14:

Sketch of reinterpretation

**Hypothesis:**

The significance which thermal qualities lend to the places people inhabit and the rituals which develop around this inhabitation aided in shaping the research question: How can architects embrace thermal diversity and use it as a driver in the design process to generate novel spaces for diverse kinds of work?

Through the examples of thermal contrast which characterised non-modern architecture practices detailed by Knowles and Heschong, I began to consider what type of thermal diversity would be welcomed in an office setting. For a building in Ireland, the HSE Sustainability Office indicates the temperature of 18 – 23 degrees is the comfortable range. These recommendations are based on the PVM scale for climate-controlled buildings and while they are useful for understanding the general temperature benchmarks architects and HVAC designers should aim for, they are rather narrow and do not account for natural ventilation or differentiate between workplace activities such as meetings, group or individual work or break settings. To obtain a more qualitative assessment of people's thermal preferences in the workplace I constructed a questionnaire which asked respondents to rate their ideal working environment based on temperature perception for a series of the following activities: 'focused work', 'ideation and reflection', 'collaboration' and 'relaxation and disconnection'. These categories were adopted from a study which identified the most important activities people engage in at the office across 400,000 respondents (Leesman, 2018). The 19 responses obtained from my questionnaire showed a large variety of preferences both between individuals and within each individual's set of responses for different activities. The preference for a neutral working environment was most significant for collaborative work, presumably as it allowed different individuals to feel comfortable while occupying the same space. The data was represented in both a quantitative and qualitative manner, the latter was developed to show a graphic impression of each respondent's activities in a thermal landscape.

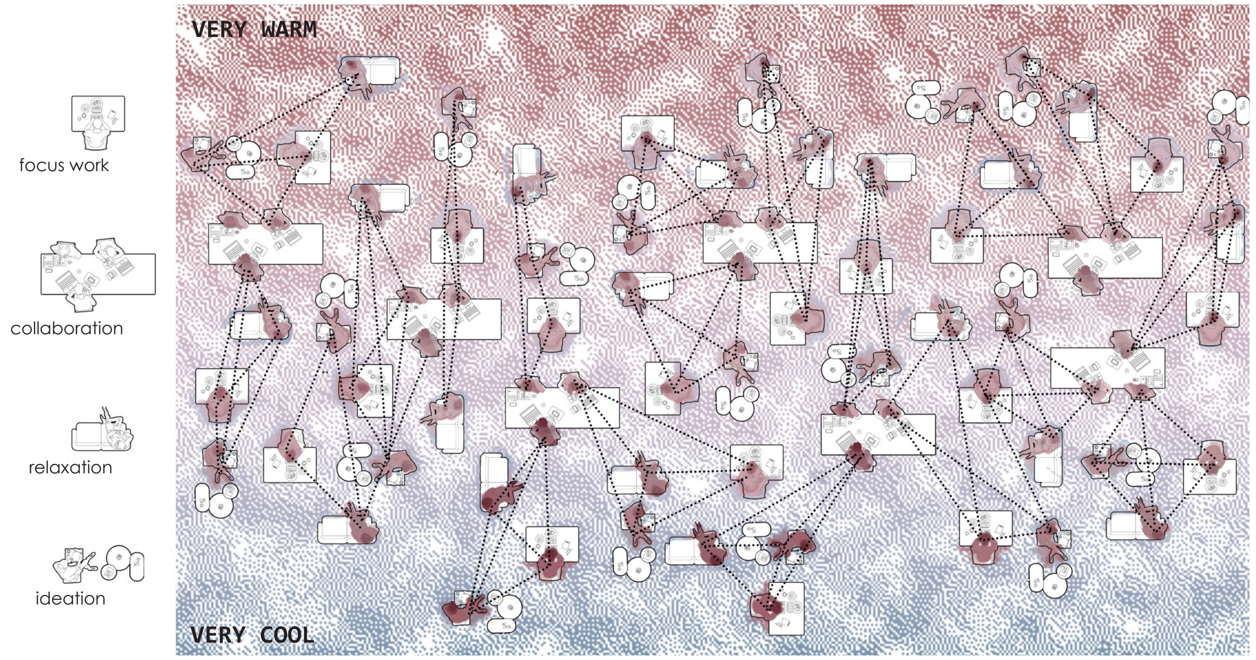



Above - Figure 15:

Thermal Perception survey results

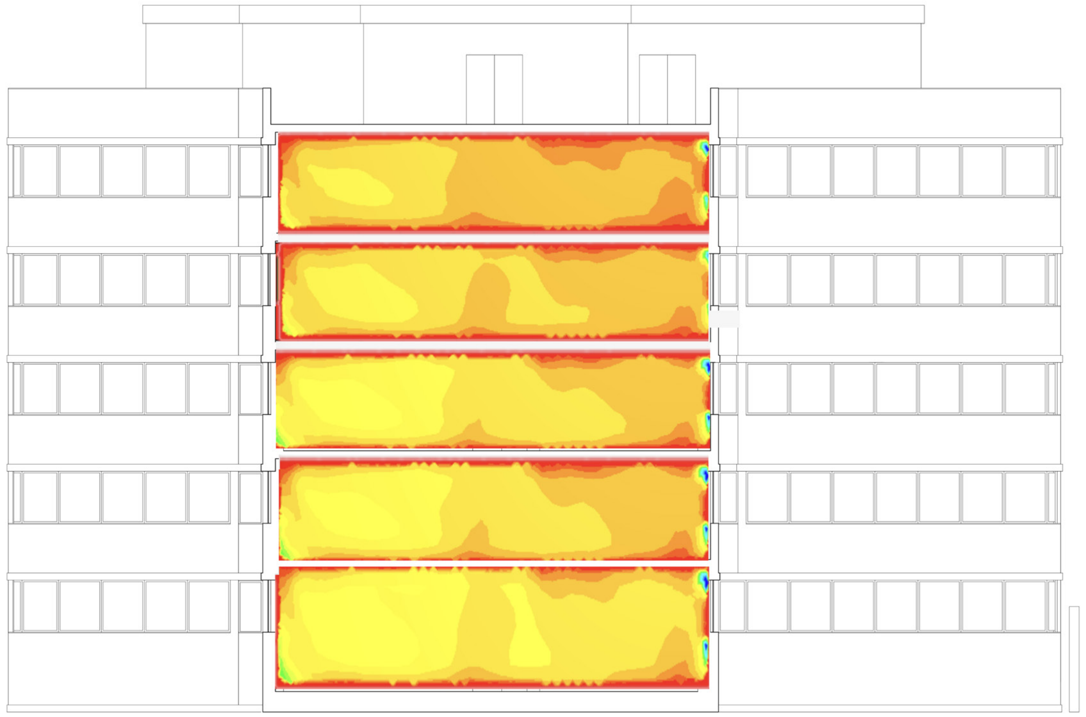
Below - Figure 16:

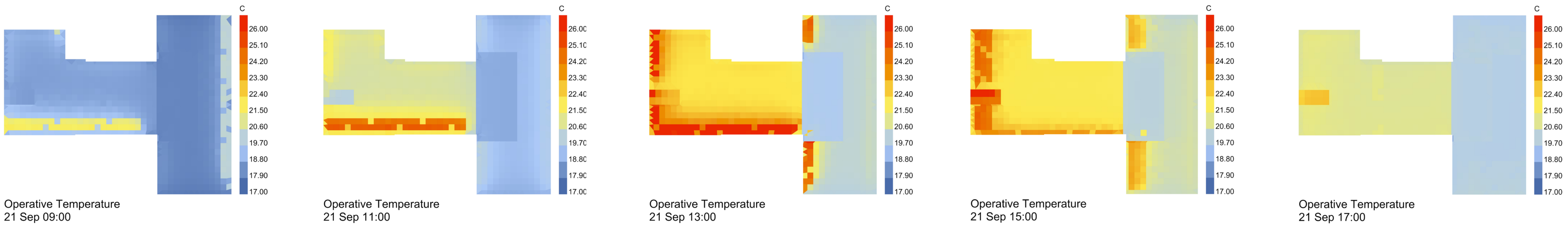
Graphic of respondents' presferences mapped



**Thermal Modelling and Simulation:**

The questionnaire aided in establishing a case for a thermally heterogeneous office design which began with a survey of the thermal conditions of the existing building. Through the operative temperature analysis conducted using the Honeybee plugin for Grasshopper, in which climate data was used to predict temperatures within the building at different times of the day. Temperatures variations were found to occur seasonally in a similar distribution. The higher temperatures were concentrated at a 3-meter distance from the internal south and west facing walls. There was a stark contrast in the temperatures experienced at any deeper point in the plan due to the limits of solar penetration for the space of 3.2 meters in height. Using the internal temperatures obtained from the Honeybee simulation, a further computational fluid dynamics (CFD) analysis was carried using SimScale to determine the distribution of temperature vertically due to convection currents.






Top Right - Figure 17:

CFD sectional view of heat distribution

Center - Figure 18:

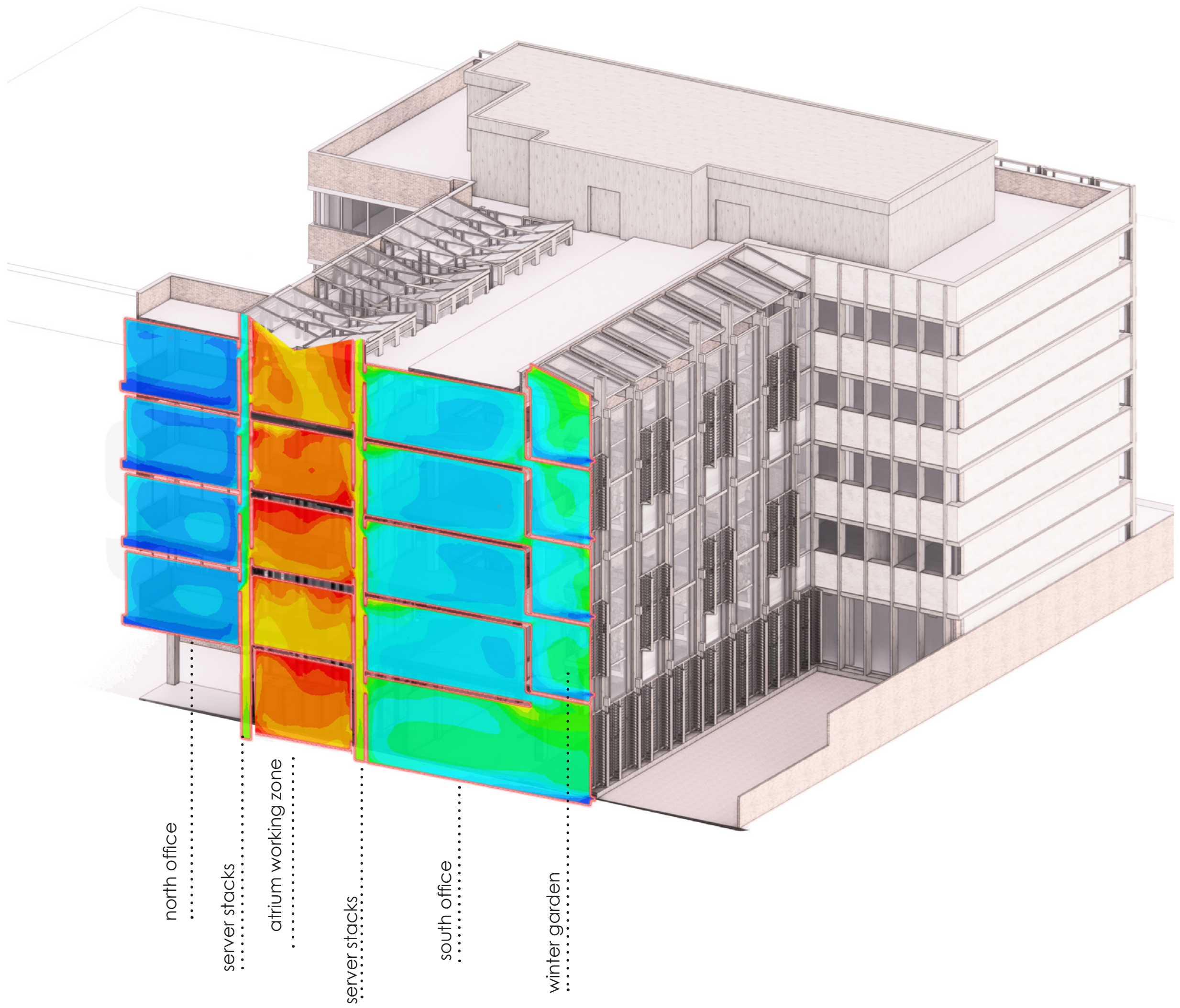
heat distribution maps for various points of the day

**Material Energies as a Spatial Generator:**

The act of using material energies to shape physical space in architecture is explored work of architects Sean Lally and Phillipe Rahm. Lally suggest that that the notion of threshold should exist 'not only as lines and surfaces, but also as intensities, accumulations and gradients – the inherent properties of the spatial distribution of temperature, scent and light' (Lally, 2009, p56). Rather than the elimination of physical boundaries, material energies could be granted more agency in their generation, a strategy typically deployed in Rahm's work. By exploitation of temperature difference resulting from thot air's natural tendency to rise, vertical stratification becomes a means of spatial organisation, with each stratum providing a thermal quality suited to a specific domestic activity.

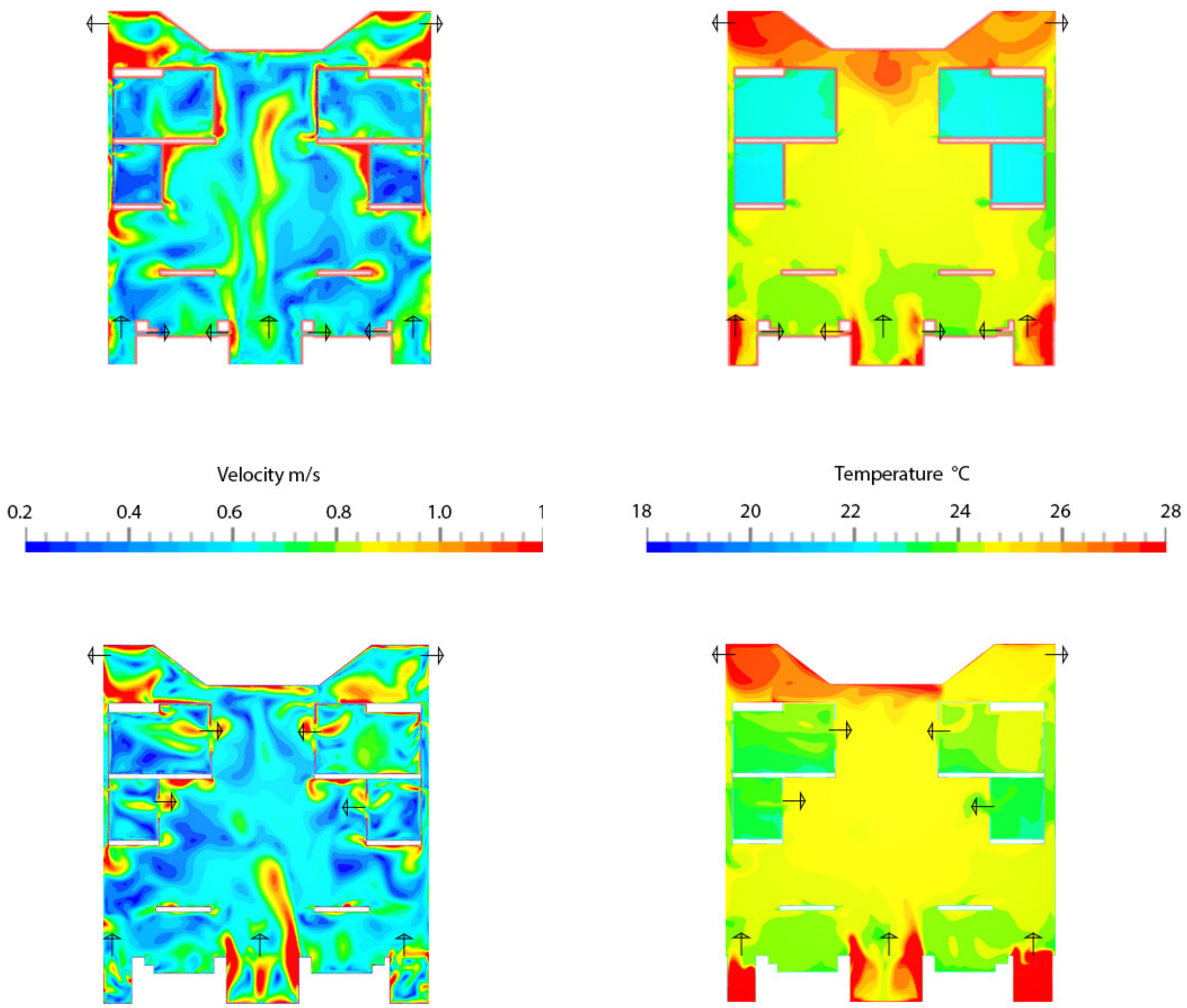
The practice of allowing material energies to dictate the design of physical built elements led me to consider Gandon House as a system of distinct thermal layers (figure 19). This change in heat and light intensity, seen to occur at south facing side of the building at the exists as an energetic boundary, immaterial in nature, albeit for the effects it has on the occupants sitting at this distance from the façade. To reduce the heat and cold experienced in these areas during more extreme winter or summer conditions, a second skin is introduced to temper the environment of the existing building. Rather than limiting this architectural feature to a service zone, it is extended to become a winter garden. While acting as a buffer for the spaces within the existing building, it also provides a thermal experience that is distinct from the interior - brighter, more responsive to external temperature and wind fluctuations. The addition of an internal atrium was then developed to allow light into the deeper plan and ventilate the building using the stack effect which is accentuated through the hot air emitted from server outlets on the ground floor and allowing this hot air to rise through the stacks, while pulling stale air from adjoining spaces.

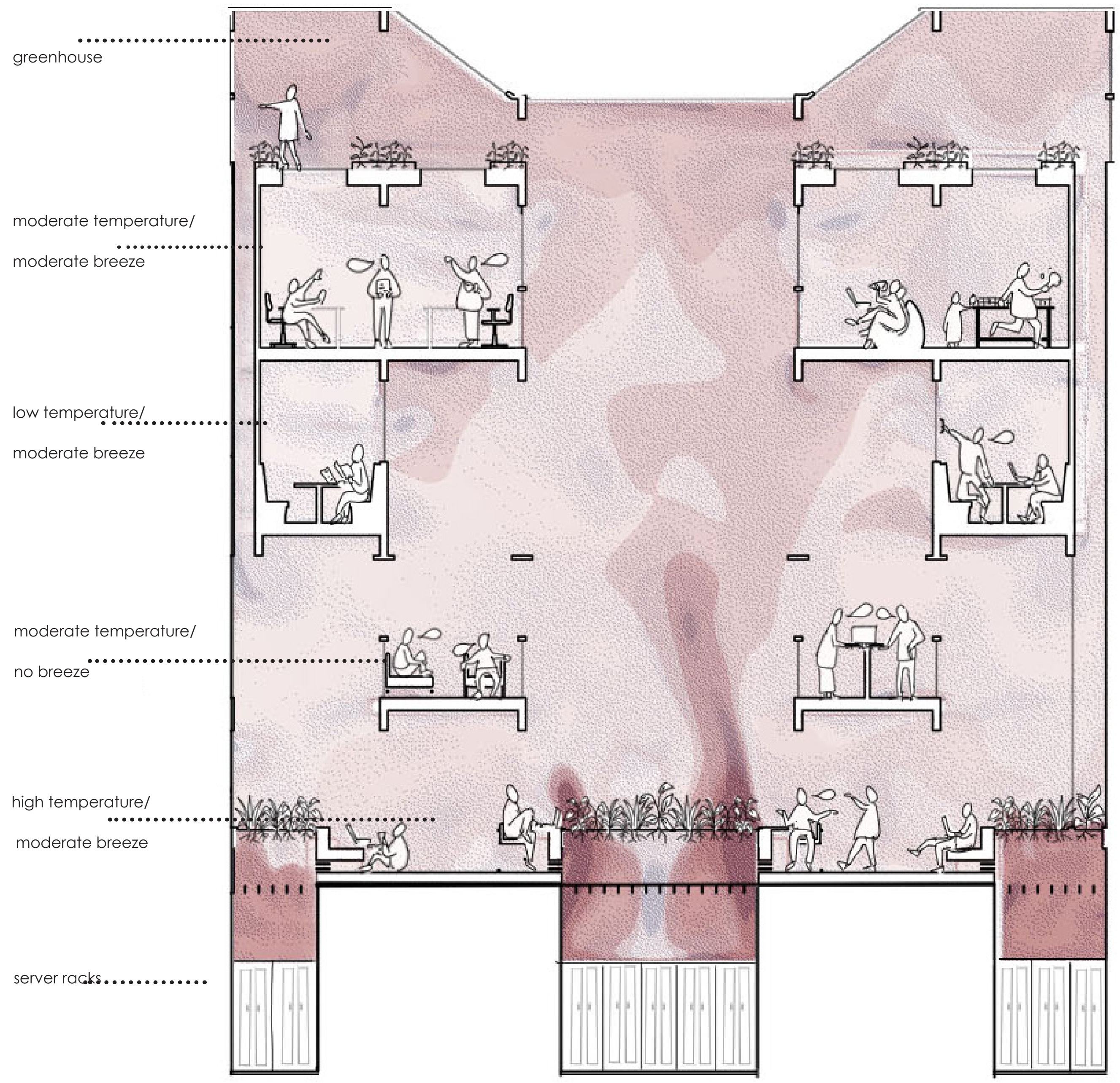
The framework of Rahm's design practice advocates for the role of the architect as meteorologist which places greater emphasis on 'the movement of air, pressures and depressions, stratification of temperatures as new ways of architectural composition' (Rahm, 2008, p46) rather than minimising and concealing them through technological means. In my own experience as a designer, I recognised a lack of knowledge about these phenomena as they had never been particularly central to informing my own practice. Through iterative simulations of air flow and heat transfer for differing ventilation opening placement, I developed a design which was informed by the movement of air and heat and provided thermal contrast within different parts of the building. The resulting air and temperature patterns were overlaid on the building section to depict the change in atmosphere and occupation by different individuals (see figures 24,25,26). The computational fluid dynamics simulations served as a basis for informing the building's mass, voids and openings. Once established, traditional methods such as drawing and modelling were used to further the design.



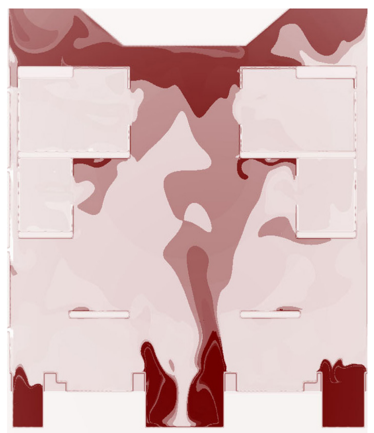

Above - Figure 19:

Proposed thermal layering, CFD results overaid on model

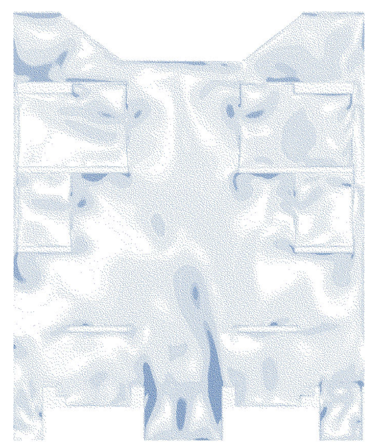



CFD analysis all windows open vents closed



CFD analysis all windows open vents closed



Above (left column) - Figures 20 & 21:

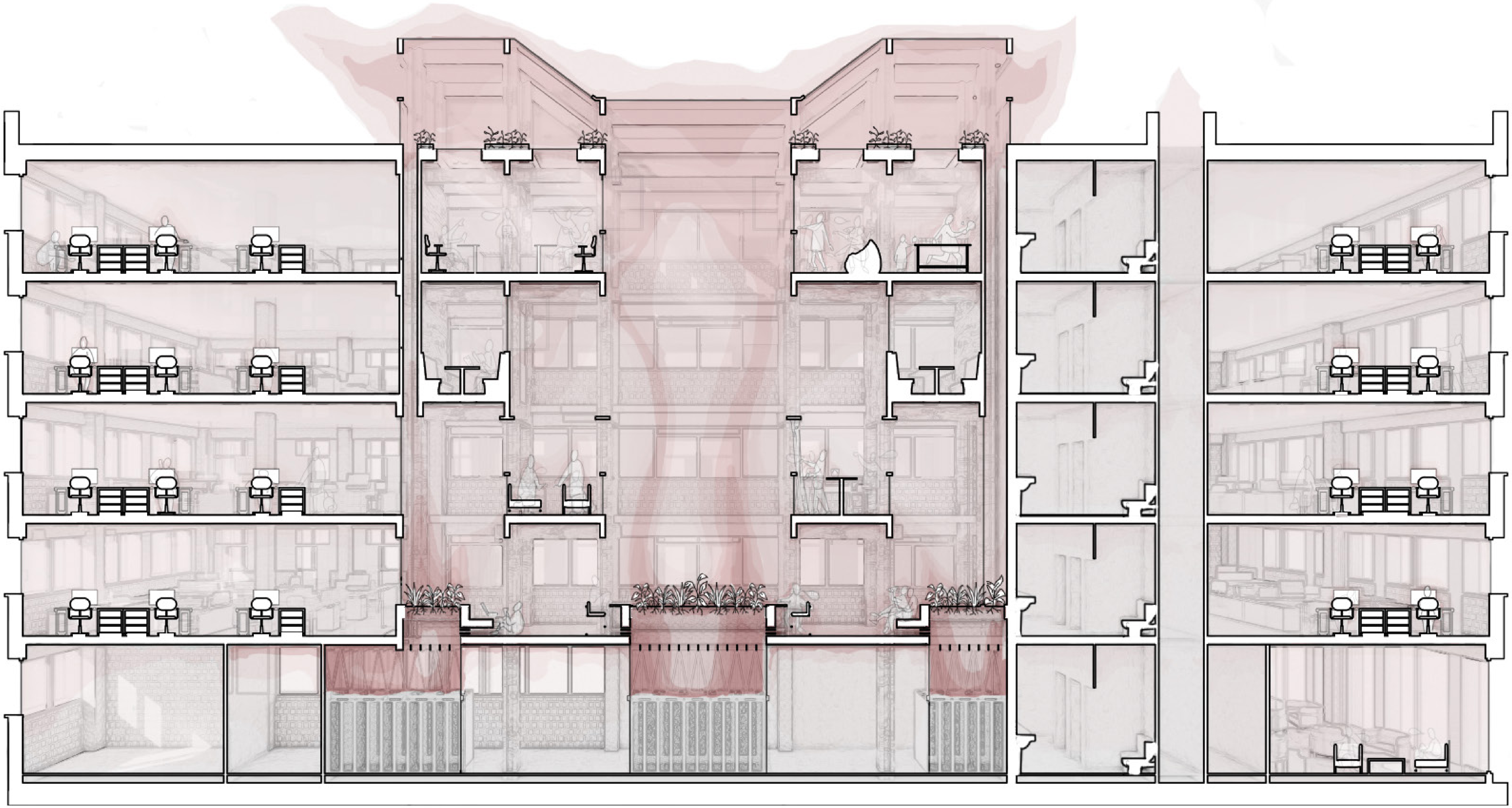
Airflow patterins in attrium with different opening configurations

Above (right column) - Figure 22 & 23:

Airflow patterins in attrium with different opening configurations

Right - Figures 24,25 & 26:

Layering of heat, air and acitivity in atrium



Above - Figure 27: Inhabted section:

**Construction Ecology:**

In a broad sense, the open thermodynamic perspective demands the consideration not only of the energy exchanges that occur once a building is constructed, but also those involved in its engenderment. This forms the basis of construction ecology, introduced by Charles J. Kibert and adopted in architectural field by Kiel Moe (2009) and Jane Hutton (2020), in which the authors undertake investigation into the stories of material movements from sites of production (landscape) to sites of consumption (building). While such long form accounts are outside the scope of this project, the material energy in this retrofit is worth considering. The façade, which is the primary focus of this retrofit, typically constitutes 13% of the total energy embodied in a building's construction materials (LETI, 2020). The proposed features of the winter gardens and atria require a large quantity of additional glazing, while the existing glazing is to be replaced with new double-glazed windows in parts of the building which have no second skin. This presents an opportunity to examine how the exiting unitised ribbon-glazing panels could be re-used for the new features, to form a regenerative cycle which is typical in the ecosystem dynamics described by Kibert as 'the creative part of destruction which occurs when destruction allows the components of a system to be reassembled into a new, potentially improved organization' (Kibert and Sendzimir, 2001, p145).

Following this rationale, the glazing façade and atria are designed as modules comprising windows from the existing building which are to be removed and assembled off-site. The dimensions of the elements in the former building are retained to allow for continuity with the existing fabric. The brick and concrete block portions of the façade are preserved and supplemented with a layer of hempcrete insulation externally, lessening the thickness of hempcrete required and allowing the external walls to act as one mass heat-storing element. The tectonics of the retrofit are developed through axonometric drawings which show the assemblage of new and existing materials.

Figure 28:

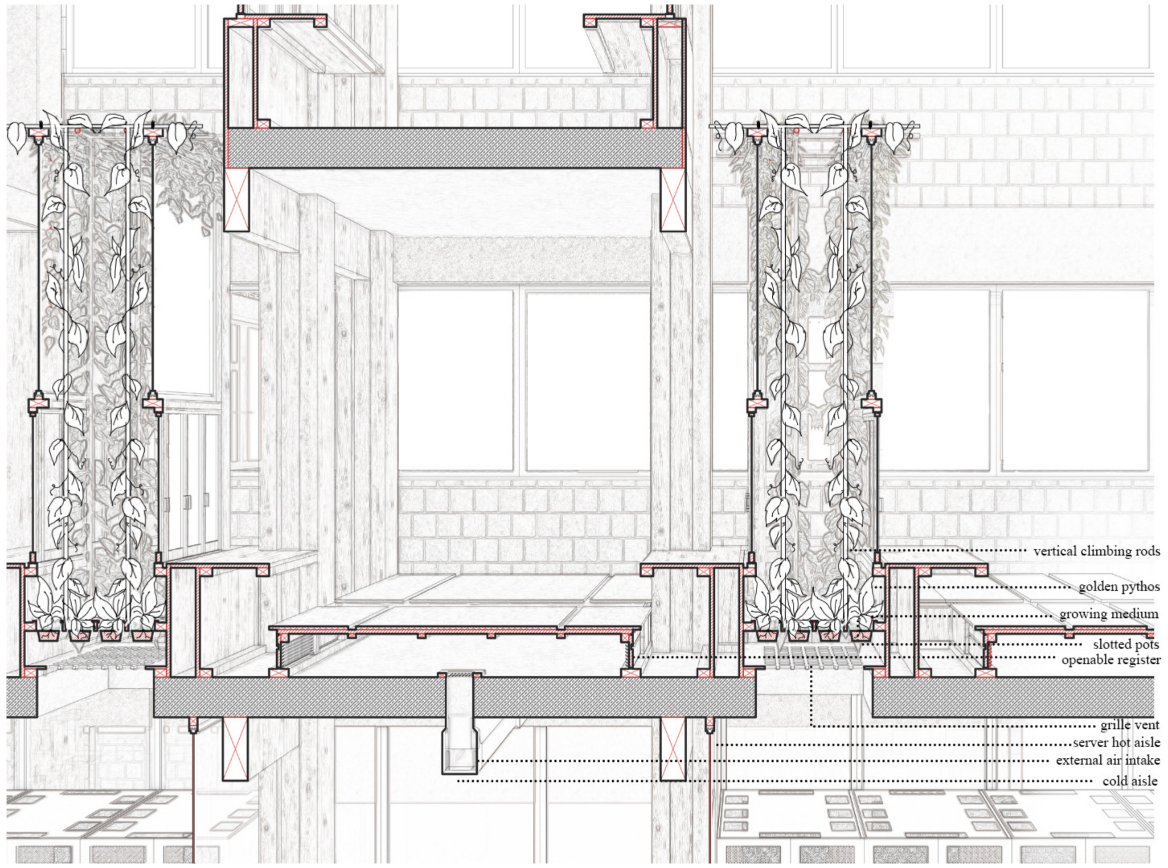
Facade buildup with glazing assembly

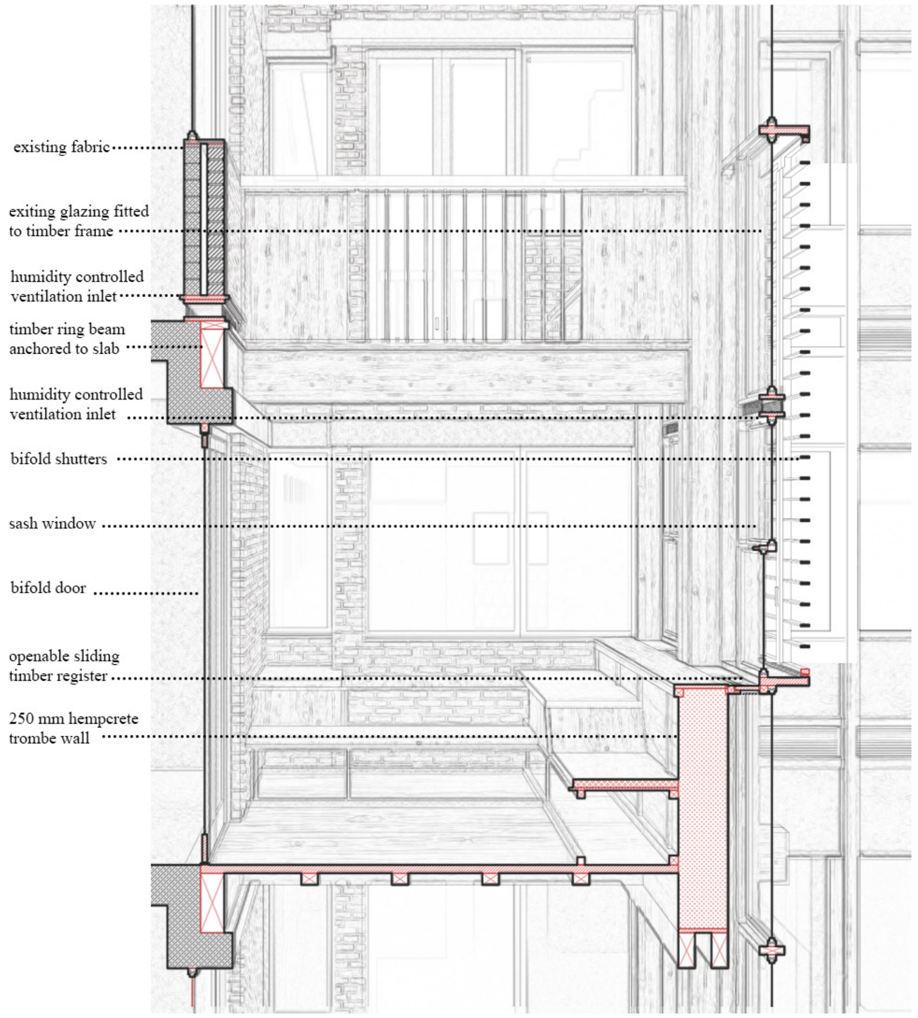
**Ritual Adaptations:**

The adaptations which people engage in during their occupation of a space give rise to the rituals are detailed by Knowles and Heschong through actions such as seeking refuge from the sun under a shaded porch or adjusting the jalousie in the window of a traditional Turkish house to let the light and heat in. He laments the absence of such modes of adaptive behaviours in contemporary buildings, arguing that:

> Architecture, by depending too much on machines, has worked against adaptive rituals as a mode of self-expression. This is the result of neither designed nor accidental chaos in the patterns of space and events. It is, rather, the product of rhythms that are too simple and continuous to capture our notice and challenge our imaginations.
> (Knowles,2012, p20)

This observation may be viewed as a response to satisfy the largest number of occupants such that no individual can make a change that impacts the comfort of others, particularly in workplace settings. However, the design of a heterogenous thermal landscape suggests that there should be room for these small adaptations, particularly in intimate spaces where an occupant may retreat from the collective. These areas remain separate to the main open plan space communal work occurs. Details of the adaptive spaces were developed to show various individuals making changes to their environments in the winter garden and atrium through the opening of windows and ventilation registers to increase the sensation of heat or air movement. These drawings were then animated to show the effects of these interactions with the building on the atmosphere of the space. The stills of these animations are presented here for each adaptive action (see figures 31 - 36).



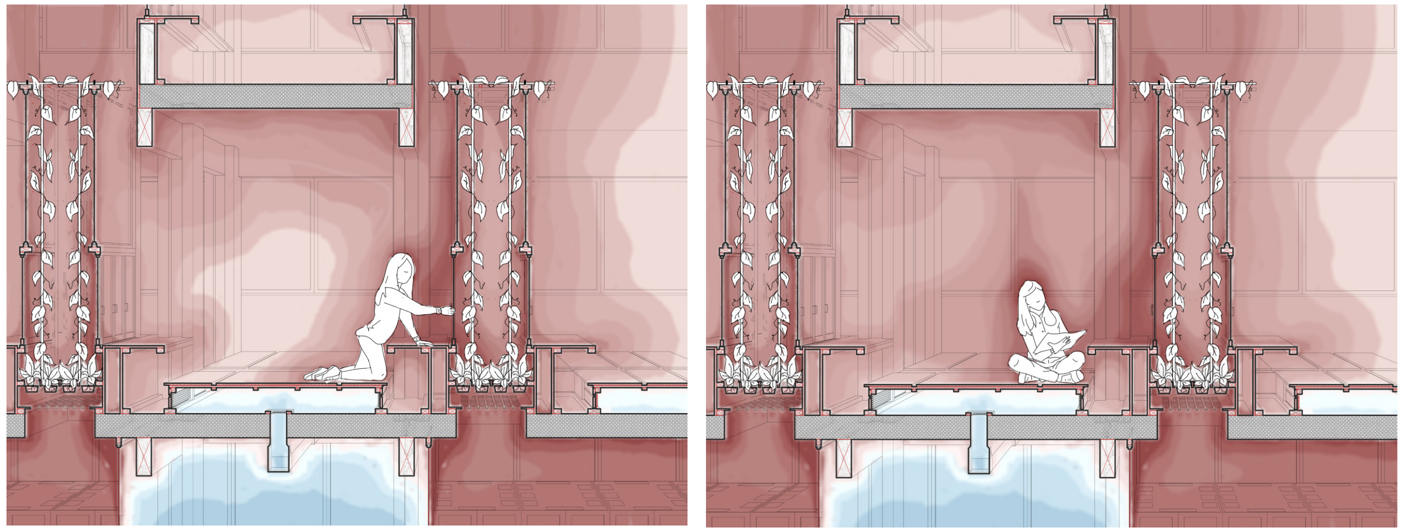




Above - Figure 29:

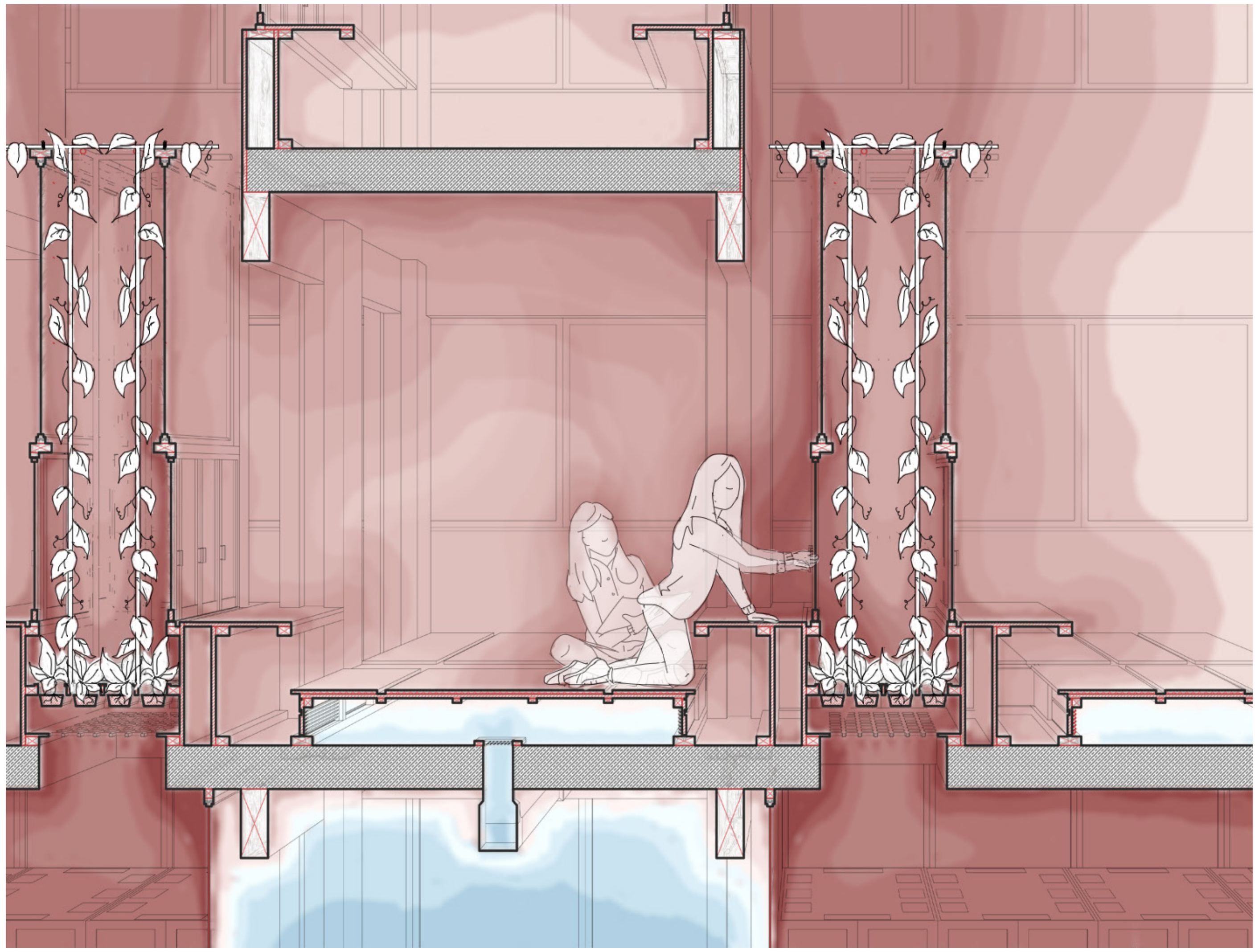
Atrium detail ground floor

Above - Figure 30:

winter detail ground floor

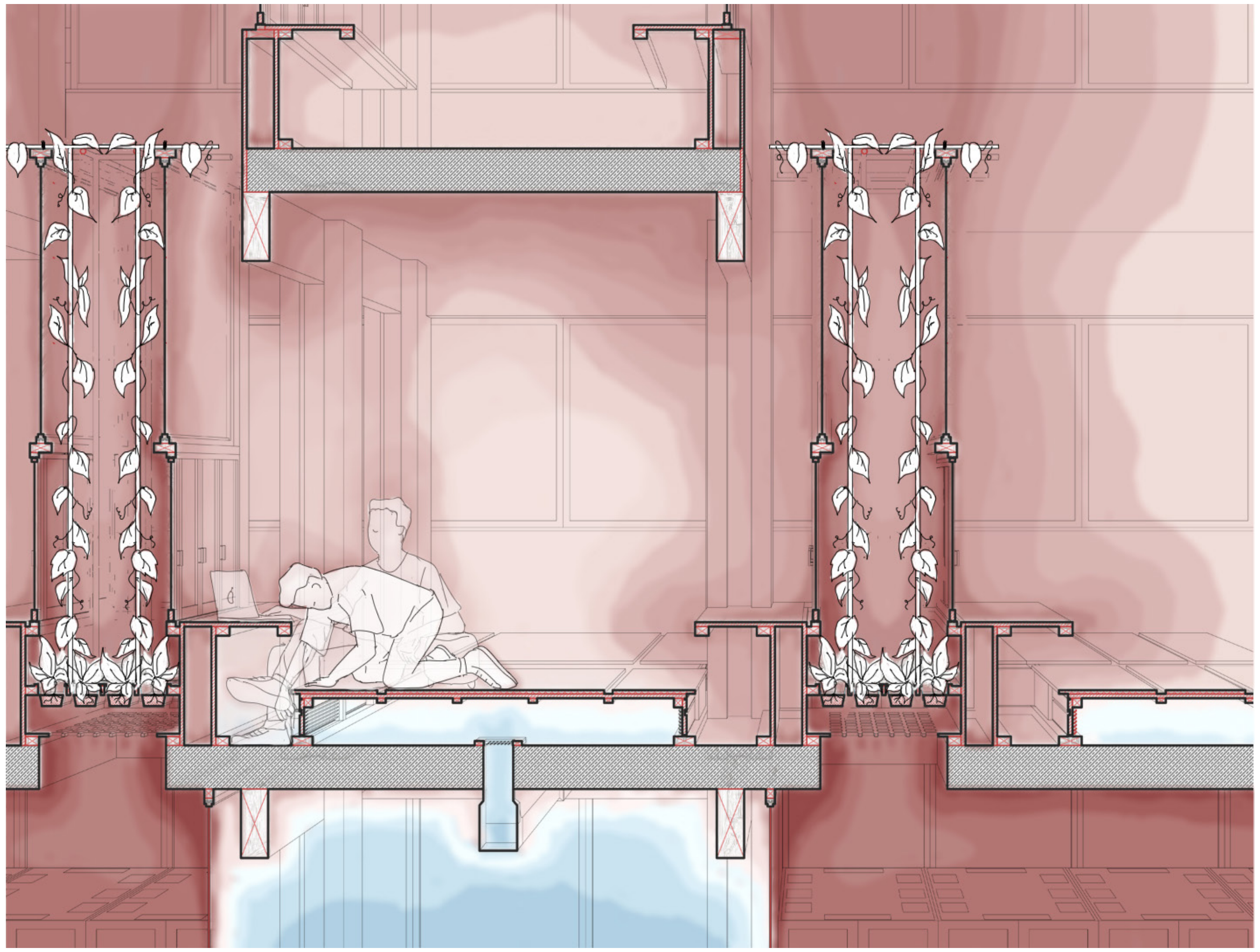


Above - Figure 31 & 32: atrium cuppant adjusting for comfort - warmer

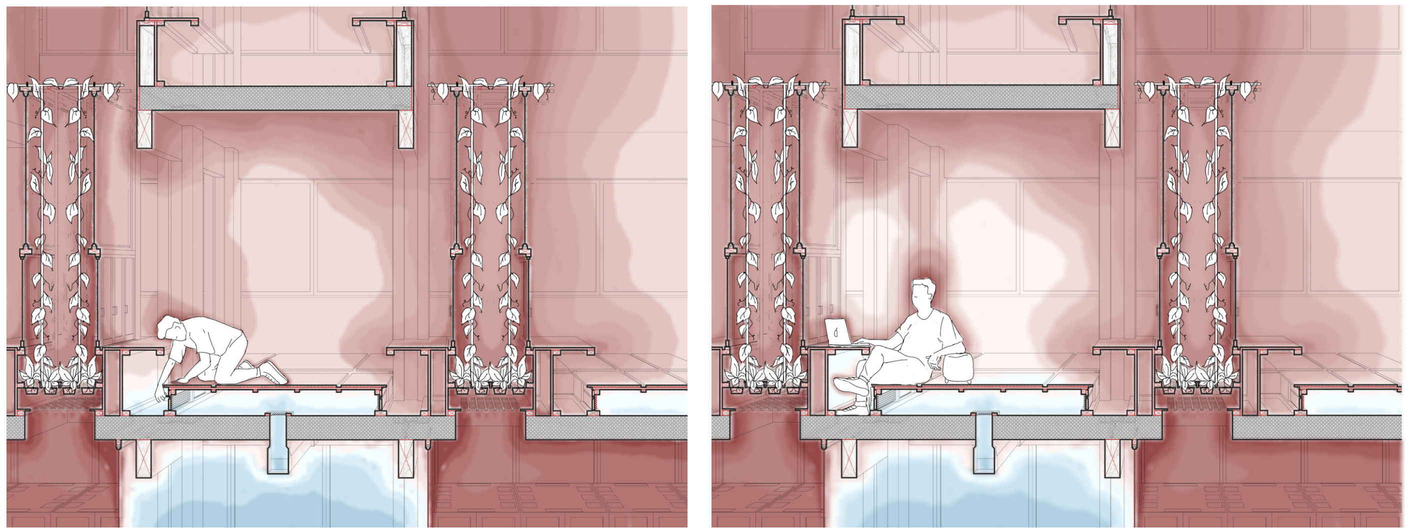


Above - Figure 33: Atrium ocuppant adjusting for comfort - warmer (layered)

Below - Figure 34: atrium ocuppant adjusting for comfort - colder (layered)



Below - Figure 35 & 36: atrium ocuppant adjusting for comfort - colder



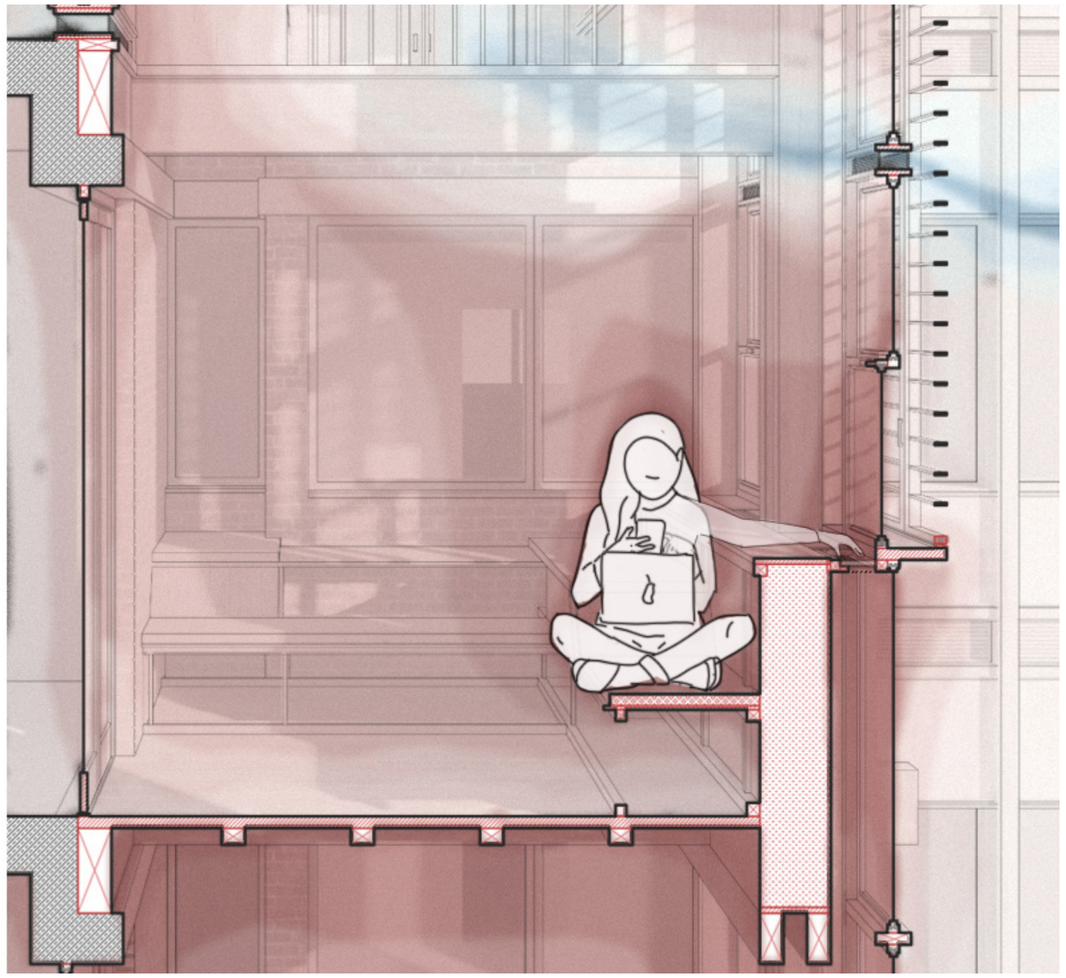
**Reflection on Process:**

> we continue to believe in the sciences, but instead of taking in their objectivity, their truth , their coldness, their extraterritoriality—qualities they have never had, except after the arbitrary withdrawal of epistemology—we retain what has always been most interesting about them: their daring, their experimentation, their uncertainty, their warmth'
> (Latour, 1993, p142).

Latour's words on becoming Non-Modern articulate my reflection upon the research project. A large driver of this exploration was the use of thermal modelling software to simulate heat distribution for various locations of ventilation openings and atria and allow the resulting temperature patterns to aid in making design choices. Such emphasis on simulations could be viewed as reducing the architectural process to the subservience of technological determinism, and deferring to a 'technocratic, scientistic posture to validate a range of design strategies and agendas' (Moe, 2016, p1129). His critique is not unfounded, as it is apparent that these simulation techniques can be used to bolster efficiency claims that may not hold up once a building is constructed. However, I would argue that their value varies depending on how they are used. My interest in using computational fluid dynamics came out of the limited knowledge I had of heat transfer and the desire to learn understand what the thermal possibilities were within the existing Gandon House.  The initial design intent was to investigate ventilation in the central atrium but design changes continued to the be made and tested through observing the effects they had on airflow and temperature patterns.

Deleuze and Guattari describe the itinerant artisan as 'one who is determined in such a way as to follow a flow of matter,' for whom it is 'a question of surrendering to the wood'(Deleuze and Guattari, 1987,p408). So to0 can architects use tools such as to surrender to energies and use these phenomena to inform their design choices. By granting architecture more agency over thermodynamic forces, rather that relegating them to the realm of mechanised services, perhaps novel ways of organising space could emerge through such an experimental attitude. The current problem with this proposition, however, is that tools such as Honeybee and Simscale which were used on this project, are difficult to master and take a long time to generate results. At present, they are predominantly used not as early-stage design tools but rather to optimise hvac equipment once a project is near completion. If I were to take this project further, I would consider looking at how to develop tools that make it easier for architects to evaluate the thermal conditions in their designs without in-depth knowledge of fluid dynamics.

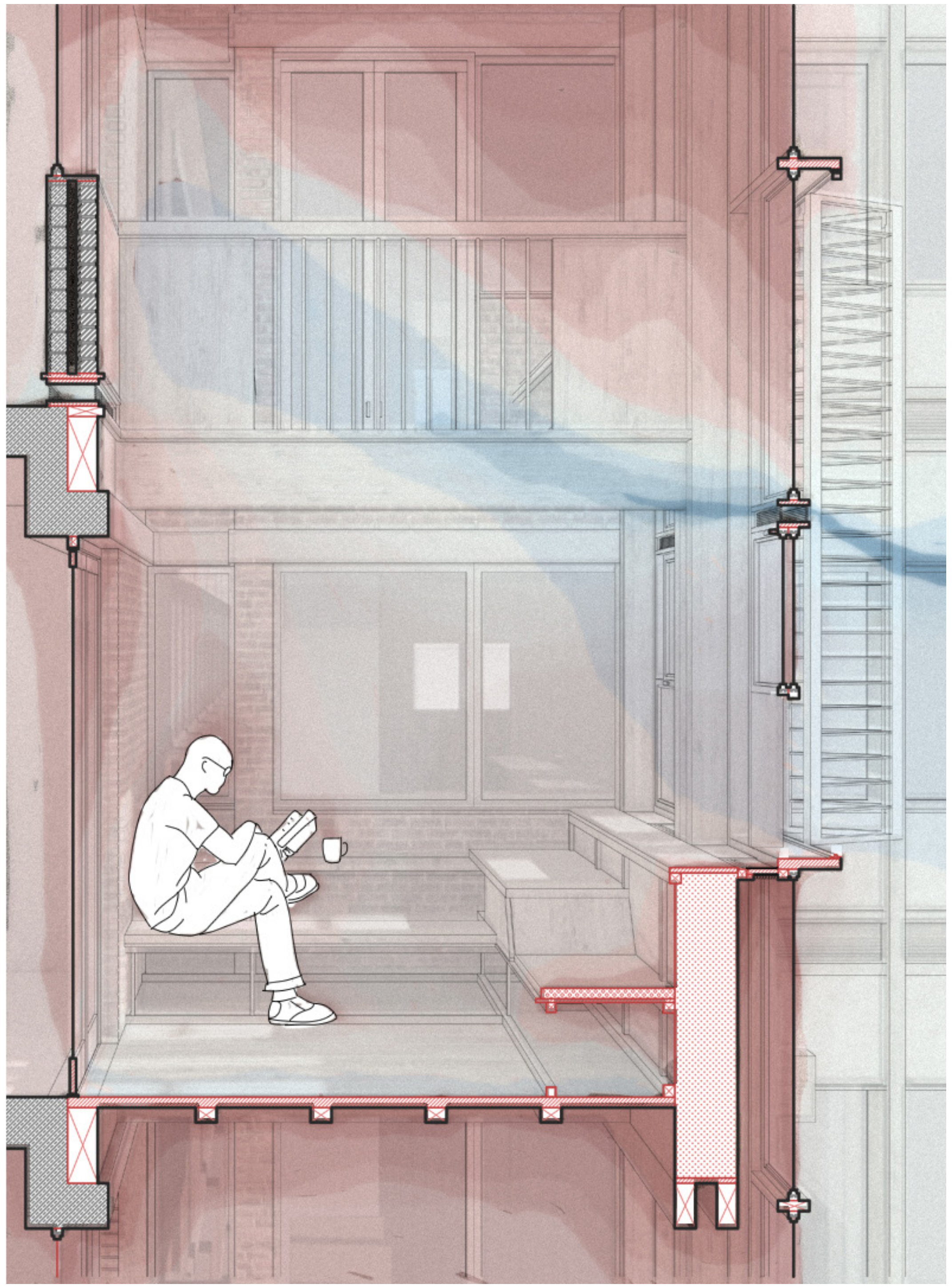
There is furthermore, the question of how to convey thermal comfort qualitatively in architectural representation. When one imagines an image which captures the atmosphere of a space, they most likely do not think of heat maps. The incorporeal nature of heat is difficult to capture, though materiality and light may give a glimpse of its presence. 'A picture of a mosque in Isfahan, for example, with its polished marble floors and heavy masonry walls, its high airy vaults and deeply shaded recesses, looks invitingly cool and refreshing' (Heschong, 1997, p35). The detailed drawings of occupation and changing atmospheres over time were quite ambitious as they combined 3 drawing media - rendered perspective images, CAD drawings, heat maps into one animated drawing. The success of this format I believe, was due to the animation element. Presented here in still format, they lose the dynamism which accompanies the stream of cold air or pulse of warmth that the moving image brings. There existed very few examples to draw from in creating these illustrations, and I wondered if others too, have struggled with making visible the invisible the currents of air or wavelengths that I had tried to capture? Perhaps my drawings might inspire someone else's valiant attempts.



Above - Figure 37: atrium ocuppant adjusting for comfort - warmer

**Conclusion:**

Ultimately, it is my hope that this research project can prompt a reconsideration of how architects might approach thermal environments. The examination of current approaches to thermal comfort demonstrates that, although the field showing progress in the establishment of less deterministic models of comfort, the notion of thermal optimum persists. As suggested by many of the authors examined in this research, the striving for homogeneity is a relatively new concept, one which was grew with the advent of technologies such as air conditioning and was readily adopted by modernity and architectures of the machine age. Through this quick uptake, lost were the instances of delight that arose from the traditions of building in tandem with natural rhythms. This project looks to recover this delight and embed it in the daily rituals of a contemporary office. To achieve this, the architect must become meteorologist and learn to work with the forces of convection, conduction and radiation, even if fully mastering these complex phenomena is still out of reach. This is the reality of living in what Karl Popper terms, a 'world of propensities', a world of largely indeterminate processes which probabilistically tend towards some states over others, but whose dynamics can never be known with true certainty, (Popper, 1995). Nonetheless, I feel that it is important to communicate the range of these possible states through the design process, rather assume humanity will continue to inhabit an indoor climate of 22 degrees as the planet edges closer to climate catastrophe. 'The largely unquestioned hylomorphic model of causation that has led to the Anthropocene—that of human intent imposed on a seemingly inert world—should be a core ontological concern for the present moment' (Moe, 20196, p3). Architecture has long been complicit in complicit in supporting this habit of mind by producing buildings that function as closed isolated systems. By shifting the perspective to a more open thermodynamic view, it is hoped that architecture can re-connect people to their wider environments and make room for moments of thermal delight in the workplace.



Above - Figure 38: atrium ocuppant adjusting for comfort - colder

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