Sensual Building Systems:
A Thermodynamic Approach to Urban Public Space

by

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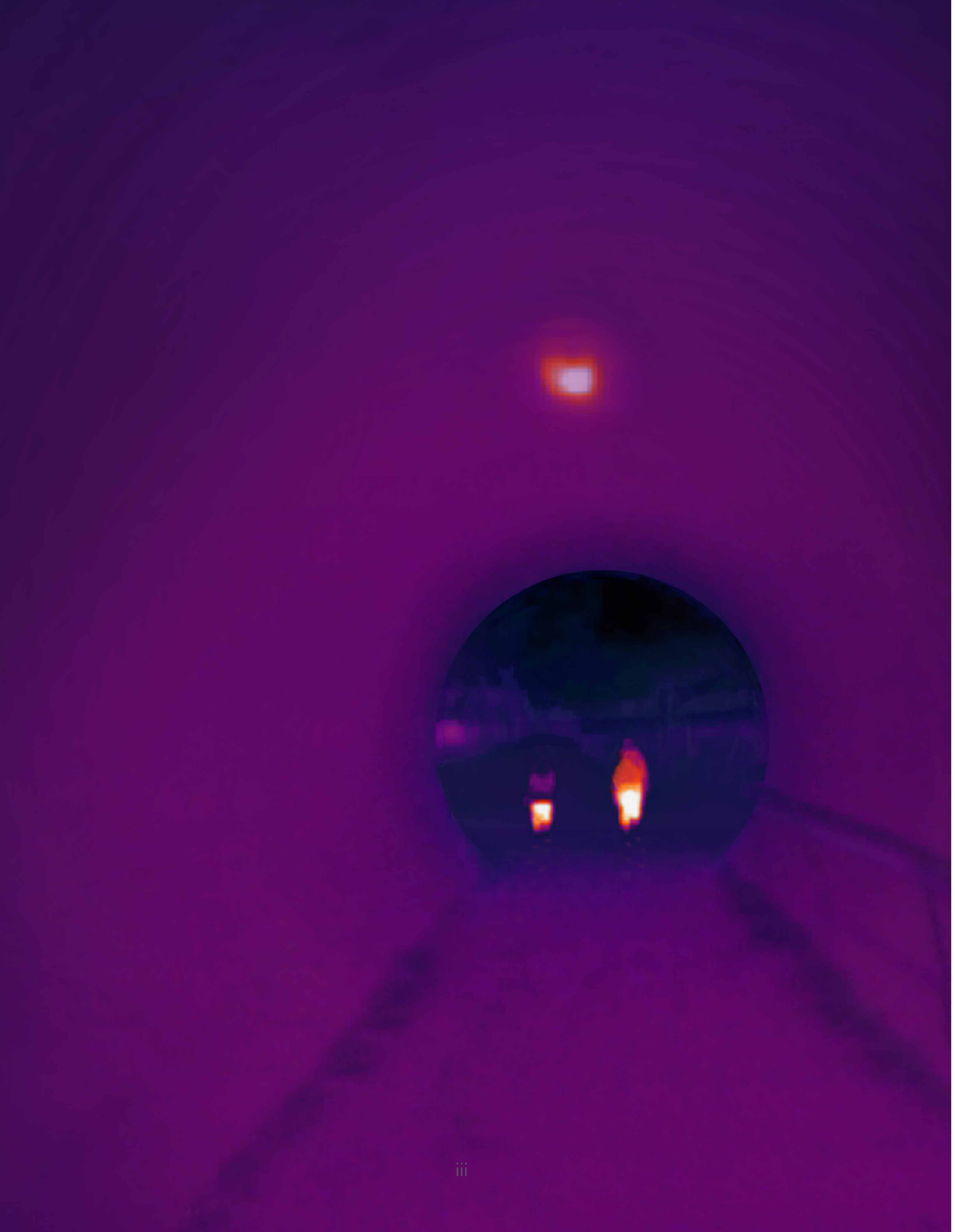
ABSTRACT

There is energy all around us, left unperceived by the senses. At the interface of the envelope, energy transformations are constantly occurring within the layers. For architectural design, these predominantly unseen energies affect perceptions of the exterior, and potential 'felt' experiences of the interior. The zones of energy that exist amongst the envelope should not separate the interior from the exterior, rather they should be seen as a transformative system of exchange between the exterior and the body within a thermodynamic space. In effect, this creates a zone 'in-between,' with various ergonomic conditions that can be felt by the body.

Within the urban environment there is constant sensory overload. Preference is given towards natural environments for places of relaxation and well-being. Parks and green-spaces attempt to encourage comfort in the city, but the provided places rarely consider the dynamics of the seasons and the interactions between demographics. By filtering and modulating our perceptions of 'energy,' and the occurrence of microclimates, there can be a re-attunement towards the ways urban environments are perceived and experienced. The awakening of thermal perceptions can increase sensitivity to the 'felt' senses, tempering the visual, and promoting well-being through sensual building systems. In terms of sustainable design, common approaches rarely look at the provided support for the occupants' well-being and the relationship between the body and the 'felt experience' of architecture. Sustainable practice tends to focus on quantitative factors rather than qualitative needs. With a lack of visual means and simulation technologies to understand thermal behaviour and the energy transformations that occur, sustainability has a difficult time advancing in terms of well-being and body comfort. Accordingly, there should be an alternative perspective on energy. Where energy is understood as a vital component to public space and the interactions between people and their experiences within the built environment.

As the hub for Northern Ontario, Downtown Sudbury will be investigated, along with the need for urban public space under winter conditions. At the proposed Downtown site of 70 Elm street, the public space will engage the varied demographics, whilst providing an intriguing insight into designing with thermal energy. As a south facing pocket park condition, the public space will bring a thermally-rich engagement towards the senses, and serve to generate positive experiences, for a new perception towards urban environments. In turn, a more inclusive micro-culture will be formed through the incorporation of 'energetic' interactions, acting as a social and sensory therapy to destress and connect with others, and become more attune to urban thermodynamic surroundings.

Experimentations with thermal energy and energy phenomena will be conducted to understand thermal radiation and laminar flow to ultimately create a range of potential 'felt' experiences amongst threshold spaces, suggesting activities for warmth or cooling. The method of thermal imaging will develop an understanding of material application and form, in terms of thermal conductivity and mass. The findings will lead to a knowledge of spatial properties, creating platforms with spaces that are thermally ergonomic and can be modulated for customized comfort. From the research into thermodynamics and the zone of concern being the 'in-between', the experiments will provide a translation of these interests to potential sensory experiences; enabling an urban site to be conceived for community healing and well-being.



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This thesis seeks to uncover:

How thermodynamic space
defines the zone between the inside and outside,
and the ways this can sensually enhance the experience of exterior conditions
in order to engage symbiotic connections and synesthetic perceptions,
between ourselves and the urban environment.

Sensual Building Systems

A Thermodynamic Approach to Urban Public Space

PREFACE

Through urban practice and livelihood, there is an increasing detachment from the natural world. Indoor environments do not provide the variances as we experience them in nature. With a majority of time being spent indoors, the need to be attune to our exterior surroundings is generally overlooked. In effect, the built environment becomes relied upon for our connection and beneficial understanding of the natural world. Simultaneously, there is an urge for sustainability to reconcile the built environment with nature. Yet the ways in which architecture affects our own relationship to nature is neglected.

Although technology has brought sustainable design strategies, there is risk in interrupting our associations with nature; as technology is inclined to generate sustainable systems geared towards the model of energy-efficiency, and not necessarily the well-being of its users. This is a problem. As the misrepresentative use of technology can impede on sensory perception, increasing the sense of nihilism and forming a societal tendency to engage less with the physical world.[1] However, if the perceived awareness of nature and its phenomena are already weak, as in the case of urban environments, "one can only see the aesthetics of nature with the aid of the technical object."[2] In this way, when applying the concept of the 'technical object' towards architecture, there is potential to achieve a more fluid relation between us and the natural environment through sensual building systems.

There is a reliance on nature for our well-being, just as nature relies on us for maintaining ecological balance in a symbiotic relationship. As our time spent indoors increases, the window becomes a customary means for connecting to the outside, and technology prevails for accommodating our sensory engagement and interaction needs. In spite of this, there is opportunity for a "curious exchange" to take place between the body and the building at the face of the window.[3]

The compelling potential of the window lies in the limited boundary between the inside and outside, allowing for the mediation of exterior conditions. It is in this mediary zone where sensorial aspects of nature can be enhanced, playing with conditions of climate in the space of the building envelope. Correspondingly, the apparent interface of concern is the building envelope, the zone 'in-between,' directing the interrelationship between ourselves and the outside world. By understanding the 'control layers' of the building envelope: weather, air, vapour, and thermal flow; these layers can begin to distinguish the thermodynamic environment in-between the inside and outside, the artificial and natural, the human dwelling and nature. Since the building envelope has the ability to control, mediate or enhance exterior conditions, there is possibility to use the sensory aspects of nature to enable synesthetic environments supportive of health and well-being.

1 Alberto Pérez-Gómez, *Attunement: Architectural Meaning after the Crisis of Modern Science,* (MIT Press, 2016), 210.
2 Gilbert Simondon, "On Techno-Aesthetics," trans. Arne De Boever, in *Parrhesia,* no. 14 (2012): 5, https://www.parrhesiajournal.org/parrhesia14/parrhesia14_simondon.pdf.
3 Lucy Huskinson, *Architecture and the Mimetic Self: A Psychoanalytic Study of How Buildings Make and Break Our Lives,* (Routledge, 2018), 96.

INTERFACE OF THE BUILDING ENVELOPE

INSIDE, OUTSIDE, AND IN-BETWEEN

The inside and outside are understood as two separate environments, but what about the in-between. At the interface of the building envelope, what occurs within this threshold that allows for the inside to have such different sets of conditions than the outside. If an authentic architectural experience relates to the approach and confronting of the building, through entering a door or looking through a window, then it is the space of the building envelope that allows for these experiences to occur between the inside-outside.[4] Subsequently, the performative qualities of the building envelope may be affecting well-being, by putting aside these significant experiences of interaction with architecture.

Figure 1.1 Thermal Interactions at the Interface of the Window.

WINDOWS AND THE BUILDING ENVELOPE

The building envelope is not merely a skin, it is made up of layers which control thermal energy, moisture, airtightness, acoustics, and light.[5] As an interface, the building envelope physically separates the interior environment from the outside through floor, wall and roof systems. Traditionally, the building as a shelter never had a need to provide comfort, as it served only to relieve the extreme conditions that were beyond the human body's ability for adaption.[6] The building envelope developed into a tighter enclosure to withstand these weather conditions, and as technology became more sophisticated, it was able to further serve this shift.

Technology brought mechanical environmental control as a lasting modification to the primacy of architecture,[7] evolving the building envelope into "the place to exhibit technological sophistication."[8] Here, the performative qualities are displayed in keeping the weather out, and the conditioned environment inside; where the customary aim is to minimize exterior energy and climate loads, in order to harness a controlled interior environment. Yet, this technology discounts the benefits of porosity and the working layers of the envelope, which form associated states that are more responsive to the environment. The precision technology has brought to environmental control, also, does not gauge the extent to which controlled interior environments are truly healthy and comfortable. The specific interior parameters of temperature, humidity, and ventilation, usually dismiss the customized comfort of the occupant or their physical and psychological well-being.[9] With each person having their own conditions of comfort, the sense of well-being can be subjective, and thus variances within interior environments must be considered. Further in view, "the sense of comfort or well-being of a person contributes significantly to the person's health and productivity."[10]

Current means of experiencing these variances, and connecting to the outside from our indoor environments, is usually through building systems such as windows. As the boundary of one's tactile engagement with the outside, the window mediates the experience of weather conditions, providing "a transitional element of depth, at the visual and thermodynamic junction between inner needs and outer givens."[11] Not only does the building envelope layer bring daylighting indoors, but also serves as a passive heating strategy, and can reduce energy usage. However, when windows are not articulated or implemented appropriately, such as creating a glare or draft, they become a hindrance, and desensitize our need to connect to the outside world. This is a problem, as windows play a significant role in boosting well-being, so much so that Glasarchitektur was phantasized in hopes that this new type would "respond to changes in external and internal illumination, and [be] programmed to enhance [the] daily routines and emotional states of the inhabitants."[12] Though excessive use of glass is not ideal under certain climate scenarios, the importance of the window should be highlighted, as time is increasingly spent indoors. In relation to the building envelope system altogether; understanding the ways in which these systems control, mediate or potentially enhance our perceptions and connections towards exterior conditions, can initiate the relationship of well-being at the interface of the building envelope, the zone 'in-between'.

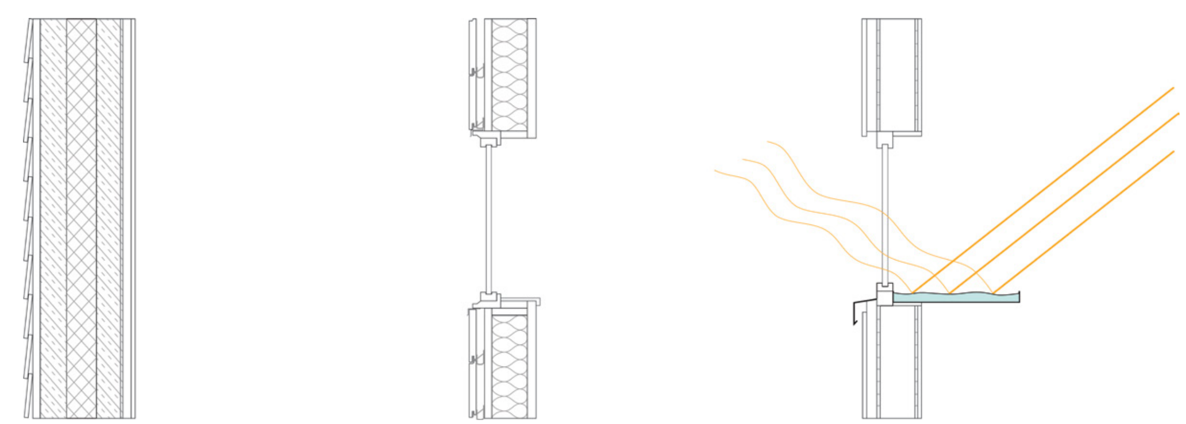


Figure 1.2 Building Envelope Types: exhibiting methods of control, mediation, and enhancement of the exterior conditions.

4 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture,* (William Stout, 2006), 35.
5 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction,* (Birkhauser Architecture, 2018), 7.
6 Sean Lally, "Energies: New Material Boundaries," in *Architectural Design,* 77 no. 3 (London: John Wiley, 2009), 13.
7 Reyner Banham, *The architecture of the well-tempered environment*, 2nd ed, (Chicago: University of Chicago Press, 1984),14.
8 Rosa Urbano Gutiérrez, "The naturalisation of architecture," in *Architectural Research Quarterly*, 20 no. 3 (2016): 264.

9 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction,* (Birkhauser Architecture, 2018), 7.
10 Ibid., 13.
11 Josep Lluis Mateo, and Florian Sauter, eds., *Earth, Water,Air, Fire: The Four Elements and Architecture*, (Actar, 2014), 13.
12 Reyner Banham, *The architecture of the well-tempered environment*, 2nd ed, (Chicago: University of Chicago Press, 1984), 292.

CONTROL, MEDIATE, ENHANCE

Boundaries and borders are more of a "transformative tension" rather than a dividing line,[13] where the building envelope acts as the object of transference, exhibiting these tensive elemental interactions between the outside and inside.[14] There are several measures which define the ways the building envelope behaves with exterior conditions. In consideration of extreme climate, or maintaining a consistent conditioned interior, the building envelope functions as a measure of control; where the system acts as a strict climate barrier between the interior and exterior. In the case of windows and doors, these elements mediate the relationship between the interior and exterior, as they break the defining threshold of the envelope. This brings opportunity for light, solar gain, ventilation, air circulation, and sound to flow in from the outside.

Although these mediating functions of the envelope bring a means of experiencing variances, phase changes are also occurring due to the energy flux between the outside and inside, which in terms of a controlled environment can cause thermal bridging issues and moisture problems.[15] Phase change materials maximize the latent heat present, where sufficient energy can be absorbed, stored and released, within the threshold space, to provide useful heating and cooling. The principle of perspiration relates to the phase change of evaporation, which can be experienced by the body when the withdrawal of energy causes the skin to cool.[16] Understanding phase change can generate ways for transitional spaces to interplay the exchanges of energy with the physiological aspects of the body's health and comfort. In relation to sustainability, an argument arises as controlled interior environments are not optimal for health and well-being, nor are the mediating conditions for a controlled environment optimal for energy efficiency. By applying principles of phase change in relation to sustainability and health, a system can enhance exterior conditions, and elements can express the resulting variances.

In order to create a system which enhances exterior conditions, the elements need to be perceived in a manner that is not usual. Rather, it is grounded upon the interaction of weather variances between the building and the body. For instance, a water shelf is a method used to enhance conditions of the exterior. Light is filtered in through the window, where reflective water patterns are casted onto the interior ceiling; the effect is dependent on the conditions of the sun, and the water movement from the wind. Interestingly, this system promotes a calming effect on the individual, as the system relies on the unpredictable movement of the wind, and light of the sun.[17] In a sense, the uncontrolled nature of weather, having a specific time and place, is what allows for a building system to have the most potential in enhancing our connection to the outside. If the system implements the experience of energy exchange undergone by the body, well-being can also be improved.

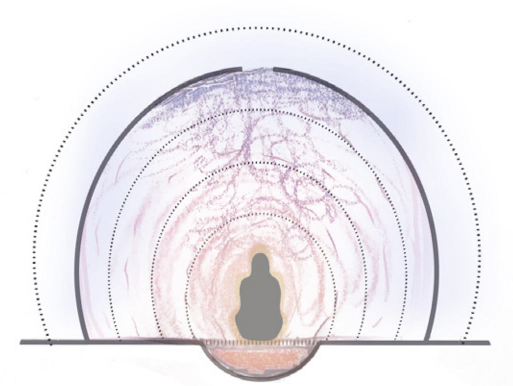


Figure 1.3 Interactions between the body and the outside through the modulated building envelope.

13 Jane Rendell, *The Architecture of Psychoanalysis: Spaces of Transition*, (London, New York: I.B. Tauris, 2017), 226.
14 Phillip James Tabb, *Elemental Architecture: Temperaments of Sustainability*, (New York: Routledge, 2019),175.
15 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction*, (Birkhauser Architecture, 2018), 9.
16 Ibid., 28.
17 Kevin Nute, "The next Step in Sustainable Design: Bring the Weather Indoors," The Conversation, (July 2017), https://theconversation.com/the-next-step-in-sustainable-design-bringing-the-weather-indoors-80126.

THE OUTSIDE AND WELL-BEING

Building design tends to focus on the interior and exterior as two separate environments, yet there is also an opposing desire for architecture to converse with its surroundings. This desire comes from our need to be attuned to our surroundings, and reflect on the qualities of a place. The eighteenth century put a great emphasis on this relationship between people and nature, recognizing the role of weather as an architectural author.[18] There was value in the ways that exterior conditions could evoke emotions, and form experiences of changing perceptions,[19] by acknowledging the exterior conditions, and allowing people to relate to their surroundings.

"With more and more people living indoors with urbanized lives, there are fewer opportunities to experience both incidental and direct connections to nature."[20] These interactions are all activated by our senses, often producing profound sensual experiences."[21] People conceivably get sick because they don't have access to changes in their indoor environment, having limited experiences of sensual awareness. A 'new age' view of aesthetic logic, looks at how both the functional efficiency and the sensual aesthetic of the architectural form, together, can articulate the environmental message of sustainability.[22] In this view, the role of green buildings is concerned with deepening our understanding of Nature, whilst engaging with both environmental and cultural issues, creating a new architectural language. This approach highlights the social conditions of green building where there is a comfort logic and ethical responsibility for the well-being of building users, to prevent the creation of 'sick buildings,' and to be more aware of our impacts on the environment. In recognition of pandemic situations, there is an increasing need for the design of 'healthy buildings,' to keep cities operable in times of infectious disease spread.

The building envelope is recognized with varying perspectives, being both a separation device and a facade portraying the face of the building.[23] Regarding sustainability, this interface takes on a performative, climate control approach, but is deceptive in the concerns for the inhabitants' well-being. The 'breathing wall' attempts to break free from the idea of 'climate control', by acting as a technical device which modifies the climate.[24] However, as a device, intentions are relative to air pollution and vapour permeability, not the ways it induces experiences supportive of the nature-body relationship. The need for climate control is really about understanding habit and its relation to climate, and how the body is trying to attune itself to engage with the conditioning of the interior.[25] Inducing new habits related to adaptive comfort can be achieved by having an adjustable envelope, which seeks to engage the inhabitant with climatic patterns. Also, since building systems influence our experience of architecture, they in turn affect how we perceive the outside environment. Hence, there is opportunity for building systems to not only support a relationship between the inside and outside, but modulate an enhanced, multi-sensory experience, where both the outside and inside play roles in curating this performance; to nurture through nature.

18 Jonathan Hill, *Weather Architecture*, (Routledge, 2013), Introduction 4/9, Kindle edition.
19 Ibid.
20 Phillip James Tabb, *Elemental Architecture: Temperaments of Sustainability*, (New York: Routledge, 2019), 1.
21 Ibid.
22 Carmela Cucuzzella, "Is Sustainability Reorienting the Visual Expression of Architecture?," Revue D'art Canadienne/Canadian Art Review 40, no. 2(2015), 79, http://www.jstor.org/stable/43632234.
23 Ajla Aksamija, *Sustainable Facade: Design Methods for High-Performance Building Envelopes*, (John Wiley & Sons, 2013), 2.
24 David Leatherbarrow, *Architecture Oriented Otherwise*, (Princeton Architectural Press, 2009), 23.
25 Daniel A. Barber, "Climate-Sensitive Architecture as a Blueprint: Habits, Shades, and the Irresistible Staircase," RCC Perspectives, no. 2 (2019), 84, https://www.jstor.org/stable/26631564.

BUILDING ENVELOPE AS ‘SPACE’

To perceive something is for it to have an inside and outside.[26] As a space, the building envelope undergoes significant loads of energy which it attempts to tame through layers of control. However, if these layers were layers of mediation, elements of nature could be sensed and perceived from the inside. Through the modulation and play of the envelope, a reciprocal exchange would occur between the body and the outside, enhancing awareness through the senses. In this way, if the building envelope became an architecture in itself, an environment in-between. A perceptual shift towards sustainable design could improve our well-being by interplaying with conditions of the environment.

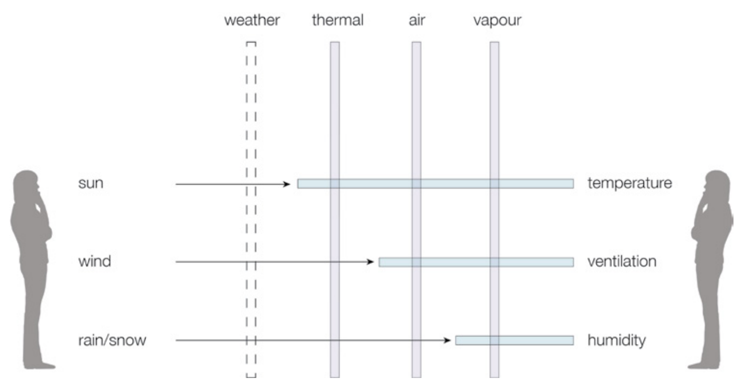


Figure 1.4
Analogous Temperaments: experienced by the outside, envelope, inside, and perceived by the body.

ANALOGOUS TEMPERAMENTS

The layers of the building envelope are comprised of transitional zones of energy. The energy can be ‘seen’ in a constant state of transfer: from the outside, to the building envelope, into the interior space, and to the body. This interaction is relative to the temperaments of the climate, being translated through architecture, and interpreted by the perceived sensations of the body. A controlled environment breaks this interaction, where only the temperaments of the conditioned interior is perceived by the body. “Trying to control the dynamic condition of energy through architecture, [when] the nature of energy is ephemeral” creates problems, in that we lose our associations with the exterior and to place.[27] In relevance to the space of the building envelope, the interaction of the temperaments is vital, as the ‘in-between’ is where environmental conditions and human states can relate.[28] Olafur Eliasson began to look at this relationship with *The Weather Project*, where he investigated the city as a filter for experiencing the weather.[29] The project became a way for people to re-engage their connections to weather patterns and the sun, questioning and re-evaluating the relationship between their body and the space of a controlled weather experience.

There are zones of transition which connect the body to the outside, operating at different scales of influence. They stem from the meteorological aspects of climate, to the architectural means of mediating the inside and outside through the building envelope, along with the physiological factors of the body

26 José Ortega y Gasset, *Phenomenology and Art*, trans, Philip W. Silver, (Norton, 1975), 112.
27 Rosa Urbano Gutiérrez, “The naturalisation of architecture”, in *Architectural Research Quarterly*, 20 no. 3 (2016): 258.
28 Gernot Böhme, *Atmospheric Architecture: The Aesthetics of Felt Spaces*, Edited by A.-Chr. Engels-Schwarzpaul, (Bloomsbury Academic, 2017).
29 “Olafur Elliason: The Weather Project: About the Installation: Understanding the Project,” Tate, https://www.tate.org.uk/whats-on/tate-modern/exhibition/unilever-series/unilever-series-olafur-eliasson-weather-project-0-0.

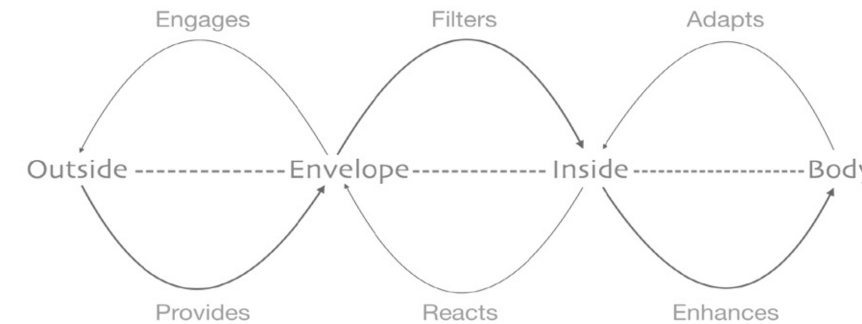


Figure 1.5 Functions of a Symbiotic Relationship: between the outside, envelope, inside, and the body.

perceiving these energy variances as a result. Philippe Rahm’s work applies an understanding of this relationship, looking at how both the meteorological and physiological is expressed through the architectural aspects of the envelope and the interior.[30] For the *Tadeusz Kantor Museum* project, Rahm explores the function of double glazing glass, and how increasing the space between the layers of glass can start to inform varying temperature gradients in-between. The outcome of exploring the materiality and form of glass, resulted in an architectural solution for the envelope which addresses the meteorological aspect of temperature, its effects during the seasons, and the plausibility of the building envelope itself becoming an occupiable space. The *Digestible Gulf Stream* project is a bit different, as it considers the physiological aspects of temperature gradients in relation to activity and space. Several activities are reviewed for their ideal temperature conditions, within a space of several gradients,[31] playing against the idea that interior environments should conform to a consistent temperature. Reviewing energy as zones of transition, these layered spaces can accentuate aspects of the climate to create sensual experiences; based on the interactions of energy amongst ‘layers’ of varying forms and material properties.

Within the space of the building envelope, an “in-between reality,” can be formed by “overlapping spaces” of the inside and outside;[32] where the building envelope is considered an occupiable zone and no longer a boundary. Conditions of the outside have an influence on our behaviour, just as our behaviour has an influence on the outside. When applied to architecture at the interface of the building envelope, there is potential to reawaken our connection to the outside through engaging the senses. This symbiotic relationship becomes a new criterion for comfort based on the dynamic relation between external climatic conditions and the physiological, behavioural, and psychological dimensions of humans. To create an architecture tied to the senses, a theory of space needs to be grounded in the reactions of the human body to its immediate surroundings and atmospheric conditions.[33]

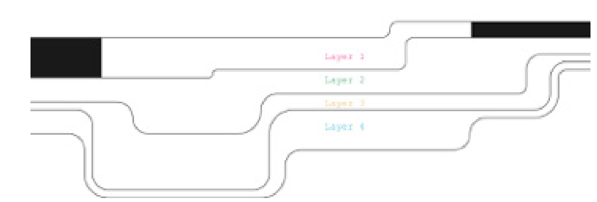


Figure 1.6 “Living in the interval of the double-glazing glass.” Graphic. Philippe Rahm. Reformatted by author.

30 Philippe Rahm, *Thermodynamic Architecture,* http://papers.cumincad.org/data/works/att/acadia08_046.content.pdf.
31 Ibid.
32 Steven Holl, “Phenomenal Zones,” In *Questions of Perception: Phenomenology of Architecture,* (William Stout, 2006), 45.
33 Gilles Clément and Philippe Rahm, *Environ(ne)ment: Approaches for Tomorrow.* (Skira, 2007) 44.

SENSORY ENGAGEMENT

The sensual relates to the gratification of the senses, which occurs between the skin and the environment. There is an urge for architecture to restore this experience, by understanding the sensuous, and the things that evoke sensorial experiences. Specifically, there is focus on sensory cues, enabling the unconscious to engage with the architecture, transforming perceptions from ordinary to evocative.[34]

The sensuous is "neither cognized abstractly nor empathized" but exerts an effect by its very nature and existence, a preconscious event.[35] In regards to multi-sensory experiences, the sensuous becomes most powerful when the conditions are perceived through multiple senses of sight, sound, smell, taste, or touch; where the experience becomes synesthetic. An example of the synesthetic would be how the wind can be heard from interacting with an object, but can also be felt through its movement. These synesthetic experiences can enrich architecture, by allowing building systems to have a more empathetic understanding of our sensory needs, rather than being solely focused on energy efficiency. Green building rating systems tend to not consider the synesthetic aspects of architecture, and the ways this approach could improve well-being. If sustainability is about maintaining ecological balance, not only should nature be recognized, but also having a re-oriented perception on how nature can improve well-being. In return, nature is appreciated and gives leverage to the sensuous.

Nature provides many transitions and awakens the senses.[36] With Nature being a habitual language, sensual experiences can emerge by breaking away from their familiar ways of acceptance and understanding. In a way, architecture acts as "an extension of nature into the man-made realm, providing the ground for perception and the horizon of experiencing and understanding the world."[37] For therapeutic architecture, these sensory experiences work as a communicative device, providing a "dynamic interplay of environment, movement and social function."[38] "Spaces in which environmental uniformity is replaced by variations, [brings a] sense of dynamics to the natural climate," the desired condition for the body.[39]

"Every touching experience of architecture is multi-sensory."[40] This can be rooted to Baumgarten's theory of aesthetics, which was seen as a 'science of sensory cognition', where the stimulation of the senses was deemed integral to the health and well-being of a person.[41] Architecture, more fully than other art forms, engages the immediacy of our sensory perceptions.[42] This questions the kinds of benefits with regards to sustainability and well-being, a type of architecture could provide, where building systems were more engaged with exterior conditions and created "several realms of sensory experiences which interact and fuse into each other."[43] Where the overload on the ocular senses, could be reoriented towards the energetic, allowing for other senses to be heightened. It is here where spaces can be experienced through feeling, and variances can be felt, recovering sensual experiences in ordinary life. A re-sensualised architecture that can 'honour the senses,' and where people can be more attuned to the energy of their surroundings.

34 Lucy Huskinson, *Architecture and the Mimetic Self: A Psychoanalytic Study of How Buildings Make and Break Our Lives*, (London: Routledge, 2018).
35 Neil. Everdeen, *The Social Creation of Nature*, (London: The John Hopkins University Press, 1992), 114.
36 "Olafur Elliason: The Weather Project: About the Installation: Understanding the Project," Tate, https://www.tate.org.uk/whats-on/tate-modern/exhibition/unilever-series/unilever-series-olafur-eliasson-weather-project-0-0.
37 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006), 41.
38 Terri Peters, ed., *Design for Health: Sustainable Approaches to Therapeutic Architecture*. (John Wiley & Sons Inc, 2017).
39 Simon Guy, and Graham Farmer. "Contested Constructions: The Competing Logics of Green Buildings and Ethics." In *Ethics and the Built Environment*, edited by W. Fox, 73-87, (London: Routledge, 2000), 82.
40 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006), 41.
41 Alberto Pérez-Gómez, *Attunement: Architectural Meaning after the Crisis of Modern Science*, (Cambridge, Mass.: MIT Press, 2016), 72.
42 Steven Holl, *Questions of Perception: Phenomenology of Architecture,* (William Stout, 2006).
43 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006), 41.

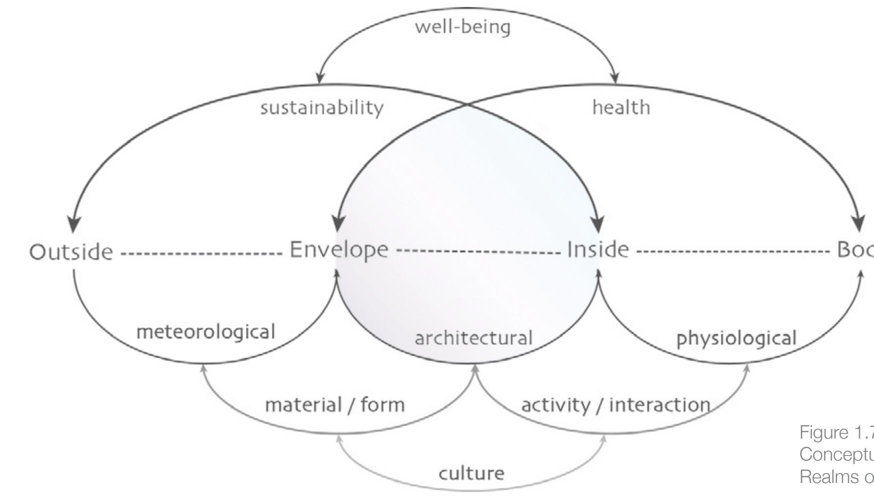


Figure 1.7
Conceptual Framework:
Realms of the space *In-Between*.

SCIENCE, CULTURE, NATURE

There is concern that beyond architecture, science is detaching nature from culture,[44] and subsequently, culture is "de-sensualizing our relation towards reality."[45] In order to recognize this issue, an 'architectural experience' is deemed crucial, where attention is focused on one's own existence through sensual awareness. It is through engaging with our sensory perceptions that architecture is able to transform and inspire our realities; just as buildings and towns enable us to recognize and remember who we are through embodied memory. In essence, architecture should be seen as an integrated whole, where the built environment is responsive and has the capacity to be empathetic, to create cultures which resonate with the social values of today's societies.[46]

Engaging the worlds of science and art helps to understand and describe the world. "Physics tries to reduce to objective determinations," where light is seen and sound is heard, except "what is sensed is the very opposite of what is objective, its pure phenomenon;" and yet it is through the psychophysical subject that the objective thing can be reformed by its individualization.[47] "Science can be more [than] the product of rational, logical, positivist consciousness."[48] When expressing the presence of natural phenomena, the science of energy and the art of perception can overlap with the perceived senses. In terms of the building envelope, the elements of environmental mediation are embedded in the vernacular, and can determine form and sensible materials more directly than local or regional culture.[49]

Designs approaching the human experience of the built environment should acknowledge our biological, affective, social and cultural dimensions; and not just be a conceptual paradigm. This creates a dual perspective in how we engage with the built environment, and in turn how the built environment shapes us. Using the poetics of science, building systems should not only cater towards sustainability, but also to the health and well-being of the occupants, whilst being empathetic towards culture through sensual perceptions. As a conceptual framework these relationships recognize the space of the envelope as the place to exhibit the sensual, producing sensory experiences that translate the perceptions of the exterior towards the felt perceptions of the body.

44 Jonathan Hill, *Weather Architecture*, (Routledge, 2013), Things of a Natural Kind 9/72, Kindle edition.
45 Steven Holl, *Questions of Perception: Phenomenology of Architecture,* (William Stout, 2006).
46 Harry Francis Mallgrave, *From Object to Experience: The New Culture of Architectural Design,* (New York: Bloomsbury Academic, 2018).
47 José Ortega y Gasset, *Phenomenology and Art*, trans, Philip W. Silver, (Norton, 1975), 112.
48 Sim Van der Ryn, *Culture, Architecture, and Nature: An Ecological Design Retrospective*, (New York: Routledge, 2014), xii.
49 Sean Lally, "Energies: New Material Boundaries," in *Architectural Design 77*, no. 3. (London: John Wiley, 2009), 13.

THERMAL PERCEPTIONS

ENERGY PHENOMENA

"The building envelope is the barrier between the interior and the exterior, the place where the energy flow is interrupted or deflected."[50] An alternative approach should be considered to distinguish a space that is not trying to control environmental conditions, but instead make programmatic use of these enhanced perceptions of energy. Since thermodynamics is relative to other conditions of energy and climate, thermal energy will be visualized to review these underlying interactions and sensory engagements we have with our surroundings.

Figure 2.1 Schlieren image of Thermal Plumes of the Body. Retrieved from https://www.psu.edu/ur/archives/intercom_1998/Oct15/research.

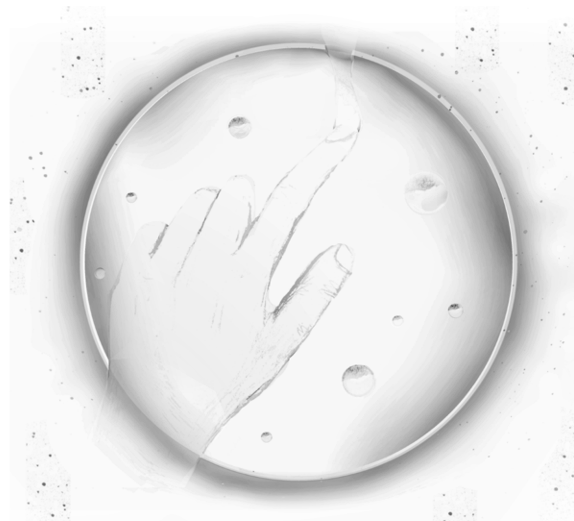


Figure 2.2 Interactions at the Interface of the Window.

'INVISIBLE' ENERGIES

The sensual is usually not measured or seen, affecting its presence in architecture culture and spatial experiences. Likewise, energy is primarily a non-visual phenomena, yet there has been rigorous attempts to visualize and cognize an understanding through science and art.[51] The discoveries made have driven the course of technologies and advancements towards the built environment and objects in society. Except, there is a lack of rigour towards focusing on the impact objects have as an interface; they have the ability to control or redefine our relations to our surroundings. If objects have such power in defining perceptions, then they should be used in reorienting an understanding and wonder towards nature.

Reviewing energy as zones of transition, these layered spaces can accentuate aspects of the climate to create sensual experiences. In the layered composition, there is the scientific performance of energy along with the phenomenological experience of energy. When pertaining to sustainability, architecture is usually only considered aesthetic when "technology has been ruled mostly by the maxim of invisibility,"

50 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction*, (Birkhauser Architecture, 2018), 11.
51 Neil Everdeen, *The Social Creation of Nature*, (London: The John Hopkins University Press, 1992), 63.

Figure 2.3 Turbulence between rising steam and falling vapour. Painting.

Figure 2.4 Visible turbulence between rising steam and falling vapour.

where the "technical 'prosthesis' [is] as unnoticed as possible."[52] However, sustainable architecture should recognize the aesthetic potentials to the technical aspects of energy; that when perceived or made 'visible,' energy can evoke a synesthetic experience. Where the 'technical object' mitigates the zone of the physical conditions and the aesthetic, bringing awareness to sources of phenomena. Technological devices can be used in support of understanding well-being by visualizing the invisible. The potential impact could make one more attune to other sensations, just as those who are blind; when the visual sense is taken away, the other senses become heightened. "Vision separates us from the world whereas the other senses unite us."[53]

"The invisible is what exists only as tactile or kinaesthetically."[54] Based on the interactions of energy amongst 'layers' of varying forms and material properties, there needs to be consideration towards phase change materials, and energy active elements.[55] These aspects can be distinguished under qualities that make up a performative building or a series of integrated systems. Climate and atmospheric conditions are the invisible parameters of architectural space, and are organized in accordance with the physiological condition and comfort of the inhabitants."[56] Although, these systems are rarely considered in terms of all the influential factors of energy, and their translation of energy through the temperaments. Hence the 'invisible' must be made visible through perception, "in which the architecture becomes not only the building but an orchestration of the other forms of energy that are designed into the form of the built environment."[57] An investigation into the non-visual energies can provide insights into synesthetic experiences in support of health and well-being, as well as an understanding of energy flows for sustainability.

52 Rosa Urbano Gutiérrez, "The naturalisation of architecture", in *Architectural Research Quarterly*, 20 no. 3 (2016): 257.
53 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006), 25.
54 Maurice Merleau-Ponty, *The Visible and the Invisible* (Northwestern University Press, 1969), 257.
55 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction,* (Birkhauser Architecture, 2018), 8.
56 Gilles Clément and Philippe Rahm, *Environ(ne)ment: Approaches for Tomorrow.* (Skira, 2007) 43.
57 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction*, (Birkhauser Architecture, 2018).

THERMODYNAMICS

Exterior conditions are influenced by thermodynamics, and play a role towards perceived comfort. In terms of thermal comfort the body prefers variances, as a consistent temperature requires adaptation under certain activities; "variability enhances the thermal quality of a space".[58] An understanding of energy, specifically thermal energy, can establish a set of thermal ergonomic conditions which when directed by exterior conditions, can utilize material energies for sensory experiences.

"The most important heat transmission mechanisms of thermodynamics are heat conduction, convection, and radiation".[59] In relation to material and object interactions, heat flux density and heat flows are concepts that help to understand heat transfer rates, and the ways energy can be mediated and shifted to other forms. An interesting discovery can be made when cold mist and warm vapour collide, producing a turbulence, similar to the phenomena present in the Rayleigh–Bénard convection. This reaction proves the influence thermal energy has on other factors of moisture and wind. At a larger scale in relation to weather, these energy transformations are influenced by solar energy, atmospheric moisture, and air pressure.[60] Another intriguing energy phenomena is how radiant energy is a kinetic form of thermal energy, and is part of the electromagnetic spectrum; where the spectrum includes sensory aspects of light and heat, travelling in waves similar to sound.[61] When applied to architecture, energy must be considered in relation to the senses, in order for the body to gain new perceptions of energetic surroundings based on climate conditions.[62]

Energy is not consistent like geometry. There are a lot of factors at play when considering the energy exchange between heat and other forms of energy. When a system undergoes a 'phase transition', it loses symmetry and changes in its dynamics,[63] creating a new order of thermal geometry. Expressing the variability in energy brings an awareness to these thermodynamic relationships amongst construction techniques, forms, and materials. A further understanding is introduced through the interplay of exterior and interior energies, where an in-between dimension of 'layered' thermodynamic space informs varied experiences that can be perceived by the body. At the meteorological, architectural and physiological scales, there are zones of transition impacting the energy exchange between each scale, affecting the 'felt' experiences of these spaces. Designing spaces within the 'in-between' zone can minimize entropy by maximizing the energies of influence, and applying principles of phase change to create zones with more consistent or dynamic ambient temperatures. With an ability to visualize thermal behaviour and explore the relationships between all forms of energy, different conditions of comfort and thermal sensitivity can be established.

58 Madlen Kobi, and Sascha Roesler, eds., *The Urban Microclimate as Artifact: Towards an Architectural Theory of Thermal Diversity,* (Birkhauser, 2018), 13
59 Urlich Knaack, and Eddie Koenders, eds., *Building Physics of the Envelope: Principles of Construction*, (Birkhauser Architecture, 2018), 13.
60 Verne Bloom and Mortimer Booth, *Physical Science: A Study of Matter and Energy,* (MacMillan, 1972), 583-584.
61 Ibid., 358-359.
62 Gilles Clément and Philippe Rahm, *Environ(ne)ment: Approaches for Tomorrow.* (Skira, 2007) 44.
63 Daniel Smith and John Protevi, "Gilles Deleuze," in *The Stanford Encyclopedia of Philosophy*, (Metaphysics Research Lab, Stanford University, 2020), https://plato.stanford.edu/entries/deleuze/

THERMAL IMAGING

To understand the activity of thermal energy, an infrared thermal imaging camera can visualize the occurring temperature gradients. The findings and knowledge taken from the photos can be applied to material experimentation, and source various heat signature typologies. By seeing the unseen aspects of thermal energy, an understanding develops towards the expression of materials and forms, in relation to the elements and energy. The findings can also influence more phenomenal forms that speak to a reciprocal energy transmittance between the outside and our perceived experiences.

SEEING THE UNSEEN

"The senses are a apparatus to form concretions of the inexhaustible, to form existent significations...but the thing is not really observable."[64] It is the sensible things that allow for the senses to translate information into the perceptible.[65] In this way, the thermal imaging camera is a device that gives objects and materials significance based on their thermal properties. Observing through a 'thermal lens' can identify parameters beyond the capabilities of current simulation technologies. The camera is able to 'see' infrared radiation, being sensitive to wavelengths greater than visible light on the electromagnetic spectrum. The emitted surface temperature are translated to the ocular through an assigned gradient colour scale, with the coolest temperature being dark blue, transitioning to bright peach as the warmest temperature in view. With architecture dominated by the ocular, attuning to the thermal would recognize the 'felt' experiential qualities of a space, and bring a thermal aesthetic to architecture.

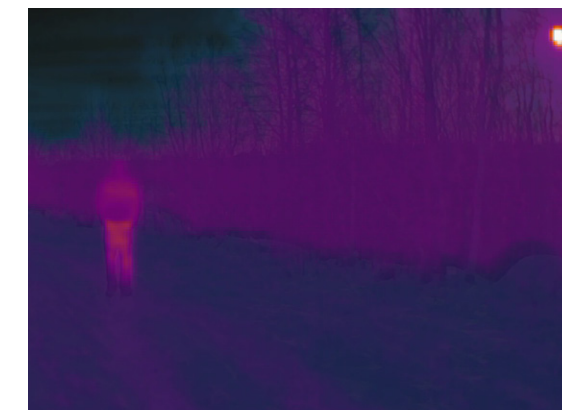


Figure 2.5 Presence of thermal energy along a nature trail in the winter.

To establish an understanding of thermal behaviour occurring in natural and urban environments, a series of images were taken in Sudbury, ON. Relationships were investigated between thermal energy, materials, and the elements of nature. Over the course of taking photos, a sequence of discoveries emerged, stemming from 'energy dumps' in the downtown, to frequented thermal zones in the city. The pathways transitioning between these two realms of nature and the city began to question their potential influences on public space, and the impact in having more natural instances of thermal phenomena in the city. Connections were examined between materials and the elements, exterior and interior spaces, and body interactions within various environments. Further strengthening the presence of heat sources and thermal phenomena, the images were taken in winter conditions.

64 Maurice Merleau-Ponty, *Visible and the Invisible* (Northwestern University Press, 1969), 192.
65 Ibid.

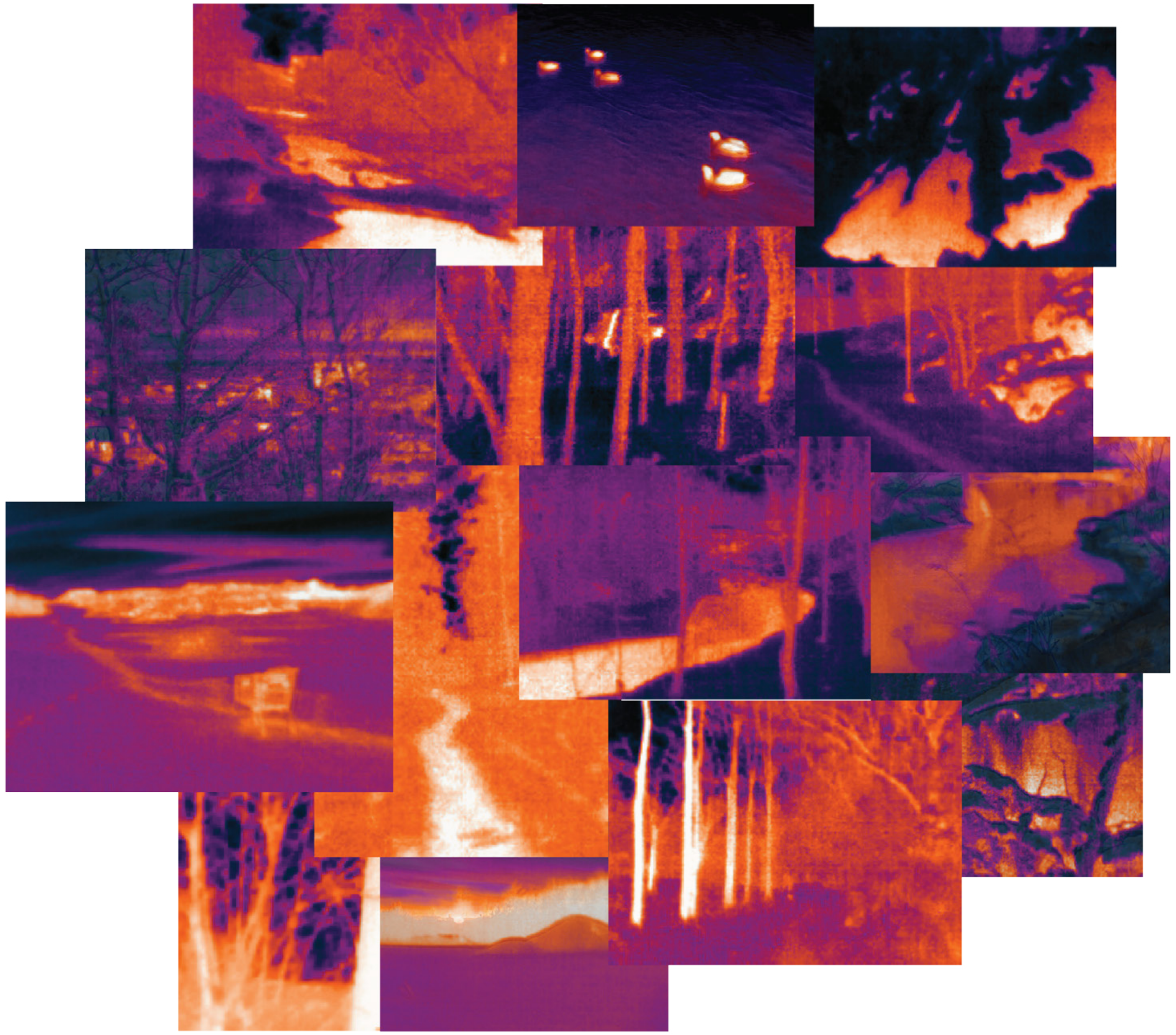


Figure 2.6 Series of thermal images within the natural environment.

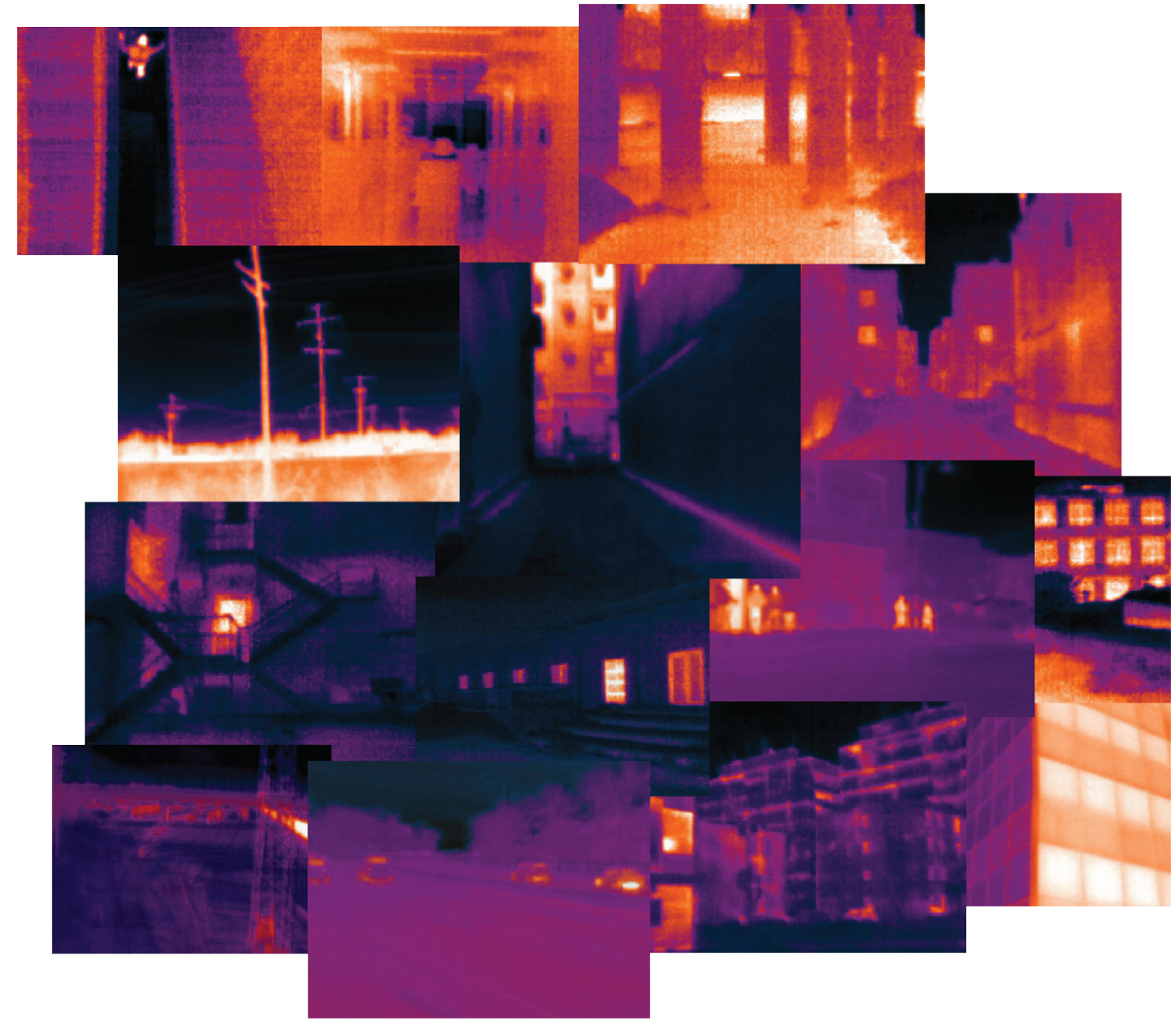


Figure 2.7 Series of thermal images within the urban environment.

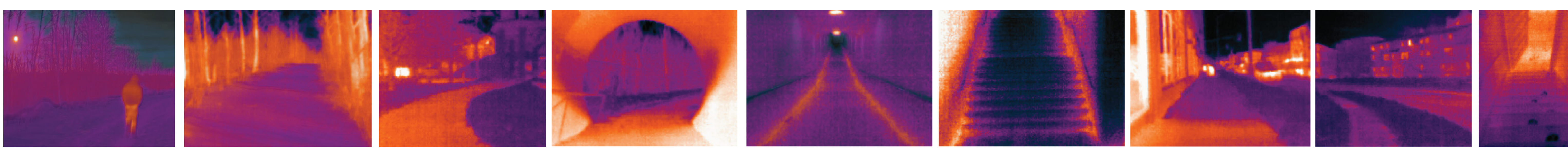


Figure 2.8 Series of thermal images transitioning from the natural to the urban environment.

NATURE AND THE CITY

Thermal energy has a varied presence and classification of comfort, depending on the environmental conditions and activities associated with the environment. Implementing the use of a thermal imaging camera identified where thermal energy exists in both the natural and built environments. When comparing these contrasting environments to their temperature gradients, discoveries were made based on the behaviour of the materials, in relation to their forms and thermal energy properties. Observations also denoted materials with thermal storage capabilities, thermally conductive properties, and the additional impact of weather conditions; affecting the 'felt' thermal qualities that can be interacted with and perceived by the body.

Whether in the natural or urban environment, thermal mass and exposure to the elements were crucial factors affecting thermal behaviour. For instance, after sun exposure during the day, exposed rock faces maintained a temperature higher than the air temperature at night. Similarly, the soil in street planter beds also maintained a higher temperature for a few days after the air temperature dropped below freezing. Creeks further validated the significance of thermal mass; with a variety of temperature gradients present, depending on the depth and spread of the water. Beyond thermal mass, energy dumps in the urban environment were another contributor to the presence of thermal energy. Sewer grates and exhaust vents continuously emitted significant amounts of thermal energy, producing warm spots amidst the winter conditions in the city. Indoor environments were photographed as well, to study the body and its responses to interior and exterior spaces of preference.

To discern heat as a 'felt' sense, and convey the sensory potentials of heat, the body was photographed in varied environments. When the body is more attune to thermal energy in the city, different thermal zones can emerge, bringing a variety of activities and comfort to public spaces. Areas exhibiting a presence of thermal phenomena tend to have signs of habitation; those who are homeless frequent these exterior warm spots for comfort. Revealed through investigation, crevices between rocks and recessed store entrances were preferred places of refuge, as they contained a few more degrees of latent heat. In the summer, there is a significant difference in the heat felt radiating from black pavement in comparison to the lighter colouration of the sidewalk paths, or the cooler alleyways blocked by sun exposure. Areas deemed comfortable during certain seasons become social condensers, as these spaces exhibit intriguing thermal phenomena and are more likely to be frequented. The thermal characteristics of these spaces could be more sophisticated by understanding how the body interacts within thermal surroundings; becoming more ergonomic towards 'felt' experiences and urban social interaction.

Figure 2.9 Series of images depicting habitation in nature and in the city.

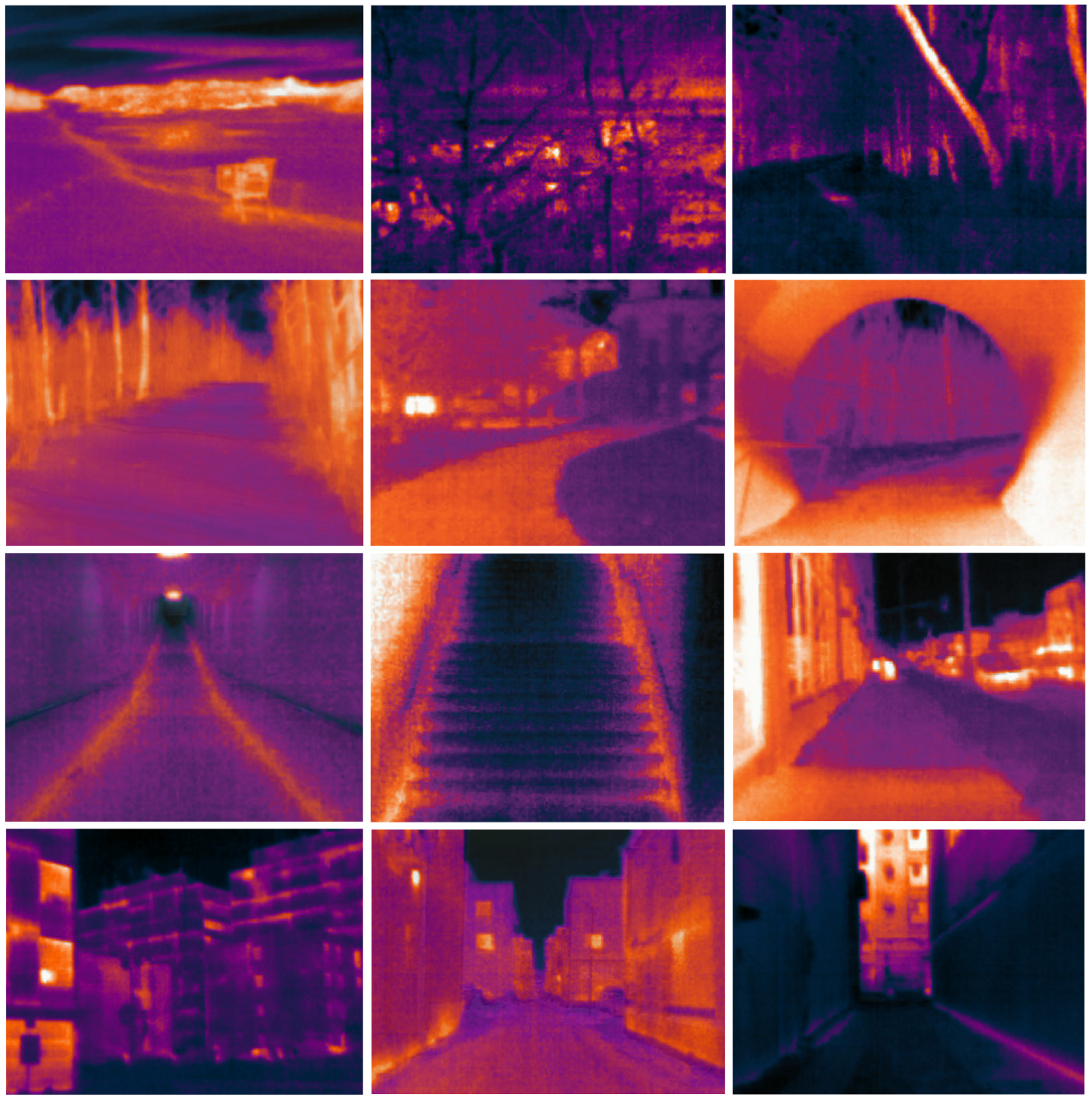


Figure 2.10 Series of thermal images depicting natural and urban environments.

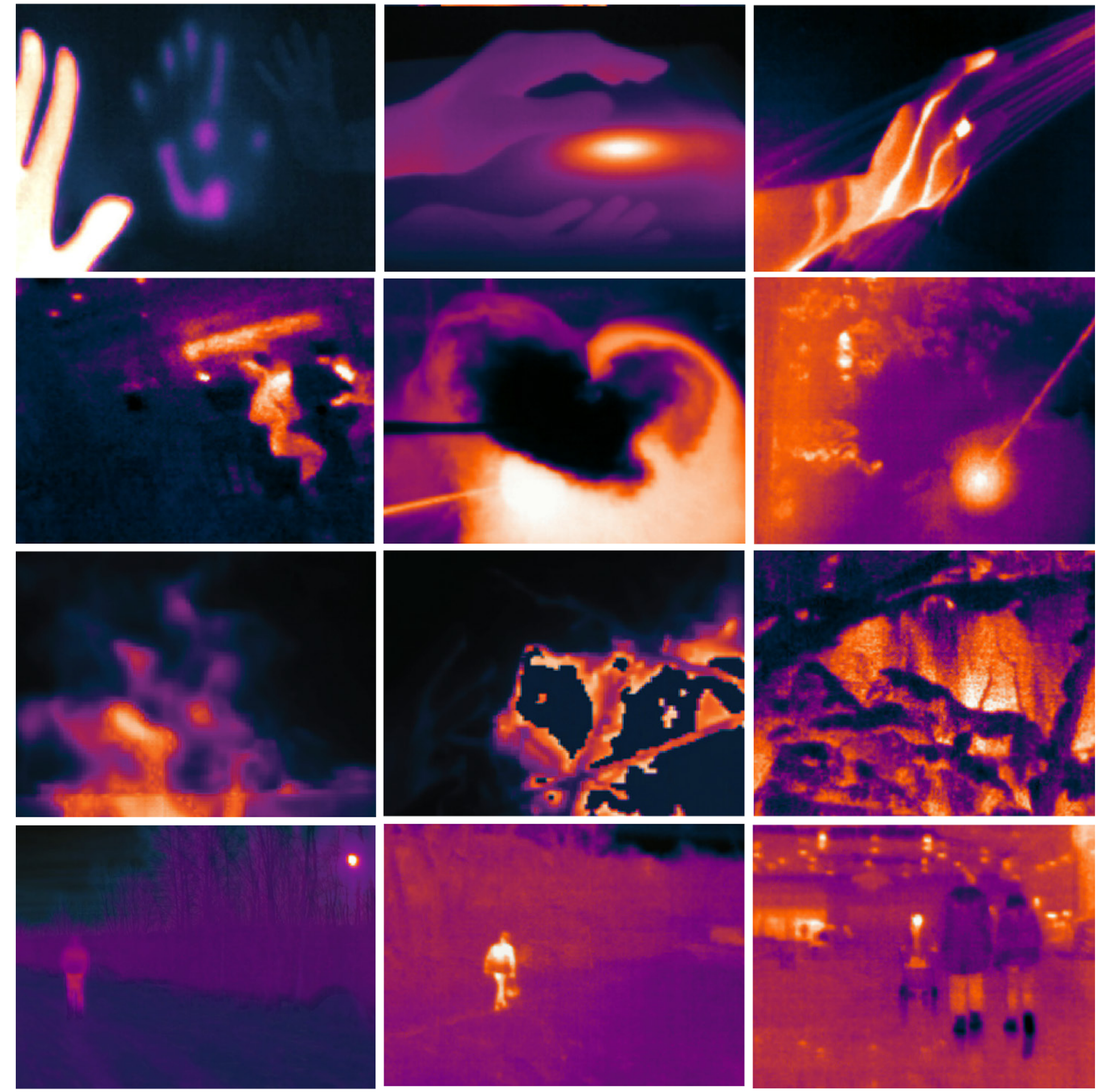


Figure 2.11 Series of thermal images depicting interactions of the body and the elements in space.

OBSERVATORY

An observatory allows for conditions to be recorded and objects to be manipulated under controlled experiments. With the use of a thermal imaging camera, surface temperatures can be observed to understand the movement of thermal energy over time, as well as the thermal interactions occurring between various forms and materials. The experimental process brings a deeper understanding of the sensory potentials of a space, without being limited by the boundaries of assumed scientific knowledge, which tends to limit the results from relating to the sensual.

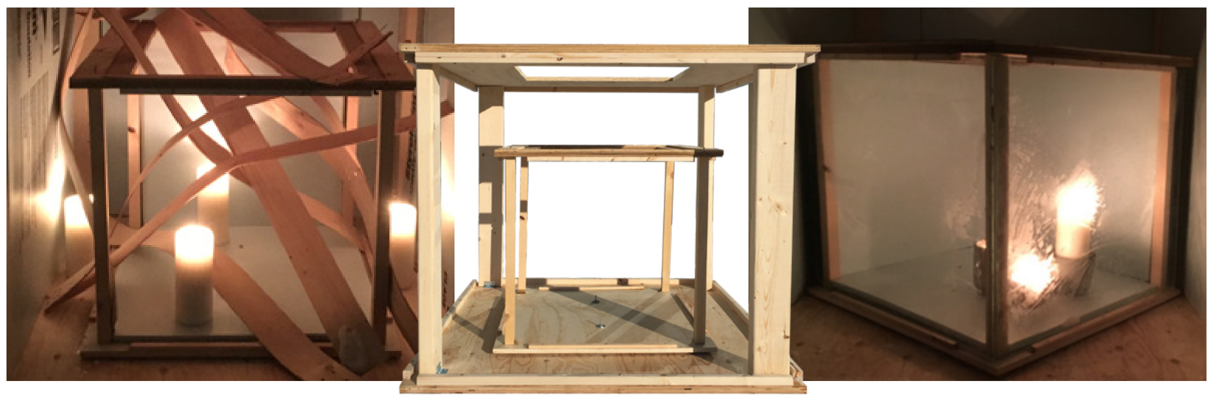


Figure 2.12 Constructed box apparatus for conducting experiments.

APPARATUS

Being a philosopher in the studies of science and technology, Bruno Latour discusses the significance of the laboratory and how the iterative process of experiments leads to the development of scientific facts and understanding.[66] Olafur Eliasson is known to use a laboratory to find a common ground between the art and sciences. A laboratory enables a comparison of objects in a relatively controlled environment, which allows a selection of variables to be observed, with a predominant importance on the design objectives. The laboratory can therefore act as a filter, leading to discoveries that propose new potentials for architectural space.

"We need the methodologies of physics and physiology and the whole reflective apparatus of introspection to isolate a pure sound...where pure sound and pure sensation are constructions of systematic science."[67] It is apparent, that in order to make directed discoveries, experiments need to take place, starting at a workable and feasible scale. The Patkau's emphasize the importance of "small installations [and how] they set out to discover material behaviour through systemic operations, to experiment on assembly processes, and to effectively think through their translation toward larger scale formal and spatial architectural implications."[68]

For Gilbert Simondon, he views the technical object as an aid to "see the aesthetics of nature."[69] In this sense, the creation of a technical object, that can develop an understanding of this

66 Bruno Latour, and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts*, (Sage Publications, 1979).
67 José Ortega y Gasset, *Phenomenology and Art,* trans, Philip W. Silver, (Norton, 1975), 84.
68 Patkau Architects, *Patkau Architects: Material Operations,* (Princeton Architectural Press, 2017), 7.
69 Gilbert Simondon, "On Techno-Aesthetics," trans. Arne De Boever, in *Parrhesia*, no. 14 (2012): 5, https://www.parrhesiajournal.org/parrhesia14/parrhesia14_simondon.pdf.

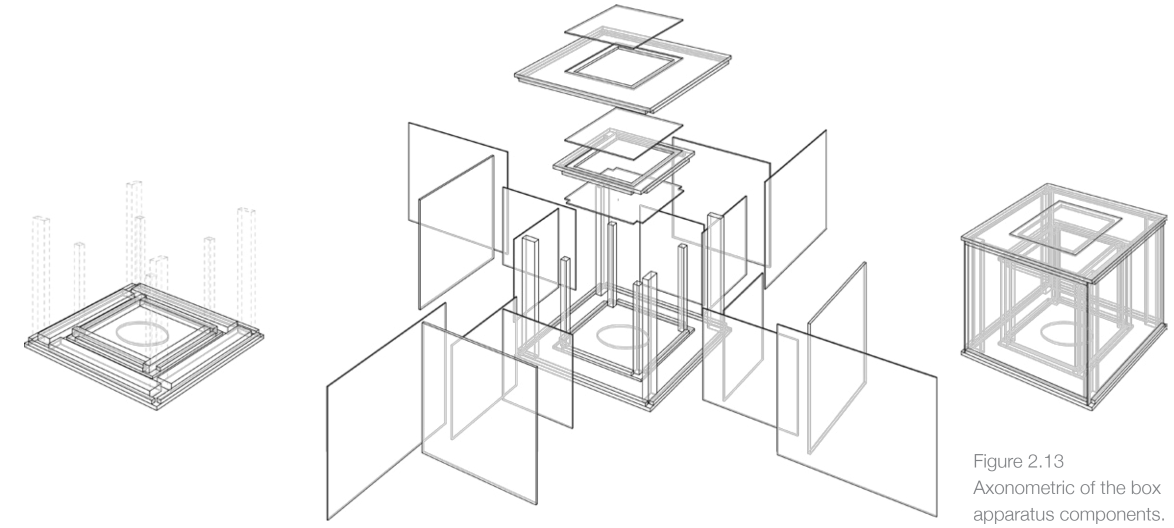


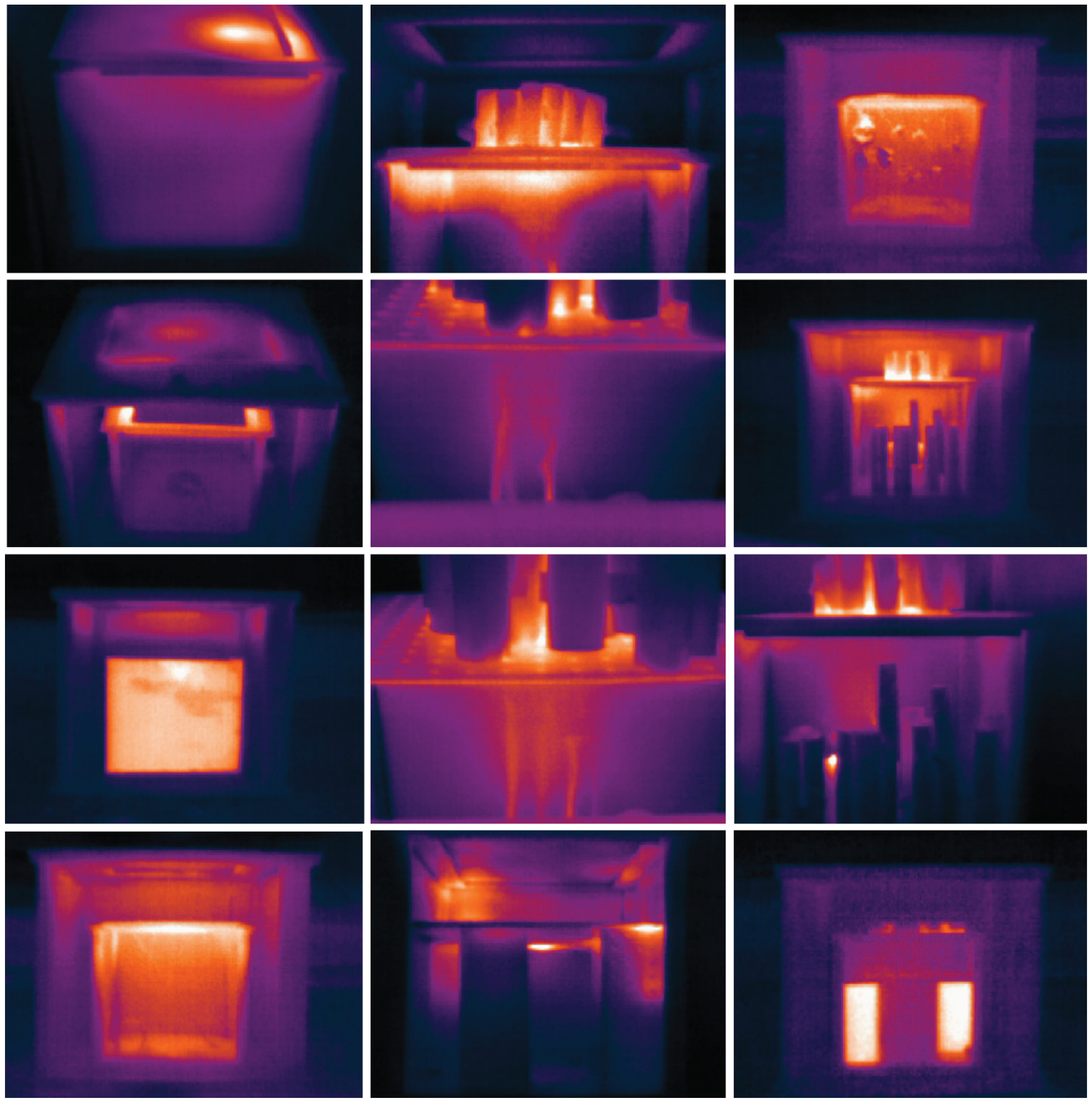
Figure 2.13
Axonometric of the box apparatus components.

relationship between thermal energy, material, and form is significant. The idea of a mediating object is where the object and the object's role both interplay in the development of the subject. This dual relation creates tension, just as materials create transitional spaces through their 'tensions,' being representational as objects but also perceptual with regards to the thermal. By understanding the behaviour of material objects, a functional, programmatic, and ornamental aesthetic can be developed towards thermal energy.

For experimentation, a double layered modular boxed frame was created for the testing of various objects, layers and panels, developing a building envelope condition as a space that can be tested outside. Findings from the naturally occurring and urban thermal phenomena, were then applied towards experimentations with this modular apparatus, where propositions of forms and materials could be tested in a controlled condition with more anticipated results. Documenting with a thermal imaging camera allowed for the experiments to be presently operated and changed according to the variables.

The panels making up the doubled layered sides of the box act as thresholds, transitional layers which play with heat transmittance between the inside, outside, and in-between. Some experiments utilized the doubled layered system, to test with the outside winter conditions, but primarily the inner box was used for more tempered conditions and controlled results. The experiments had no preference towards the scientific performance of energy or the phenomena of energy, the primary focus was to explore the movement of heat between the thresholds of forms, materials and layers; to create a knowledge that is "aesthetic because it's technical, and technical because it's aesthetic."[70] The materials and forms used for testing were generated by preceding tests, with some materials being led by previous thermal phenomena discoveries in the urban and natural environments. This approach aimed to look "beyond typical responses to emergent innovations, which usually amount to grafting new techniques onto old forms."[71] An understanding of climate conditions is applied on top of the results, where a "new spatial organization in which function and form can emerge spontaneously in response to climate."[72]

70 Gilbert Simondon, "On Techno-Aesthetics," trans. Arne De Boever, in *Parrhesia*, no. 14 (2012): 5, https://www.parrhesiajournal.org/parrhesia14/parrhesia14_simondon.pdf.
71 Gilles Clément and Philippe Rahm, *Environ(ne)ment: Approaches for Tomorrow.* (Skira, 2007) 153-154.
72 Ibid., 155.



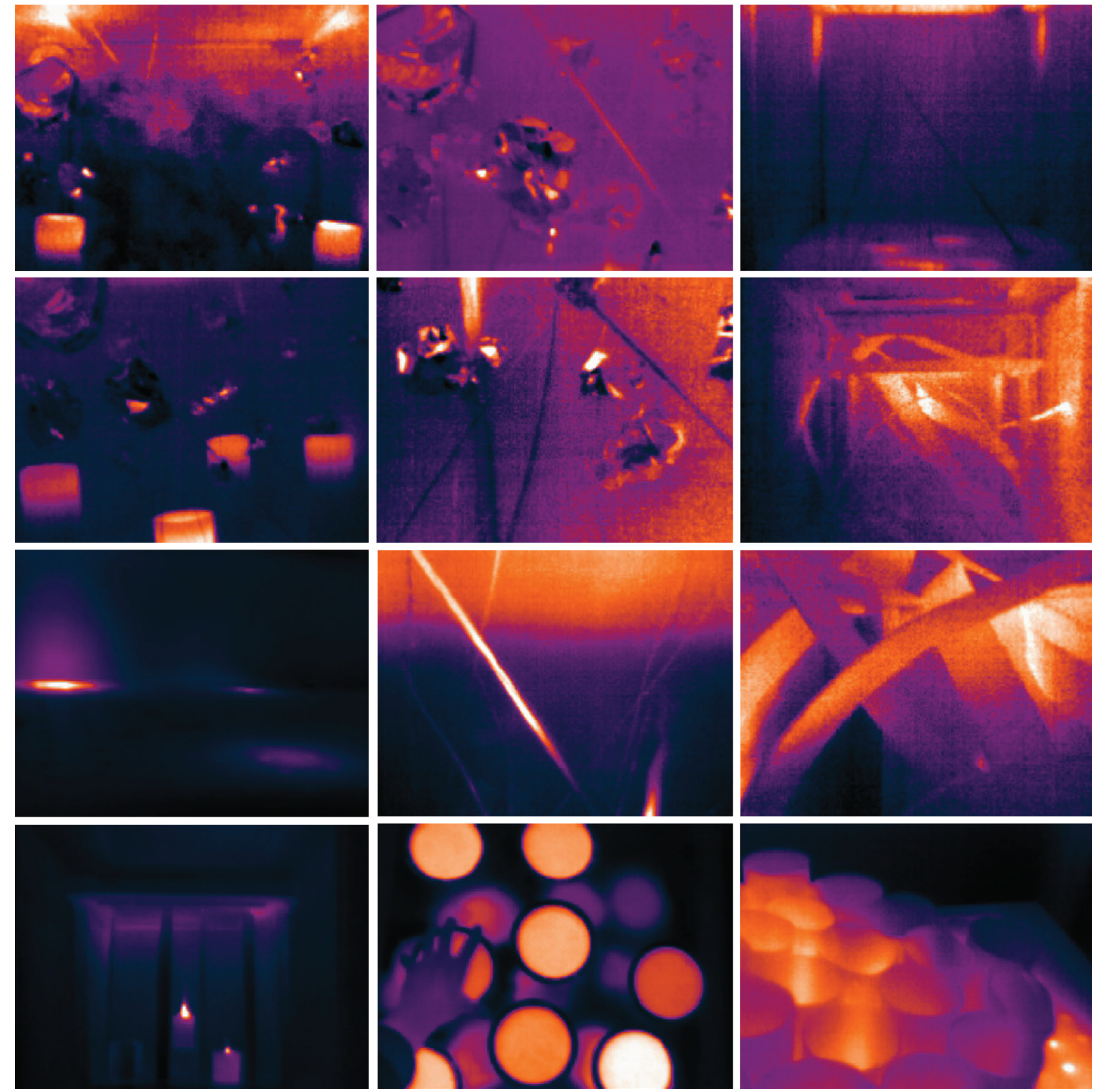


Figure 2.14 Series of thermal images depicting the experiments that took place in the box apparatus.

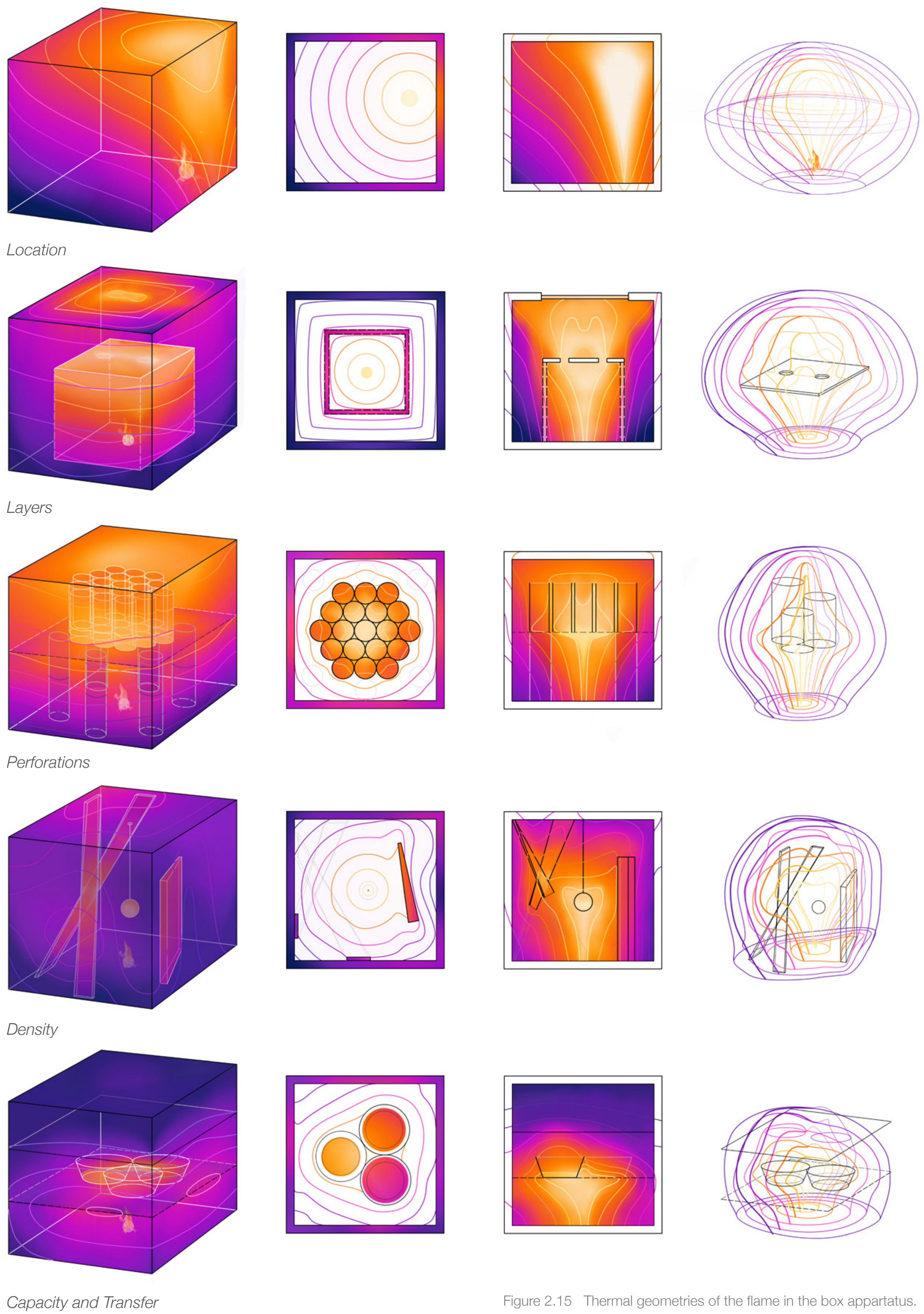


Figure 2.15 Thermal geometries of the flame in the box appartatus.

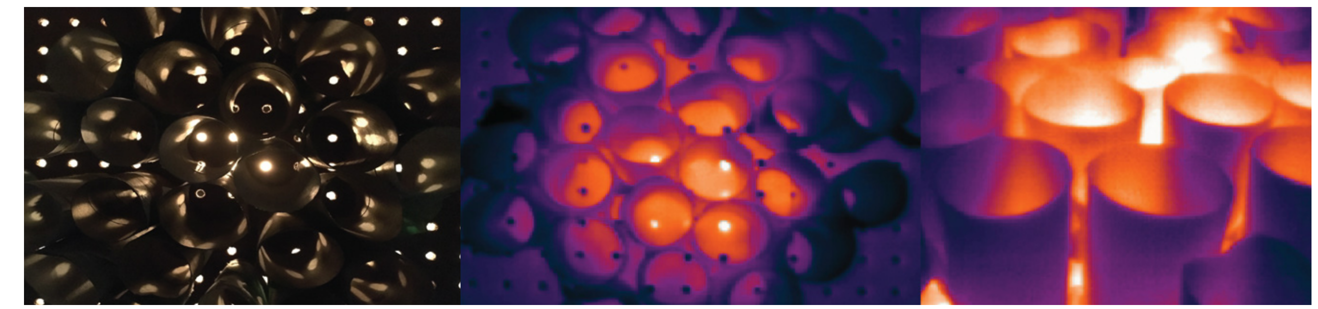


Figure 2.16 Images depicting an experiment involving perforations and crevice forms.

THERMAL GEOMETRIES

Performing several experiments with the box apparatus, intriguing thermal behaviours and geometries were observed. Candles were used as the heat source, providing radiant and convective heat, at an appropriate scale in relation to the box apparatus. Among the initial tests of placing a lit candle within the enclosed inner box, the flame's thermal path was evident. Though fire is usually considered to be a radiant heat source, the heat primarily travels by convection; resultantly the observed heat signature was radial in plan and conical in elevation, similar to the geometry of a hot air balloon. When the heat path moved through the layers of the inner box, there was an apparent disturbance in the flow of heat, the thresholds altered the thermal path, causing thermal build up at the threshold points, reducing the tendency for the heat to simply dissipate into space. With perforations and tubular forms, those located above the flame acted as convection columns, allowing the heat to travel through whilst warming the spaces within. The crevices between the tubes were notably warmer, due to their tighter openings and less allowance for air to convectively cool the spaces. Forms, such as walls, act as obstacles to the heat path, where more smooth refined forms like spheres, allow for a more laminar heat flow. Objects placed within the box, with a different density, form or position from the flame showed a significant alteration in the thermal path. Even if the object was the same material, when clustered together, thermal energy collected and stored in the denser areas. Materials and their associated properties further influenced the movement of heat and the inevitable entropy involved in the process. When thermal energy interacts with a material, the heat transfers by means of conduction and then radiation; depending on the material, the entropic process will result in the amount of thermal energy available to transfer. For instance, metals in comparison to cardboard and wood did not retain much thermal energy, unless in direct contact with the heat source. In the testing of thermal mass, water surprisingly had a slower rate of heat loss in comparison to the same volumetric amount of wood; meaning density and the heat capacity of a material are factors relied on for thermal storage. The less uniform the shape of the material, the more variances there will be with heat distribution. If spaces are defined by thresholds which create different heat signatures for spaces, material objects can be used to further alter thermal behaviour, mitigating the flow of heat and potential experiences and microclimates of space.

URBAN SENSES

PUBLIC THERAPEUTIC SPACE

Therapeutic environments can refer to physical, social, and psychological safe spaces that are specifically designed to be healing.[73] Perception of the elements through the senses allows one to slip from the subjective to Being."[74] The role perception plays in relation to well-being is seen to have significant results in pertinence to those under stress. Thus, a program of a public space where a mixed group of people could come together and destress in an environment that stimulates the senses, would be favourable. A particular focus on the senses that are felt can divert away from the dominant sense of the visual, and as a result, make one more attune to their surroundings; promoting connectedness, and a common ground for healing.

'FELT' SPACES OF COMFORT

"Architecture itself can be a communicative device" where approaches to "therapeutic design [can] propose new ways of thinking about social support and sustainability."[75] Public baths for instance used to be a part of a social system, acting as a meeting house where it didn't necessarily have public bathing facilities but incorporated relaxation therapies. Having a public place for people to unwind from the increased stresses of the urban environment, whilst providing spaces for people to connect, could be very helpful in terms of well-being.

All users of a city should feel part of the collective community, and part of society. One of the main issues is that people are losing attunement to their surroundings; they are becoming numb and desensitized to possible sensory experiences. Separation from the urban environment and engaging the senses in unexpected ways, allows for a new perception or attunement; forming positive experiences in an otherwise stressed, sensory overloaded, urban environment. "In street and city spaces of poor quality, only the bare minimum of activity takes place. People hurry home. In a good environment, a completely different, broad spectrum of human activities is possible."[76] Having a series of activities that shift in thermal experiences, can create an interactive, sensually engaging, and therapeutic environment. These public spaces would promote environmental awareness, community cohesion, and a re-connection towards nature, through the engagement of micro-climates and exterior site conditions. Since the spaces will be attuning to exterior conditions, they will create varying places of comfort between the seasons; functioning as transformative systems of exchange.

"Thermal comfort relates to the satisfaction that the body receives in an environment and is perceived through bodily function called thermal sense," giving the ability to distinguish temperature differences.[77] In combination with social therapy, these 'felt spaces' can be modulated in a customized fashion. Depending on the experience the user wants to create, conditions of comfort can be customized by engaging in the generation of heat, or altering the porosity of certain envelope layers. Along with the flexibility to create varying thermodynamic experiences, the size and shape of the spaces can vary as well, creating more secluded or social opportunities. Considering the body gives off

73 Alyssa Campbell, *Therapeutic Environments: Definition, History & Principles*, https://study.com/academy/lesson/therapeutic-environments-definition-history-principles.html
74 Maurice Merleau-Ponty, *The Visible and the Invisible* (Northwestern University Press, 1969), 218.
75 Terri Peters, ed., *Design for Health: Sustainable Approaches to Therapeutic Architecture* (John Wiley & Sons Inc, 2017), 12.
76 Jan Gehl, *Life Between Buildings: Using Public Space* (Island Press, 2011), 11.
77 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 89.

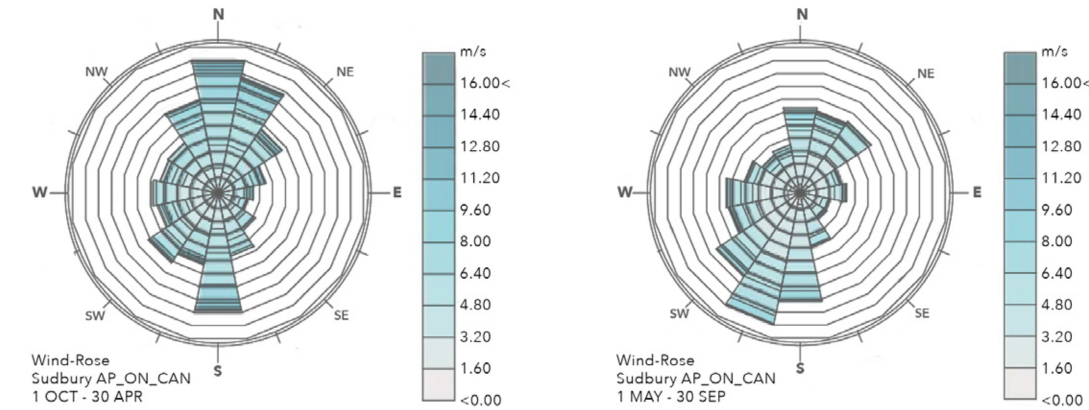


Figure 3.1 Charts displaying Sudbury's wind directions in the winter and summer months. Created using *Ladybug*.

heat, spaces can be designed to become more attune to this phenomena. Where thermal ergonomic conditions are provided for the body to experience different perceptions through the felt senses, and attune the body to be more thermally sensitive.

Within Sudbury, ON, the weather data reveals the occurrence of 'comfortable' exterior conditions approximately twenty percent of the year. In effect, outdoor public spaces are not typically experienced with an ideal atmospheric state; causing microclimates to be relied upon for comfort. A public space which can provide a set of micro-climates and make use of the current exterior conditions would be the optimal balance of architectural design. Working within the in-between zone allows for thermodynamic spaces of comfort and sensory attunement to be present, and used throughout the year. There is also opportunity to recognize other forms of energy which impact thermal energy within the urban environment. For instance, suspended structures can work with wind conditions to overlap sensory experiences, applying a synesthetic perception to thermodynamics. Intersecting these various sensory experiences thus create 'felt' spaces and new perceptions for engagement. Through the interaction of urban and natural environments, a modulated architecture can form a therapeutic synesthetic environment for community healing.

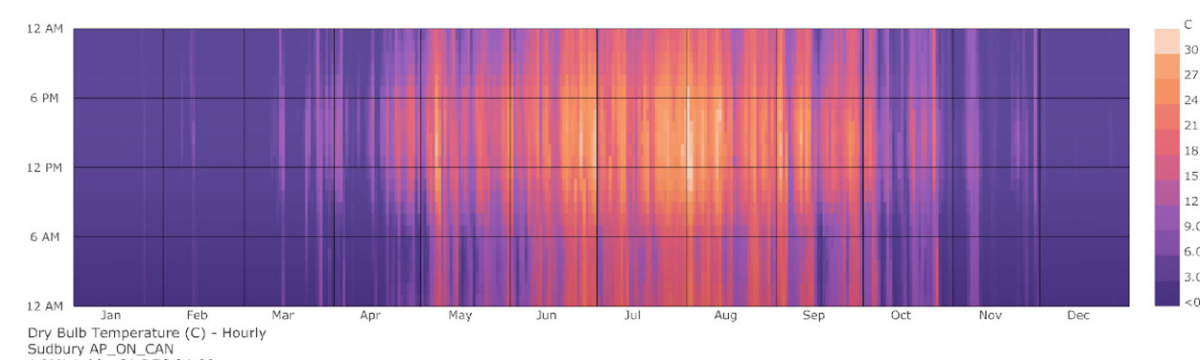


Figure 3.2 Chart displaying Sudbury's daily temperature throughout the year. Created using *Ladybug*.

GARDENS, PARKS, AND THERMAL SPACE

The picturesque movement gave an emphasis to the environment, "exploring human activity in dialogue with an evolving natural world".[78] At the same time, pleasure gardens were places for public enjoyment and recreation, interplaying with both natural and man-made materials, and ornamenting the grounds with buildings and sculptures.[79] oday, these gardens would be most similar to public green spaces or parks provided in urban environments, but these spaces lack consideration of 'public enjoyment and recreation' during the winter months. Designing thermal space would consider areas that facilitate physical activity and relaxation just as a park, but would also function in the winter as a place of comfort and refuge within the urban fabric. This is especially important to consider for those who are homeless, as they tend to face very different choices of activities when outside. For this reason, "winter attractions must be accompanied by essential services for people who are hit hardest by the cold".[80] A thermal garden, offering thermal gratuity and comfort in the winter, can provide sources of heat, bathrooms, areas to bathe, cook food, relax, and socialize with other users. Unlike a park, the provided amenities in a garden become the sensual experience, bringing attention to the *thermal* to ornament space and establish programmatic activities within the thermal garden. Transitional 'layers' of materials and forms guide the energy of operable heat sources and exterior conditions to create several microclimates. The ideal conditions for a proposed thermal garden would serve as a place of shelter that is contained but not fully enclosed. A place in-between, utilizing the verticality of an urban site for public circulation flow, and laminar flow in terms of convective heat and cooling air; whilst enabling the social conditions and opportunities associated with a public park. The garden will bring mixed experiences throughout the seasons, with the influencers of thermodynamics, and the shifting patterns of thermal energy and activity.

"Architecture holds the power to inspire and transform our day-to-day existence," everyday activities can become profound when experienced through the sensitized consciousness.[81] "To see, to feel [this physicality] is to become the subject of the sense."[82] Regarding thermal energy we can be the subject of the felt, thermal sense, as our bodies exchange heat between ourselves and the surrounding environment. Like a park, the site would provide areas for people to inhabit, with various experiences and activities that surround the thermal context. Sculptural forms will insinuate programmatic activities and bring a thermal material culture to various objects in the garden. "Just as the daily weather was part of a larger weather pattern, the picturesque garden was a means to engage the social as well as the subjective."[83] A thermal garden can occupy several levels to make use of the urban site's vertical conditions, and allude to activities surrounding thermal energy to promote social interaction between users. These participatory environmental experiences can further break down the barriers between subject and object, through the use of materiality related to the *thermal*. Attributing a new sustainable aesthetic to public space through thermal understanding and application.

78 Jonathan Hill, *Weather Architecture*, (Routledge, 2013), Introduction 5/10, Kindle edition.
79 "Pleasure Garden," Wikipedia, https://en.wikipedia.org/wiki/Pleasure_garden
80 Emily Macrae, "How Urban Design Can Make Winter a Little Less Grim," Torontoist, https://torontoist.com/2017/01/how-urban-design-can-make-winter-a-little-less-grim/
81 Steven Holl, *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006).
82 Ibid.
83 Jonathan Hill, *Weather Architecture*, (Routledge, 2013), Introduction 5/10, Kindle edition.

Figure 3.3 Thermal images of 'thermal spaces,' and photographs of 'green spaces' within Downtown Sudbury.

ATTUNING URBAN ENVIRONMENTS

In the design of buildings, there is an underlying obsession to address site conditions using algorithmic parameters, which neglects the meaning of place and the poetics of materials.[84] This stirs a decline in the psychosomatic health of society, which is most prevalent in cities; where there is a loss of nature integration, and a disconnect between physical and psychological well-being.[85] Recognizing and expressing energy in productive ways can assist in improving well-being in urban environments, and can be derived through the play with weather variances and modulating thermal activities.

MICROCLIMATES & SITE

"The natural world is a powerful source of the numinous encounter,"[86] where "a walk through the forest is invigorating and healing due to the constant interaction of all sense modalities."[87] Within any urban or natural environment, there are microclimates within the local climate of a place. These microclimates are important to understand, especially in urban environments where there is more range of activity, artificial materials, and mechanical systems at play. Natural environments are usually preferred, with their more gradual, tempered, microclimate conditions. As a natural environment located on the edge of the downtown core in Sudbury, Hynatyshyn Park was one of the public spaces investigated, to make sense of existing microclimates and their implication towards the social dimension. The site presents an intriguing mix of energy phenomena. From the thermal mass of the rock face to the kinetic movement of the creek, along with the variance in tree cover along the path; a unique range of heat signatures were observed. The park currently functions as a place of respite from the downtown for drug abuse, revealing the stressed conditions that should be addressed within the downtown urban environment, along with associated mental health concerns. Taking the energy phenomena present, and the health and social concerns regarding the users of these public park spaces, there needs to be a way to heal this relationship between those living on the fringe of society and those of the downtown.

Natural environments have a way of slowly unveiling and transitioning between new thermal interactions. These interactions are most easily perceived in nature as they have the potential to activate all our senses and support a variety of sensual experiences.[88] Yet in urban environments, the perception of subtle energy transformations are overcome by more abrupt overloads of sensory input. A majority of beneficial 'felt' experiences are resultantly tuned out, limiting the occurrences for the thermal and sensual qualities of space to be perceived simultaneously within the urban environment. Consequently, there needs to be a public space that embraces Sudbury as a winter city, validates the stressed conditions for comfort, and unites the demographics. Where perception is shifted towards activities surrounding the thermal, presenting felt' experiences that are more applicable to needs of the body and place. A thermal garden can provide a variety of microclimates of desired comfort, a means for the community to come together and heal through an attunement of the senses.

84 Alberto Pérez-Gómez, *Attunement: Architectural Meaning after the Crisis of Modern Science*, (Cambridge, Mass.: MIT Press, 2016), 72.
85 Ibid.
86 Phillip James Tabb, *Elemental Architecture: Temperaments of Sustainability,* (New York: Routledge, 2019), 9.
87 Juhani Pallasmaa, "An Architecture of the Seven Senses," in *Questions of Perception: Phenomenology of Architecture*, (William Stout, 2006), 41.
88 Phillip James Tabb, *Elemental Architecture: Temperaments of Sustainability,* (New York: Routledge, 2019),1.

Figure 3.4 Map of vibrant 'energy' activity present in Downtown Sudbury.

Figure 3.5   Massing of Downtown Sudbury.

Figure 3.6   Site panoramic views at different times of the day.

Assessing possible sites around the downtown, there were three distinct types: a narrow alleyway site, an open-space parking lot, or an existing building. Considering the interest in exploring the layers of the envelope, and the potential for systems to create various thermal and sensorial experiences, utilizing an existing building would be a unideal option. There would be a limit on the thermal modulation opportunities as the existing buildings systems would need to be integrated or rerouted. With the option of an open-space parking lot, there is a lack of site constraints to make use of more variable microclimates present in a bounding built environment; although there would be more flexibility in terms of design possibilities. As for the alleyway condition, the constraints of the site would limit the size and occupancy of the program, and the service access for the adjacent buildings would need to be reassessed. The site of 70 Elm Street is a balance between the site constraints of an alleyway and the open space of a parking lot, acting as an infill 'pocket park' condition. Similar to the experiments with the box apparatus, there are constraints but also the opportunity for 'play' within these controlled parameters.

The site of 70 Elm Street is a small parking lot contained by four of six, three-storey high faces with minimal windows, allowing for a new construction opportunity under urban constriction. The south facing side opens up to one of the busiest main streets crossing the downtown, bringing both visibility, 'energetic' pedestrian and vehicular activity both day and night, as well as direct solar gain into the site. At the rear of the site there is an alleyway providing alternative pedestrian access points. Education facilities, offices, cafes, and nightlife activities are nearby, attracting various age and demographic groups to the site. The ambition is to utilize the site as a 'porous' public place, with contained but not fully enclosed conditions. A 'thermal garden' that engages seniors, business owners, students, office workers, the homeless, and those visiting the downtown area, through the felt senses.

Based on the thermal aspects of climate and provided activities, there would be a shift in the types of experiences that occur both day and night and throughout the year. Considering the built constraints of the site, there are thermodynamic factors already present including: direct sunlight, shifting shadows, frequent wind protection from the surrounding buildings and topography, energy dumps from exhaust vents, and different thermal qualities from the site's existing materials. With Sudbury experiencing winter conditions for a majority of the year, public spaces are less utilized and less vibrant. Instead of creating a gap in the urban fabric, the site could employ its existing thermodynamic presence and vertical conditions, to inform programmatic conditions directed by thermal phenomena. Being an urban variation to what is considered to be a park, the thermal garden can make use of the verticality to maximize thermodynamic potential of conductive, convective and radiant heat, between experiential realms of low, middle, and high levelled platforms, and thresholds of the outside, in-between, and inside. By implementing a 'thermal garden', the site could serve a more inclusive function to the Sudbury public, bringing activities considerate of comfort in the winter climate.

INTERACTIONS AND SUSTAINABILITY

To create a culture stemming from microclimates, the site must account for its specific conditions and constraints, especially when modulating exterior conditions. When these factors are considered and designed for, the building becomes unique to its specific location, creating a culture. If the building was to be in another location, it would ascribe an entirely different set of thermodynamic conditions and experiences; bringing an awareness to the qualities of a specific place and "encouraging more intelligent and sustainable engagements with vibrant matter and lively things,"[89] within the urban fabric.

Like any urban environment, a dense mix of users brings along stresses that are increased by social and environmental factors. Factors include, social cohesion amongst the homeless and other users of the downtown, along with a reduced access to more natural, sensory appealing environments. These factors also influence the following issues visible in the downtown, including: addictions, mental health issues, a weakened community culture, and an absence of areas for social inclusion. In urban environments with these factors present, people are inclined to seek their own place of comfort. Amid Sudbury's northern climate, a thermal culture can develop around a public space; bringing people together through the providence of varied thermodynamic spaces of desired comfort or experience within the thermal garden.

The downtown is considered to be the "urban playground for Northern Ontario."[90] If the "downtown is a centre for everyone,"[91] interactions of all demographics should be incorporated. Considering the site's vertical conditions, there is risk for the public space to socially function as an enclosed building, making visibility imperative throughout the vertical layers. The concept of having spaces on platforms brings a flexible porosity to programming and social inclusivity, along with transitional spaces for interactive thermal experiences.

"Healthy design can bring an elemental awareness of natural processes and interactions into the urban context."[92] The thermal aspects of interaction between space and the body can use the awareness of microclimates and the present thermodynamic factors, to allow one to be more in tune to their self, along with the culture of community, and place. In terms of making use of 'free energy,' modulating thermodynamic conditions of the exterior, strongly correlates with sustainable design approaches. Designing in the framework of thermodynamics maximizes the application of energy, by creating places of habitation with activities that allow for different thermal comfort dependencies. This social expression of sustainability can provide to the health and well-being of society, giving a more holistic view of sustainability's relation to possible thermal 'felt' experiences of the built environment. Furthermore, the sustainable approach towards making use of the site's passive and active energies as a public space in the downtown, reflects on the practiced sustainable mindset that re-established and healed Sudbury back to a functioning city.

89 Jane Bennett, *Vibrant Matter: A Political Ecology of Things.* (Duke University Press, 2009), vii.
90 "Downtown Sudbury: a plan for the future, going downtown growing downtown," https://www.greatersudbury.ca/play/downtown-sudbury/pdf-documents/downtown-master-plan-eng-part-1, 30.
91 Ibid.
92 Sim Van der Ryn, *Culture, Architecture, and Nature: An Ecological Design Retrospective,* (New York: Routledge, 2014), 41.

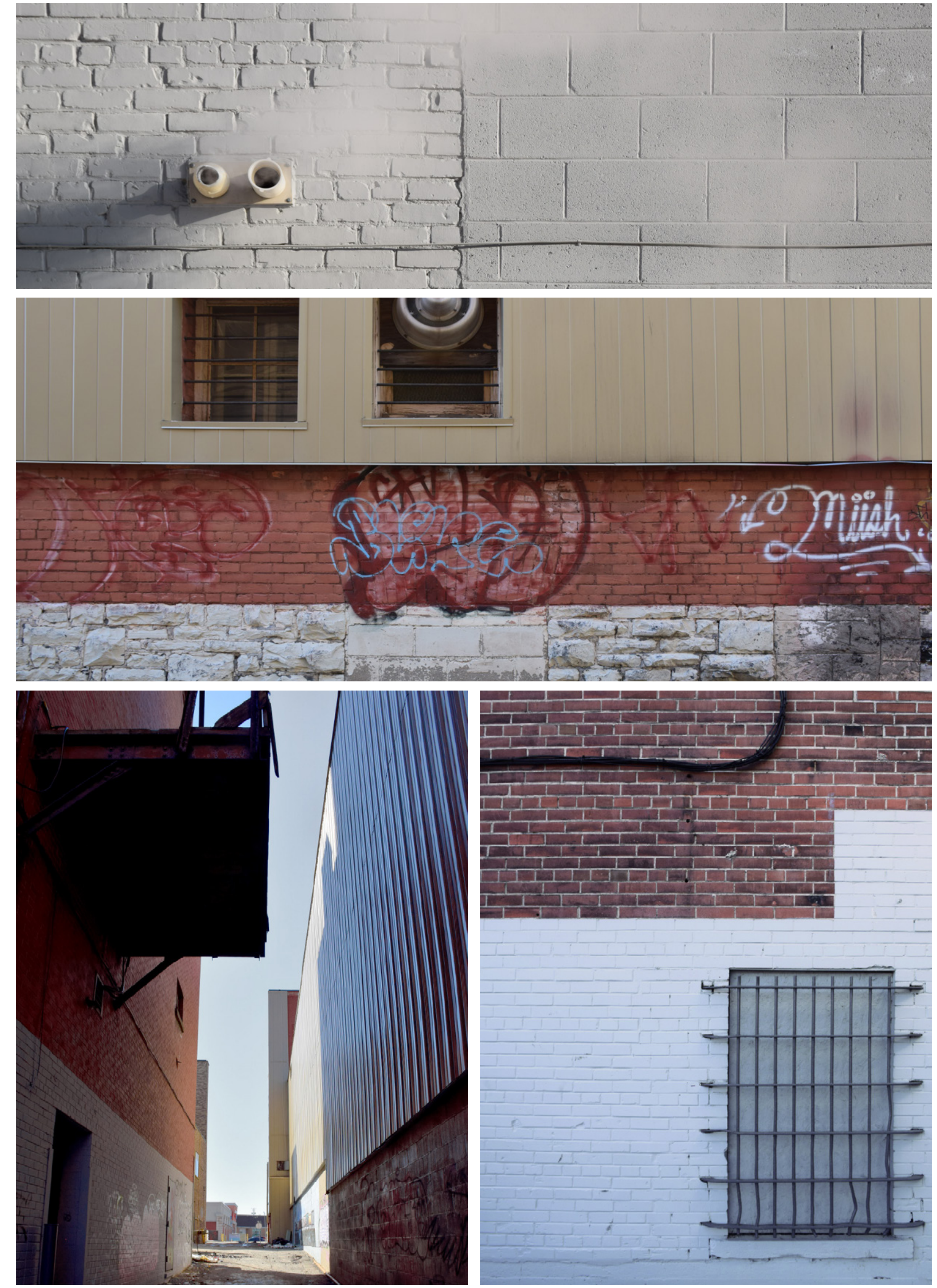


Figure 3.7 On-site thermal energy dumps, alleyway buildings and details.

TECTONIC EXPLORATIONS

THERMAL INTERACTIONS

"The more senses we employ to experience our environment, the more complete our perception of it becomes."[93] Thermal interactions are occurring constantly, serving as a method for sensing and distinguishing between interior and exterior space. First it is important to recognize the types of thermal energy and how they perform in relation to form, and then how these thermal heat signatures can distinguish activities and interactions to occur within different areas of space. Using the constraints of the site, sets of experiments will conduct interactions of various heat sources with materials and forms to uncover their programmatic potential for space.

HEAT TRANSFERENCE

Thermal energy can experience several transfers of heat, under the processes of conduction, convection, or radiation; depending on the substances of interaction. Working with the proportions of the site, different means of heating were tested amongst various materials and forms. Sources of an infrared heat lamp, hairdryer, candles, and warm water pumped through a tube, were used to gain knowledge on the behaviour of thermal energy within a building structure context. A series of models, scaled proportionally to the site, were created to test layouts that maximized the variety for heat signatures to be present.

Based on the experimentations with various heat sources, the use of forced air convection appeared to be the least optimal. Areas that were heated by means of convection alone lacked a thermal gradient, and relied on the materials of the space to convey temperature variance. However, convection as a method of heat transfer, was effective in travelling the thermal energy upwards into spaces above, utilizing the vertical aspects of the site. A building form that employs more vertical space is especially useful when considering the thermosiphon effect, where cool air pushes the heat upwards, towards cooler areas above. Out of all the heat sources, fire from the candles brought the most intriguing variances of heat transfer, providing radiant heat below, conduction to surrounding materials, and convective heat above. By starting to model building forms, it became apparent the significance the structure has with regards to thermal mass. Without constant heat, the structural aspects of the space appeared cool, bringing consideration towards integrating the structure into the thermal system. Also materials undergoing evaporation, like clay, were cooler than the ambient temperature due to the evaporative cooling process. Scenarios played out the variability of solar gain, alongside a heat source present from within the building model, to see how these thermal sources would start to inform spatial properties.

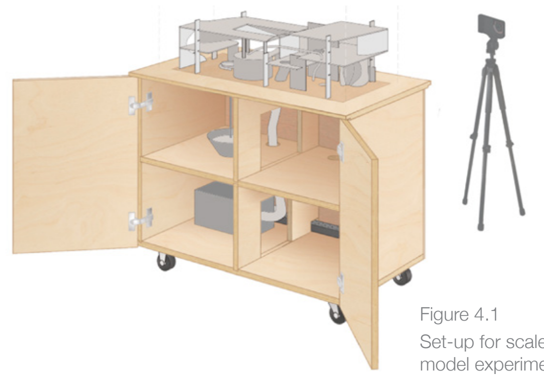


Figure 4.1
Set-up for scaled model experiments

93 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 90.

Figure 4.2 Series of images depicting the experiments of testing various materials and forms with different heat sources.

INHABITING THERMAL SPACE

Over the course of testing various form configurations, body figures were then placed within the spaces to get a vision for possible activities that could occur amongst the presence of heat signatures. Areas that were warmer would likely encourage sedentary behaviours such as sitting or lying down, whereas cooler areas would stimulate movement and groups of people to gather. Not only does playing with the ceiling height and size of the space affect the thermal conditions, but these create more social or intimate spaces for a range of possible interactions. However, like any public space, there will be predictive activities and those that may be indeterminate, which needs to be taken into account.

An arrangement of several half-level platforms, was a layout determined to increase visibility for safety, and optimize heat flow and gradual circulation between the levels. The platforms play with conditions of low, middle, and high ground, amongst the given thermal and climate circumstances. When not fully enclosed, thermal space acts as a space in-between the outside and inside. As a public space, there will be a mix of contained and open spaces on each level, to give variance to the architectural and climate experience. Flexible programming can socially "enrich community life and the sensorial experience of citizens who discover relatively undetermined spaces ready for them to appropriate in creative ways."[94]

Spaces that provide thermal comfort are often discernible through their decoration.[95] It is common to decorate spaces of heat, with objects that will induce activities of increased comfort and pleasure. In the case of public space, these 'objects' would be ambiguous elements that engage with thermodynamics and climate, but can also interact with the body. In this way, the public space will be engaging the climate and the body at an architectural scale through platforms 'decorated' with ambiguous elements and amenities, which speaks to the understanding of thermal space.

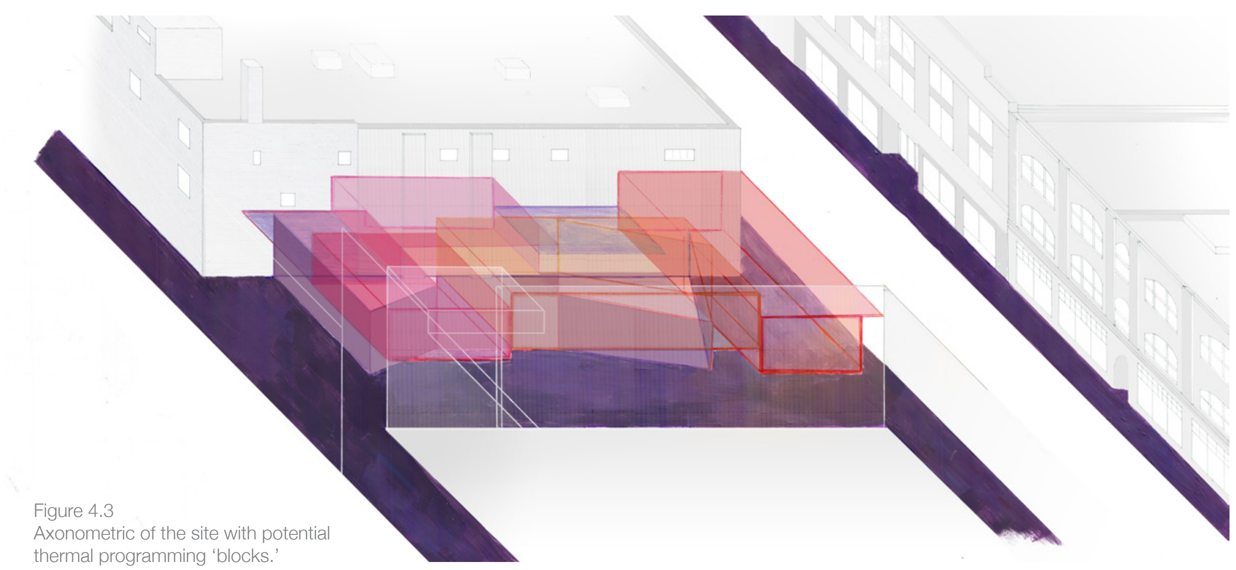


Figure 4.3
Axonometric of the site with potential thermal programming 'blocks.'

94 Armando Carbonell, Frederick R. Steiner, and George F. Thompson, eds., *Nature and Cities: The Ecological Imperative in Urban Design and Planning* (Lincoln institute of Land Policy, 2016), 239.
95 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 90.

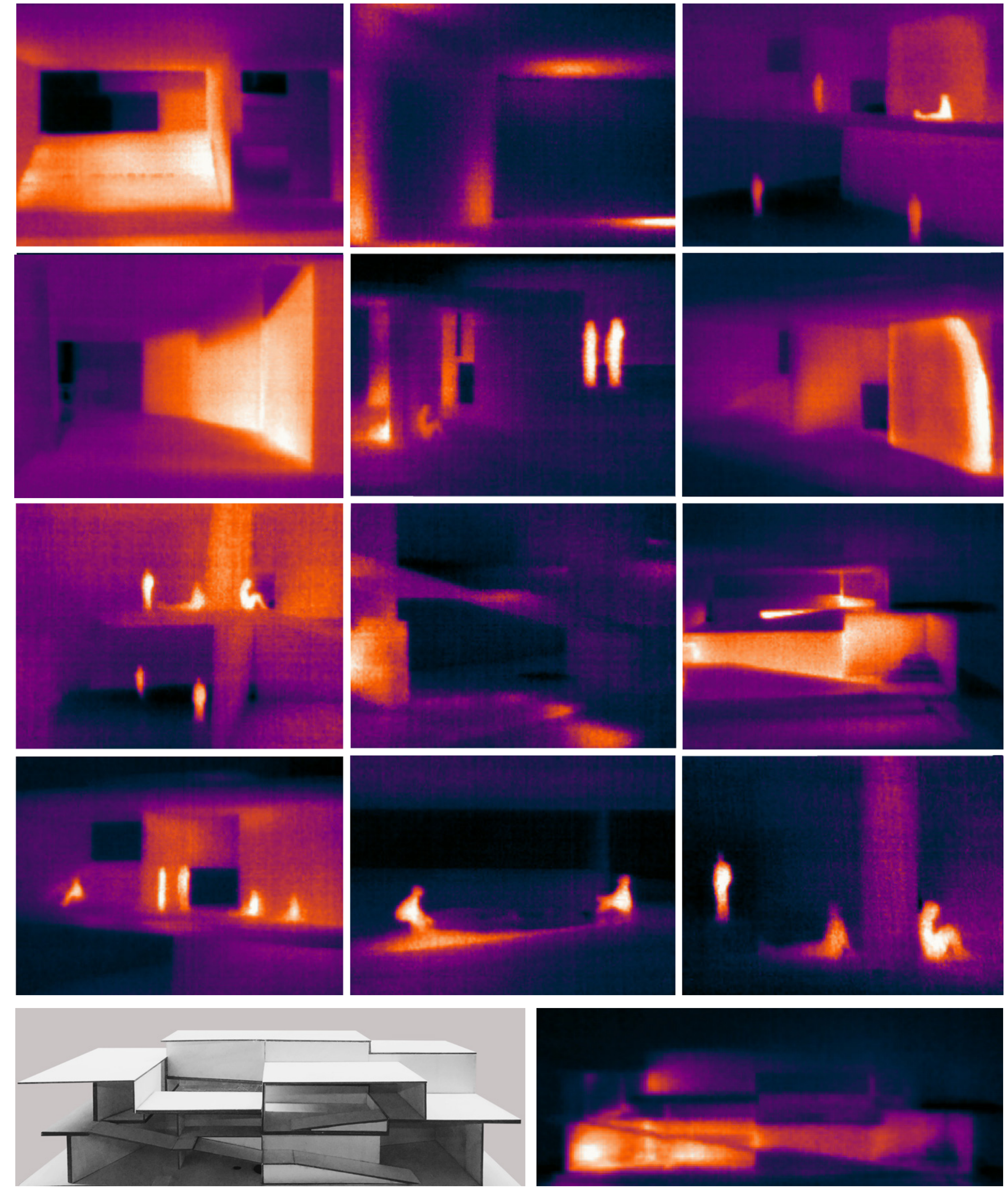


Figure 4.4 Series of images displaying the body inhabiting thermal space in various ways.

THERMODYNAMIC TECTONICS

Factors of radiation, light, matter and air, all need to be considered in the application of thermodynamics. To further develop an understanding of thermal behaviour, another set of experiments were conducted to test convective air flow, and radiant flow of heat from a central fire. Using the thermal photos of the heat traces, and analyzing the remnants of the smoke stains on the wood, a more refined understanding can take place between the layout of the platforms, and ways to make use of a fire's thermal energy within a public space.

FORM AND FIRE

"Fire was once central to architectural space," having a centrality in the primitive hut, cities, early human life, and thought.[96] An ideal organization for a fire has a radiant centre surrounded by less demanding spaces for heat, as the heat given off by fire is primarily convective. Taking the properties of fire into account, a series of forms were subsequently tested for their ability to maximize convective heat flow within the constraints of the site. Apparent from the experiments, areas exposed to the cooler conditions outside created a path for the heat to travel, resulting in heat loss. However, blocking the flow of heat caused an significant accumulation of thermal energy, wasting the potential for the heat to transfer to other spaces and create more thermally diverse experiences. The forms created gradually advanced into a mix of open and closed spaces on varying platforms, optimizing use of the radiant and convective heat from the fire heat source.

The exchange of heat requires an organization of convective understanding, including the consideration of open air locations, vertical permeability, and the conductive qualities of materials. Having an alleyway condition on the ground floor of the site was favourable in terms of convective air flow. The exposed cooler air on the ground level helps to establish a stack effect, assisting the warm air from the fire to travel upwards between the platforms and into designated spaces. Though the air and smoke released from the fire will not be directly released into the public space, the remnants on the tested models provides insight into directing the air flow through flues; where the heat can be navigated through materials of thermal mass or conductive properties, in order to radiate the heat back into the space. The smoke stains also discern the air flow path for passive convective cooling during the warmer summer months. Solar gain into the site and platforms will need to be considered in conjunction with the fire, as a sunny day will affect the thermal flow patterns between the spaces and platforms.

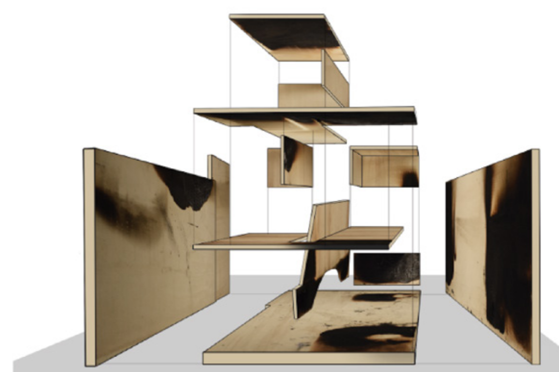


Figure 4.5 Axonometric of the smoke stain residue on *Form 4*.

96 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 88.

FORM 1

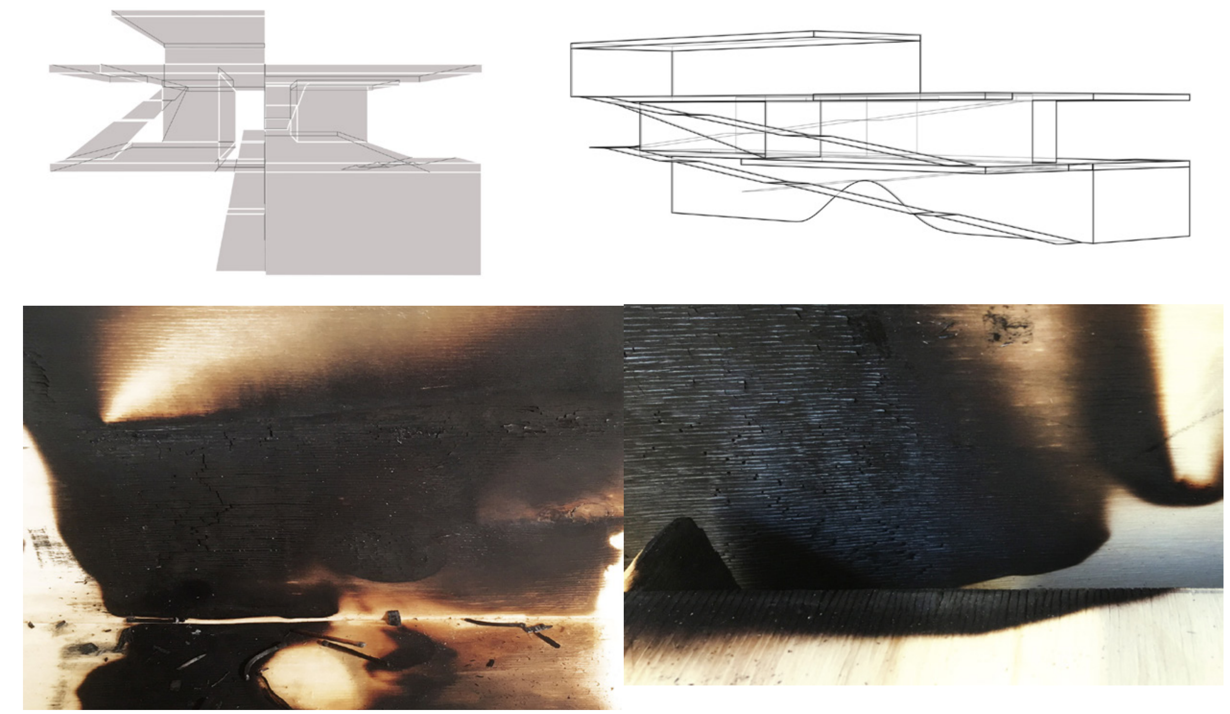


Figure 4.6 Front elevation and axonometric of *Form 1*, images of stains from the convective heat flow.

FORM 2

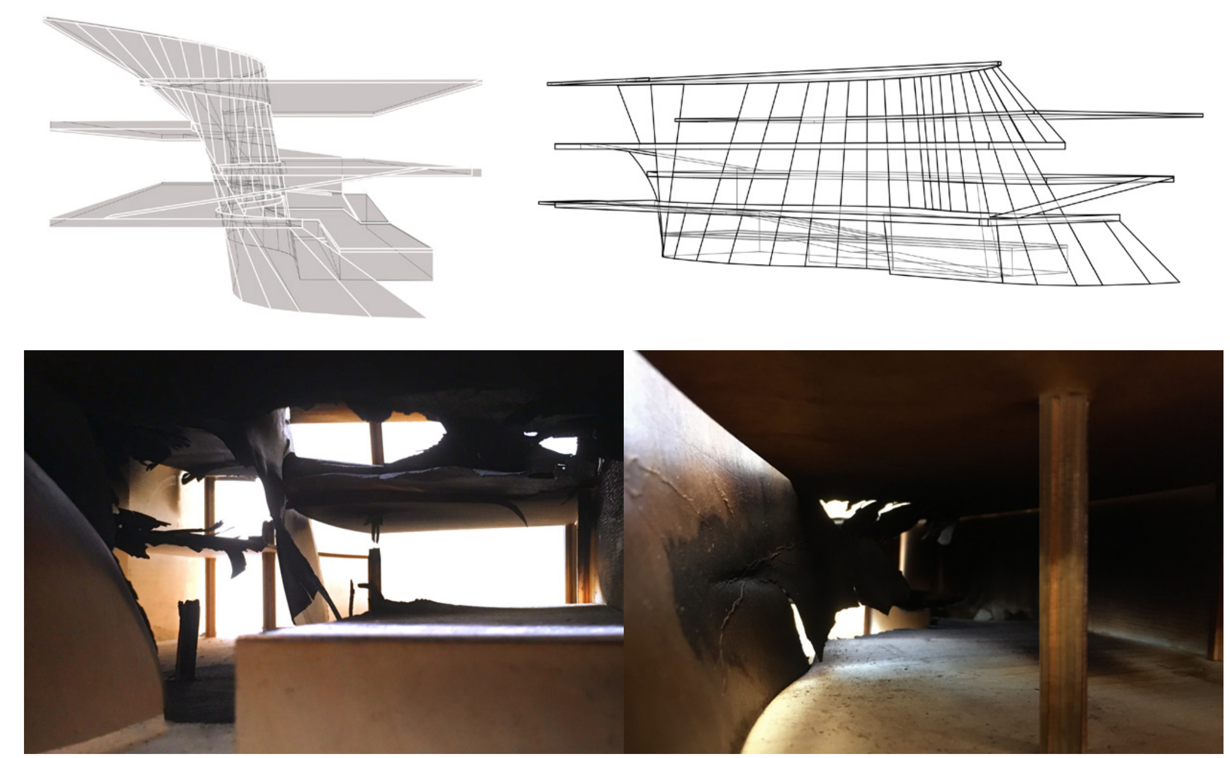


Figure 4.7 Front elevation and axonometric of *Form 2*, images of stains from the convective heat flow.

FORM 3

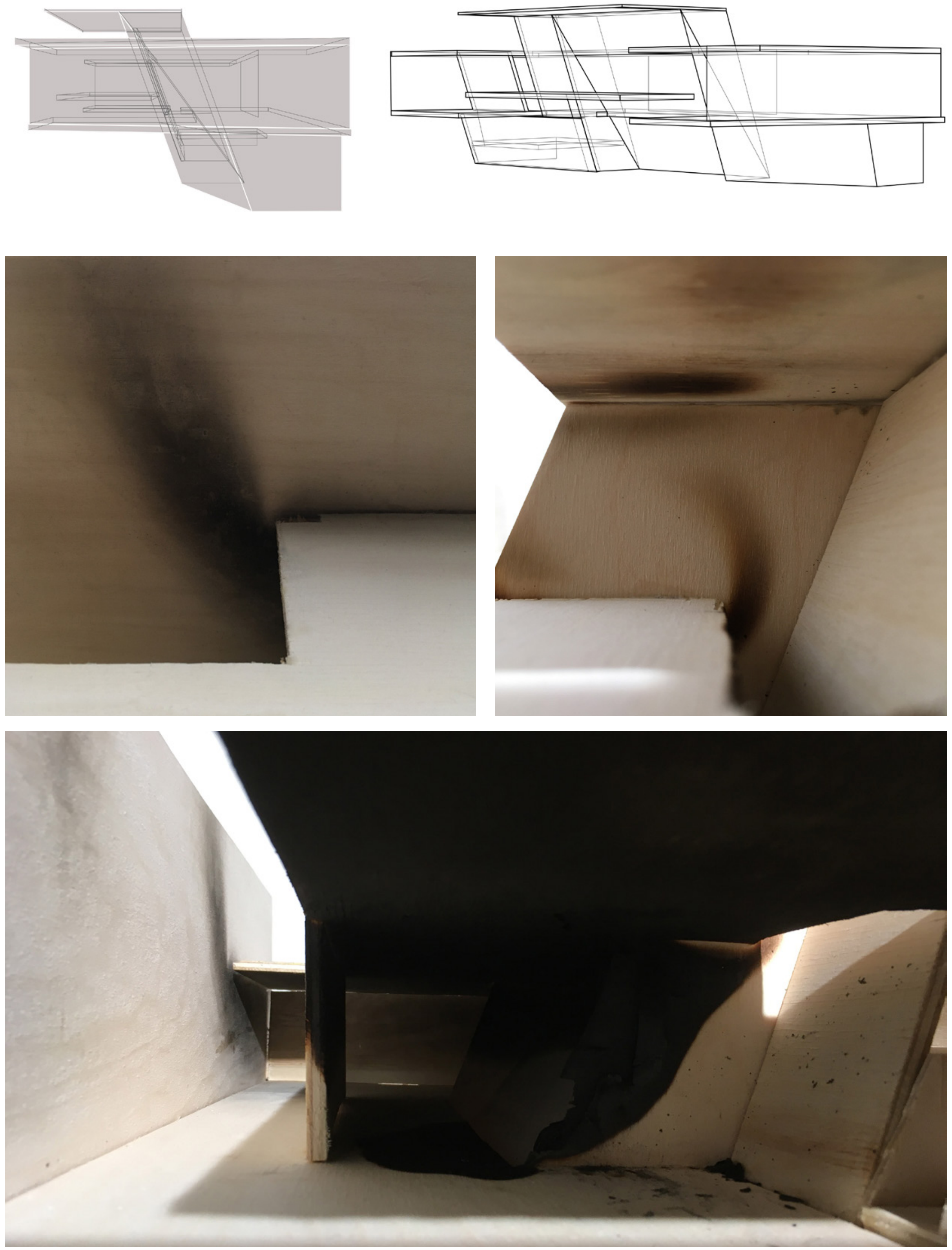


Figure 4.8 Front elevation and axonometric of *Form 3*, images of stains from the convective heat flow.

FORM 4

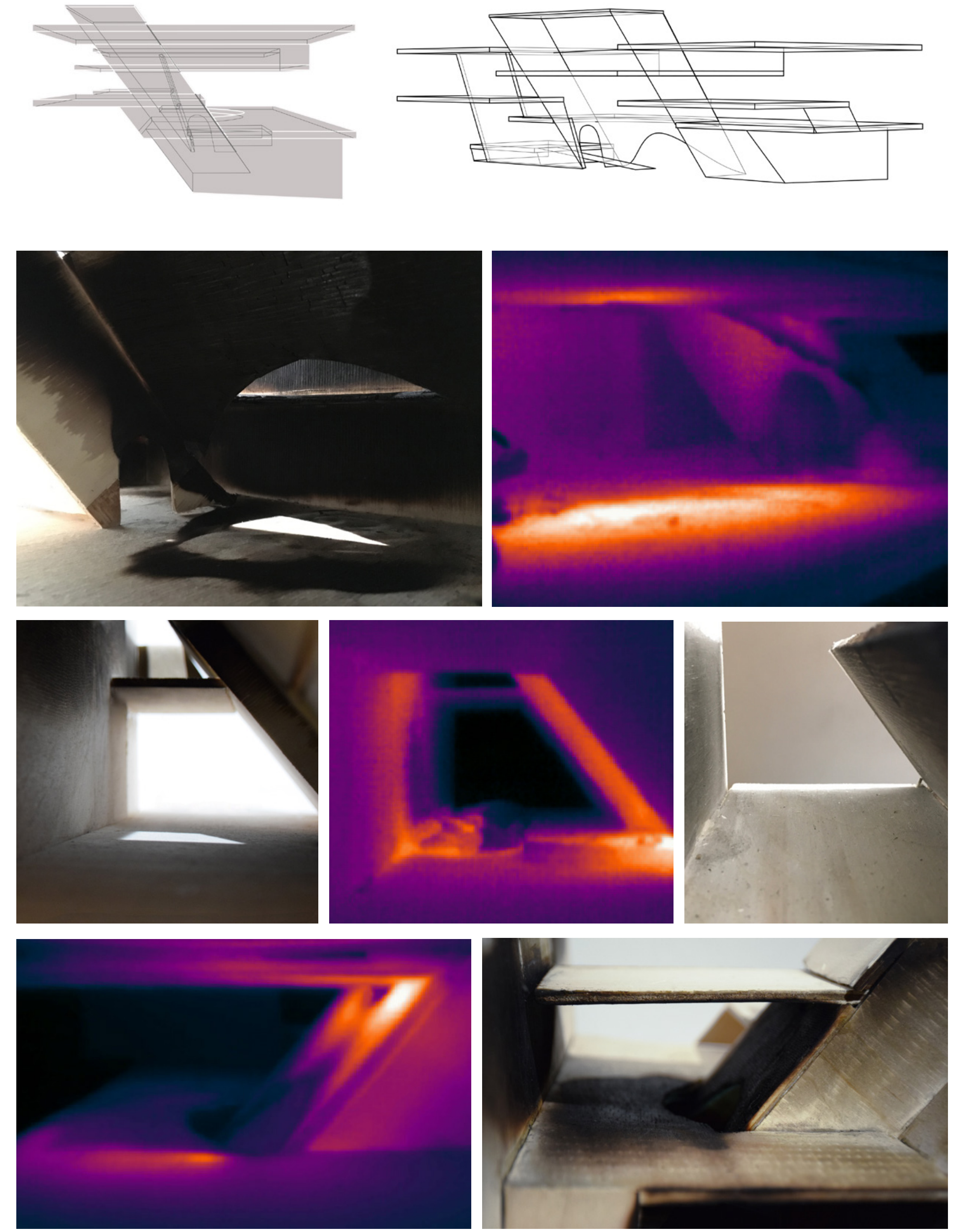


Figure 4.9 Front elevation and axonometric of *Form 4*, images of stains from the convective heat flow and corresponding thermal images.

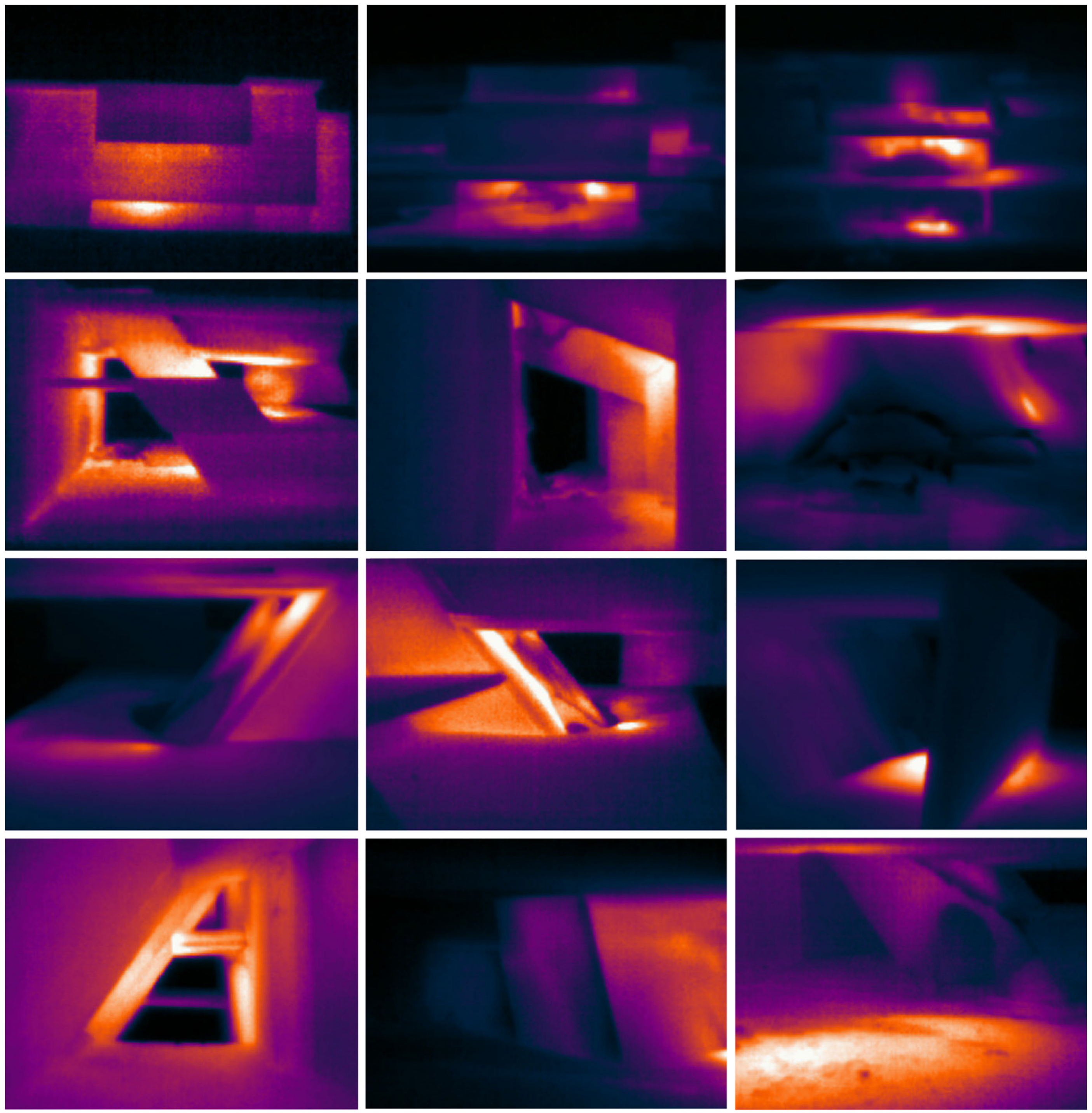


Figure 4.10 Radiant Heat: Series of images displaying the radiant heat traces left after heating the model with fire.

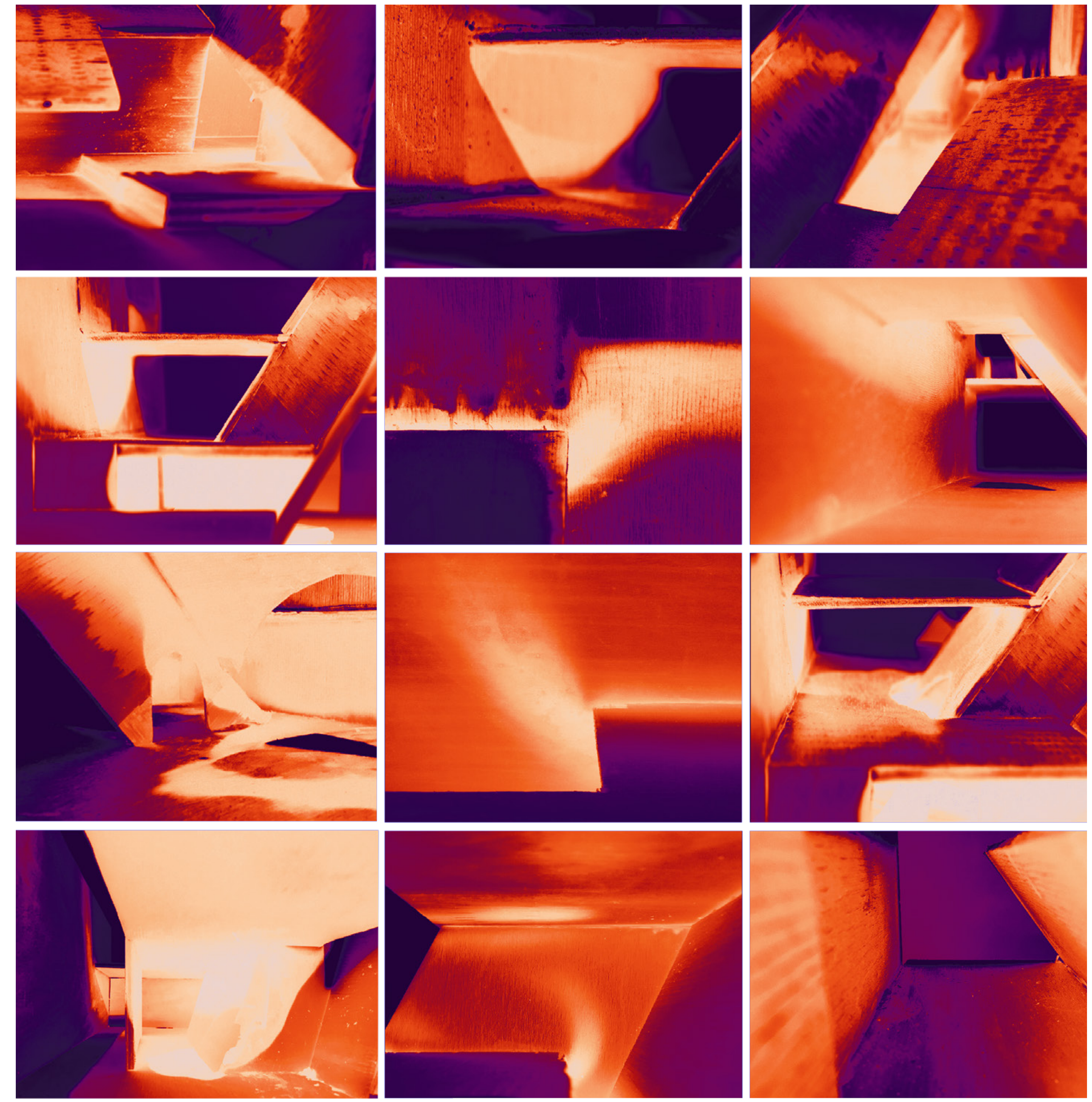


Figure 4.11 Convective Heat: Series of quadtone images displaying the convective heat flow, based on the intensity of the smoke stains.

3D THERMAL MODELLING

To unfold and examine the varying thermal spaces within the building's platformed structure, a 3D visualization was required to refine the programming and materiality for each space. The images translating the thermal phenomena present in the experiments were converted into virtual three-dimensional space, bringing visualization of the *thermal* into the architectural world. From the convective flow results of the fire experiments, *form 4* was the final form tested and optimized for convective performance. The model was re-fired, in order to gather thermal images of the radiant heat qualities in more detail, taking images of all perspectives and elevations. Given that the model was made out of wood, the distinction of different thermal spatial qualities were primarily influenced by the form and density of the spaces, along with the convective heat flow, impacting the thermal retention. The images were traced, defining eight 'contours' within their

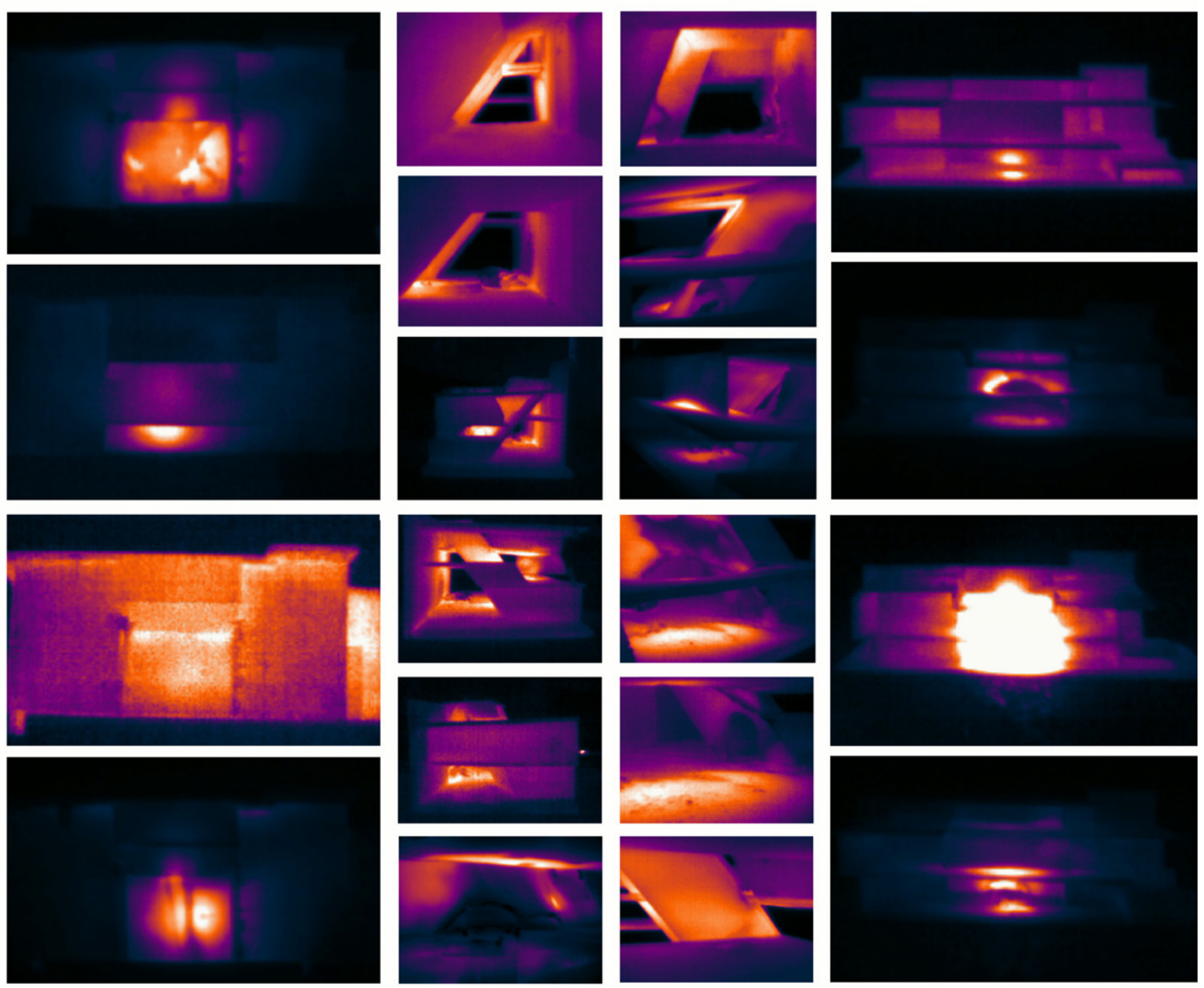


Figure 4.12 Series of perspective and elevation thermal images, displaying the radiant heat traces left after heating the model with fire.

thermal gradients. With *form 4* 3D modelled, the traced thermal contour lines were projected onto the virtual model of the building structure. Lines of each thermal contour were then connected through patched surfaces, developing a 3D thermal geometry for each thermal gradient. With the thermal gradients displayed three-dimensionally within the building form, the model was then 'sliced' to visually understand all the varied thermal spaces. The method of creating a 3D thermal visualization, based on the existing building model, made apparent the thermal transitions between each space; allowing the thermal experience of each space to be refined in material and thermal ornament application. Also, this method provided a basic understanding of the potential thermal gradients present within air spaces; based on the radiant thermal qualities of the building's form, visible in the thermal images.

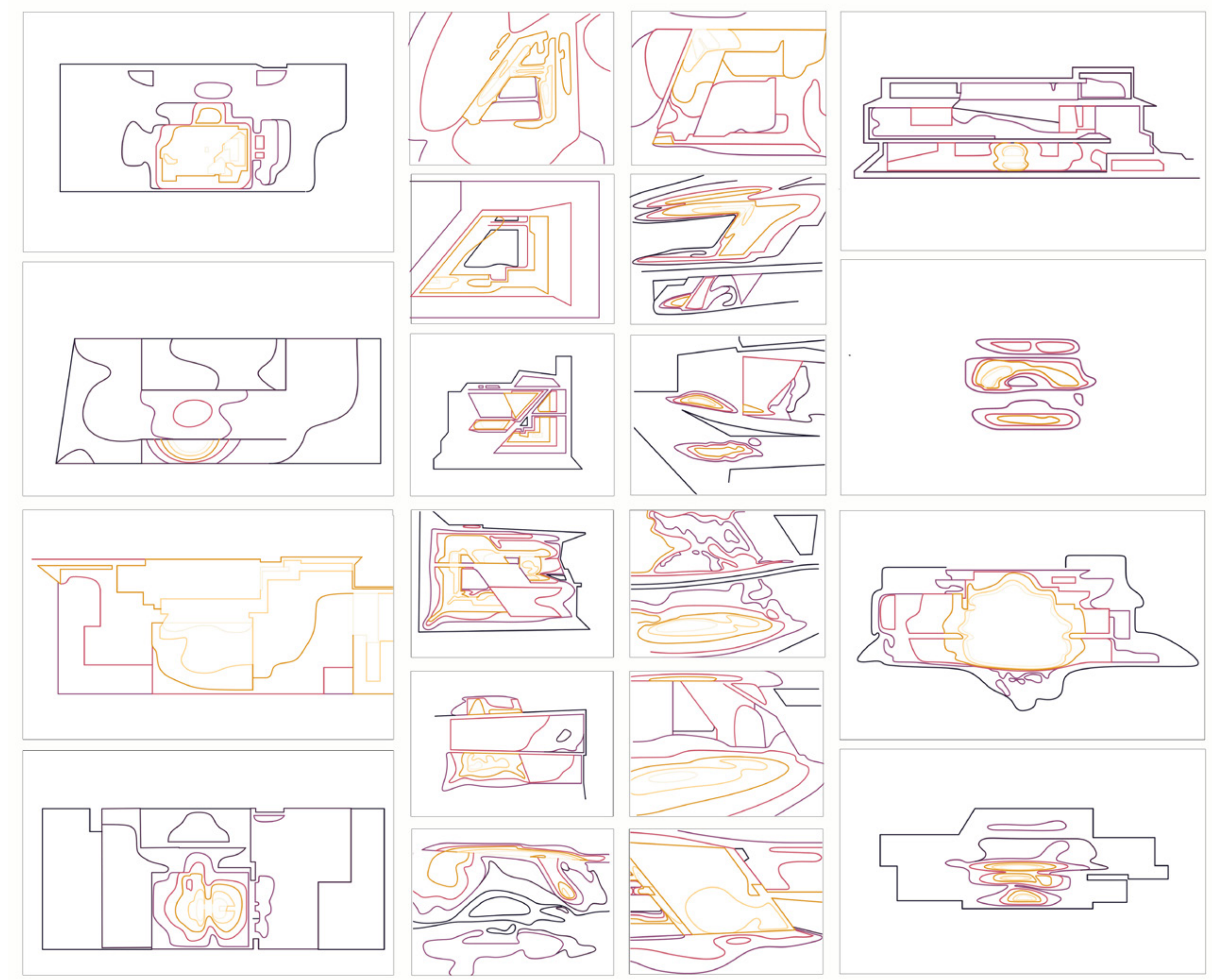


Figure 4.13 Series of perspective and elevation views, displaying traced thermal contours from the thermal images.

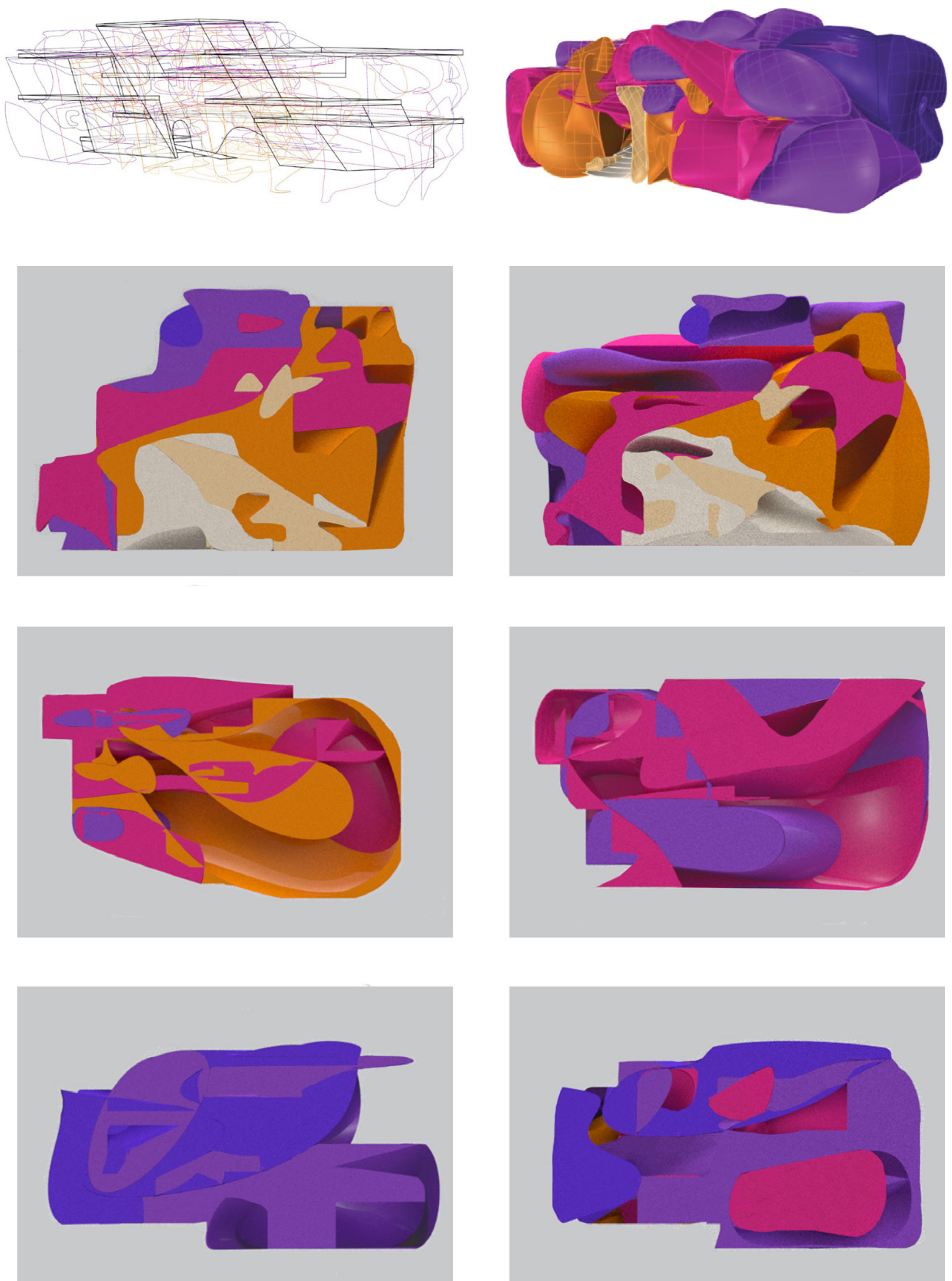


Figure 4.14 3D modelled thermal contours based on *Form 4*: axonometric set-up and thermal 'slices.'

THERMAL AESTHETIC

Fire has historically, and continues to, bring people together, offering a totality of sensory stimulation.[97] Traditionally, walls would be made thicker, allowing the heat to be absorbed and radiated back into the building.[98] A similar system included a fireplace, where hot gases emitted through combustion in the fireplace, travelling through flues within the floors, used for both sleeping and sitting.[99] These tectonic traditions gave materials the opportunity to provide the mass required to organize space, and for the structure to bring conductive and convective channels for heat gains and transference.
The concept of thermodynamic materialism redefines the application of materials, along with the way space is modelled, and "the tools and knowledge required to develop a new [idea] of architectural beauty." A thermal schema can be devised, through creating places of habitation, with activities of varied thermal comfort dependencies.

The "thermal sense is absorbed and integrated into our culture in the form of the unconscious everyday practice, which is the result of thermal associations that we develop in the environments we inhabit."[101] For instance, materials of poor thermal conductivity will feel warmer to the touch, which is why wood is deemed more 'comfortable' than metal in considerably warm or cool conditions. Materials are also thermally dependent on their heat conductivity and heat capacity, for thermal mass and latent heat storage. The significance of the thermal sense can allow materials to ascribe activities within spaces, delivering a means of experiencing the zones of transition from the scale of the meteorological, architectural, and to the body.

The thermal garden will have a primary central fire, with additional secondary operable heat sources. Each heat source will have an affect on the thermodynamic spaces and microclimates created within the thermal garden system. These modulated thermal experiences can shape a social context of program, and a cultural context of heat; influencing body behaviours and activities depending on the form and material application. Material properties have a further refined impact both thermally and programmatically, where a material could additionally present acoustic properties, enabling the possibility of a music space. Thus, insight into the world of the *thermal* exhibits spatial forms of varying correlated heat signatures, along with materials used to amplify the thermal definition of space for habitable function; where activities are informed by heat, giving an aesthetic and culture to the thermal world. Ultimately, through developing thermal associations with certain materials and forms, one can become more attune to recognizing microclimates; acquiring a thermal sensitivity to the associations felt in the thermal garden.

97 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 90.
98 Ibid., 88.
99 Ibid., 95.
100 Inaki Abalos, and Renata Snetkiewicz, Essays on Thermodynamics: Architecture and Beauty (Actar 2015), 236.
101 Stamatis Zografos, Architecture and Fire: A Psychoanalytic Approach to Conservation (UCL Press, 2020), 90.

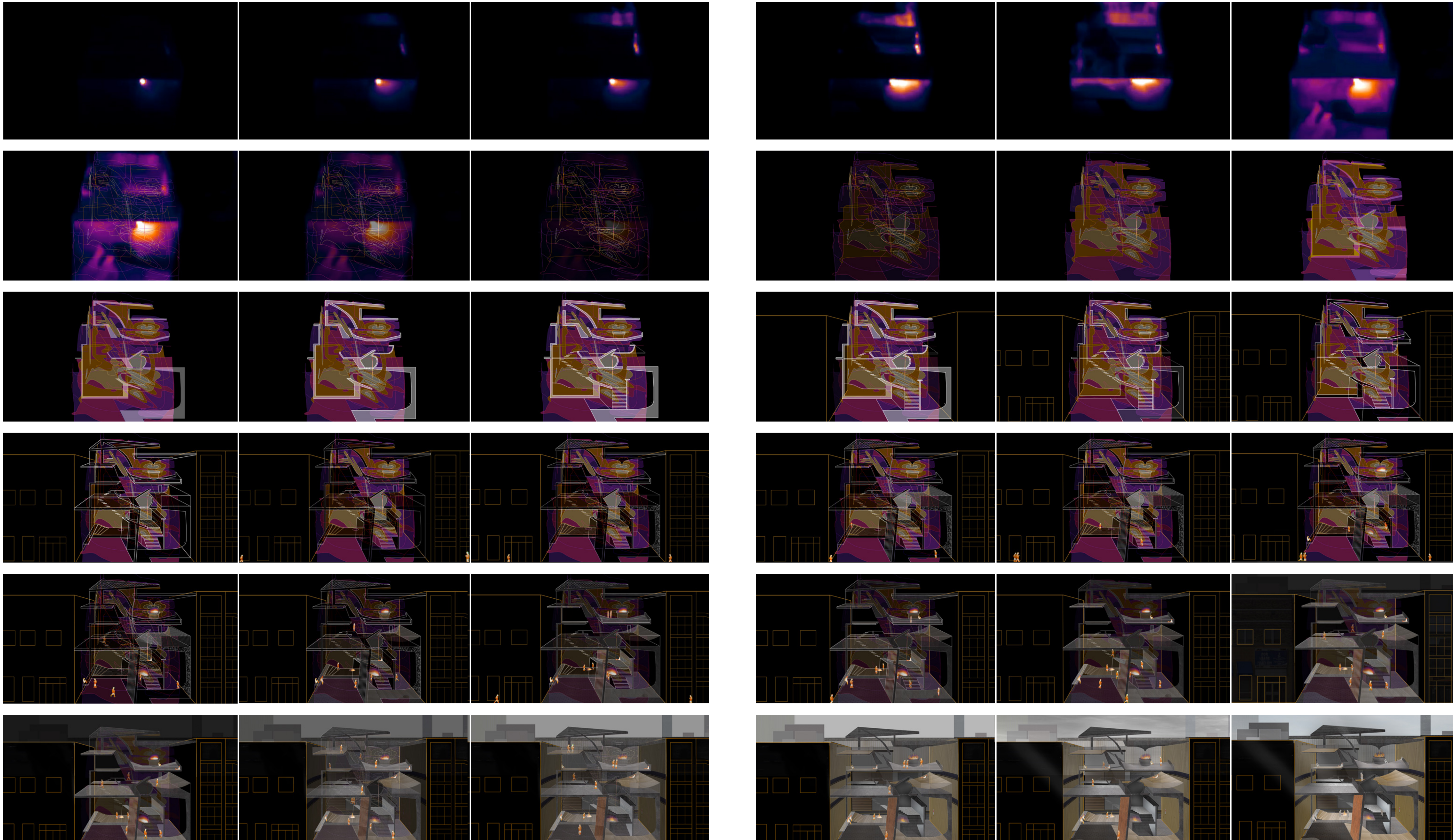


Figure 4.15 Film strip transitioning the thermal traces of a fire to material form.

SENSUAL BUILDING SYSTEMS

URBAN THERMAL GARDEN

The ‘thermal garden’ is a project proposal exploring a ‘sensual’ thermodynamic system for urban public space. Encompassing several layered platforms; three realms of the *outside, in-between*, and *inside* are used to delineate experiences surrounding a thermal schema of microclimates. Architecture derived solely from climate conditions and on-site thermal conditions, will bring a new aesthetic to thermodynamic beauty, making use of material properties and laminar flows to reduce entropy. Any object or element considered to imply an activity or behaviour will service the functional, ornamental elements to the garden. Sudbury as a cold climate city would have value for an urban public space which encourages sensory engaging activities and social interaction year-round.

Figure 5.1 Front Elevation of the proposed ‘thermal garden’ and site.

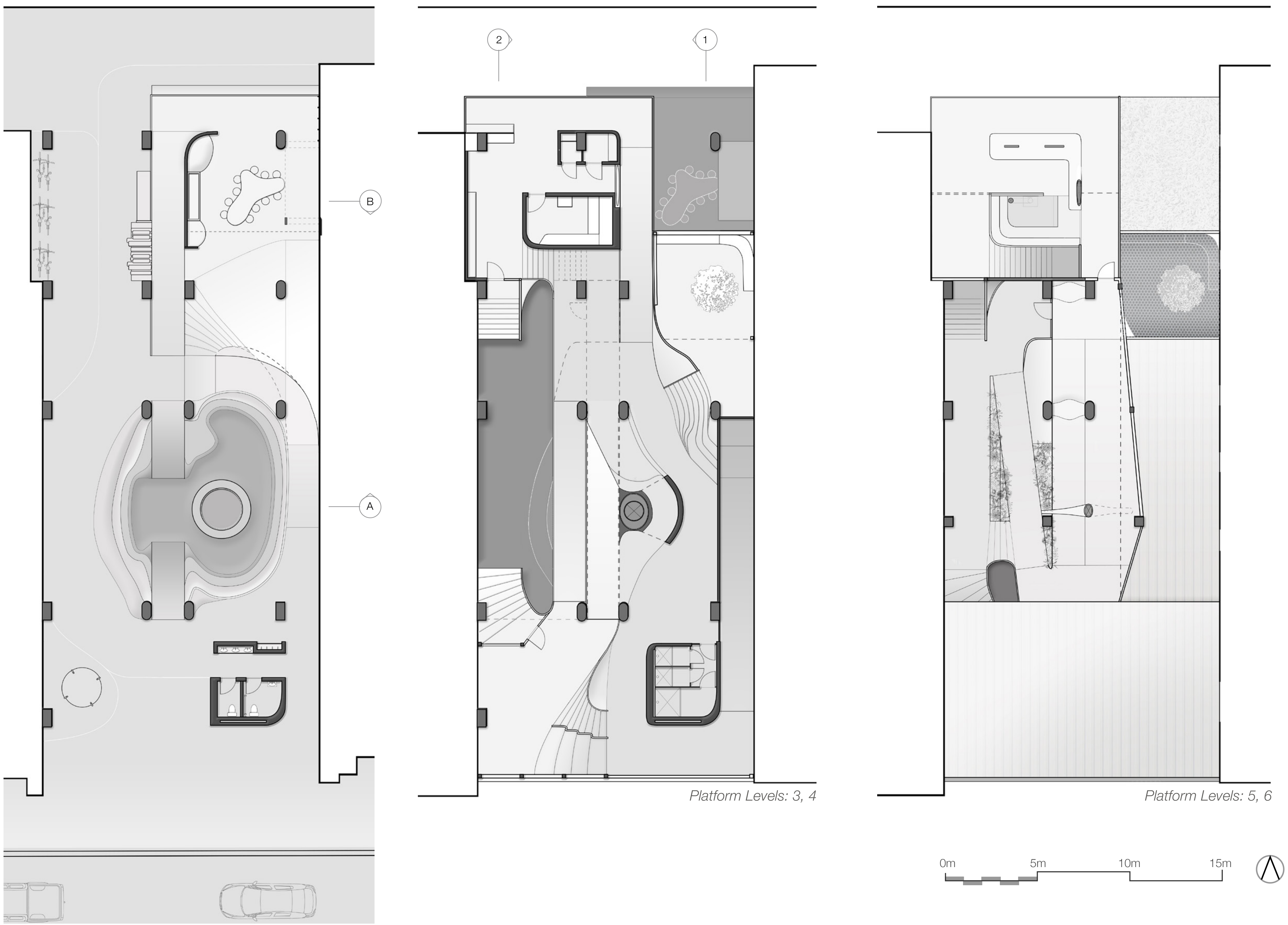


Figure 5.2 Floor Plans: Platforms.

Platforms

The thermal garden is comprised of several platforms, with each level providing a new activity for interacting with the ‘felt senses’ and experiencing thermally designed spaces. Each platformed area has different conditions, whether there is a present heat source, mitigated weather exposure, or spaces of varying enclosure.

Throughout the thermal garden there is a mix of envelope systems, which either control, mediate, or enhance exposure to the exterior elements. The resulting spaces of fluctuating ‘porosity’ determines the path of travel for thermal energy, bringing variance and play to the potential felt experiences.

As a whole, the thermal garden is not fully enclosed. The split levelled platforms enable social interactions between spaces, through the arranged visibility and thermal programming.

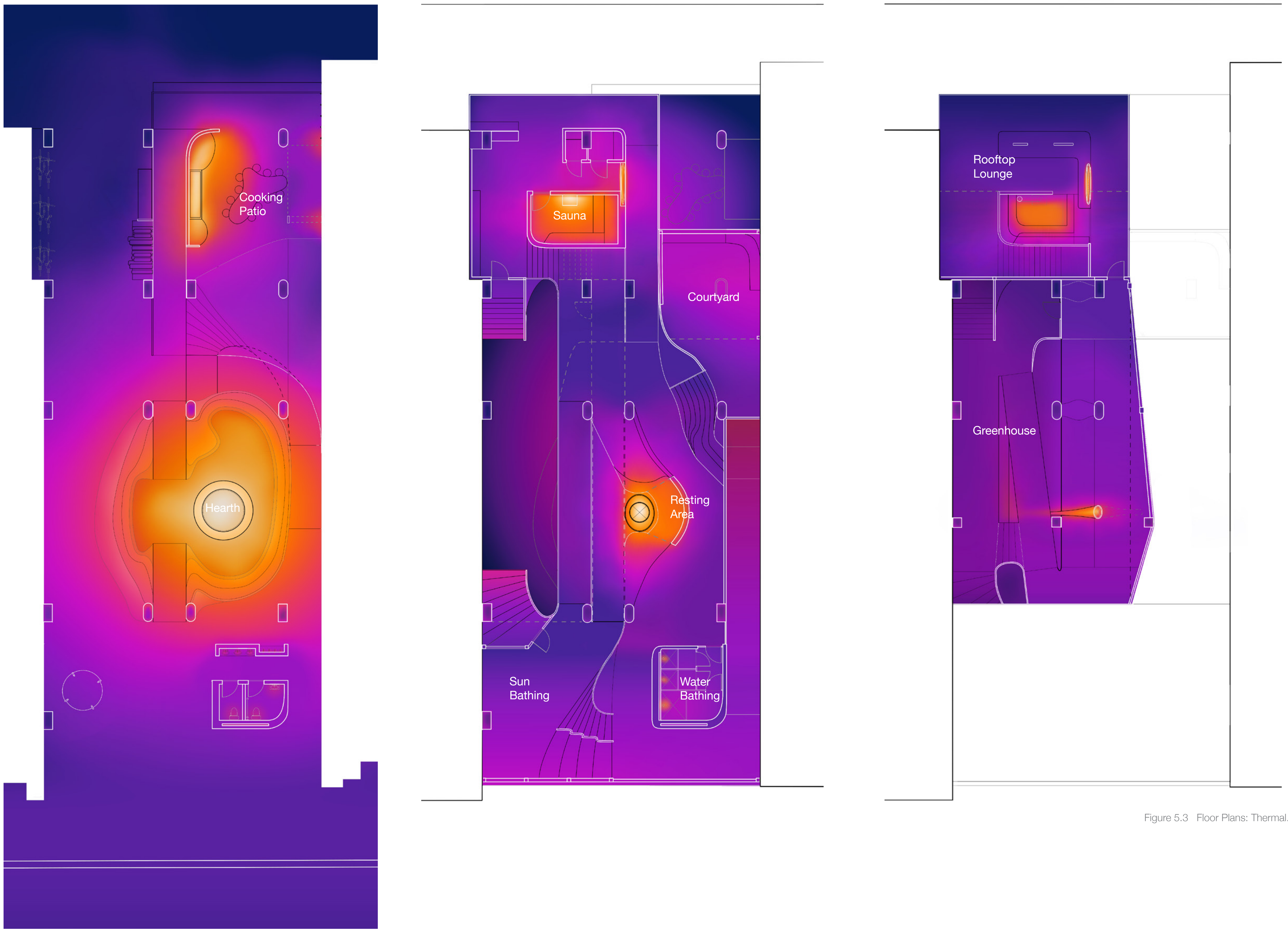


Figure 5.3 Floor Plans: Thermal.

Thermal Culture

Making use of the platforms and verticality of the site, each thermal program is influenced by its heating elements, and thermal 'flora' for interactions with heat. Moving through the different spaces and levels, there are experiential thermal gradients transitioning between the heat sources.

Depicted in the floor plans, a scenario of thermal phenomena is present within the thermal garden, where all heating elements are presumed in use, under sunny winter conditions. The heat transcribed amongst the platforms creates a scene of varying thermodynamic factors, which would produce divergent thermal gradients, if a different set of exterior conditions and heat sources were engaged.

The heat sources are dispersed throughout the platforms, each providing subsidiary thermal support to the central fire, and a sequence of diverse 'felt experiences.' As a means to utilize the thermal energy, thermally programmed spaces are crafted around each heat source. The moments between the thermal spaces in the garden, creates an 'in-between' zone of transitioning temperature gradients; allowing one to experience the mix of radiating, convective, and conductive heat, along with transitions between each thermally zoned space.

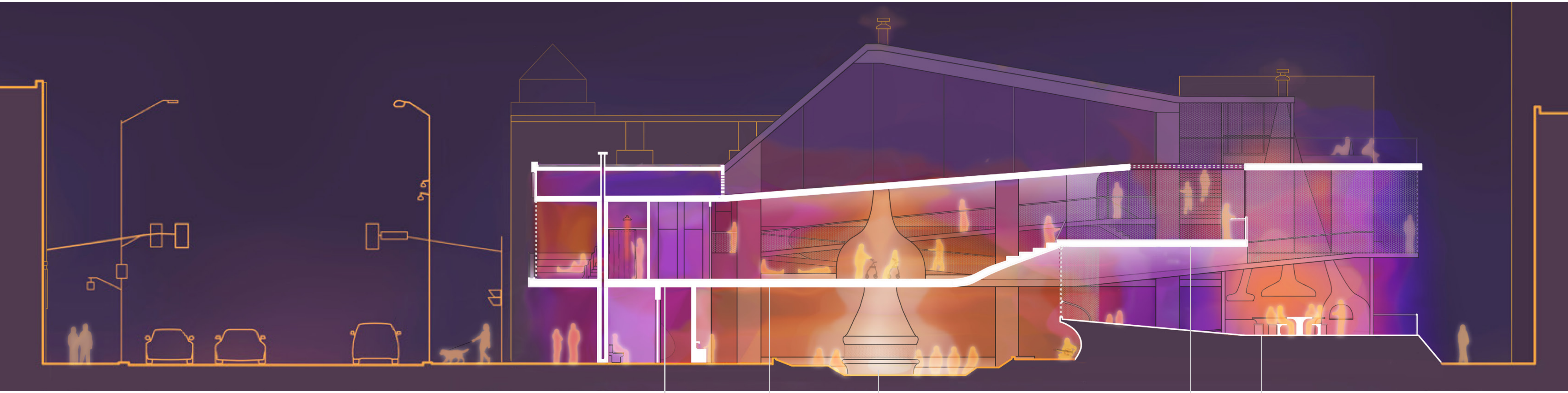


Figure 5.4 Thermal Longitudinal Section 1: East Face.

WATER BATHING *Inside - Platform Level 3*

Elements: solar powered boiler system

Thermal Flora: water

Experience: The feeling of water on the body provides a personal experience with the thermal. There will be options of warm or cool water, depending on the individual preference. A public shower and change room provides the basic amenity for body cleanliness.

RESTING AREA *In-Between - Platform Level 3*

Elements: flue radiant heat transfer, convective heat transfer through the floor

Thermal Flora: domed nook with heat retention, raised platform for resting, heated floor

Experience: A domed enclosure surrounds the chimney, creating a cozy warm space for relaxation. Raised platforms are arranged around the chimney to provide areas for sleeping or lying down.

HEARTH *In-Between - Platform Level -1, 1*

Elements: fire pit

Thermal Flora: seating cove, curved music shell

Experience: A continuous curved bench wraps irregularly around the fire, ornamented in materials of various thermal mass. Each seat around the fire facilitates a different thermal experience with the fire.At a distance beyond the seating is a curved wall, radiating the heat back towards the central hearth, and contributing an acoustic music shell to the space.

COURTYARD *In-Between - Platform Level 4*

Elements: sun

Thermal Flora: tree, roof and side wall screens, seating, counter

Experience: Partially enclosed by perforated screens, the courtyard offers an outdoor experience, not fully exposed to the elements. A central tree gives additional shade to certain seating areas. When the kitchen below is in use, moments of warm convective heat can be felt when standing at the counter ledge overlooking the cooking patio. Tempering the exterior conditions allows the courtyard to be a preferred outdoor space under inclement weather.

COOKING PATIO *Outside - Platform Level 2*

Elements: cooking elements, energy dump, partial sunlight

Thermal Flora: seating, tables, tunnel walk space

Experience: The cooking patio serves as an outdoor kitchen with various wood-fired cooking elements. An eating area is located next to the cooking area, where chairs closest to the cooking elements will retain heat for some time after the kitchen is in use. The high roof of the space allows for fresh air to come in through the cooking patio area and circulate throughout the building. This condition also brings partial sunlight into the space through the courtyard's open perforated roof. When moving through the cooking area, part of the path becomes enclosed, and can be experienced as a temporary warm space when the exhaust vents are in use by the adjacent building.

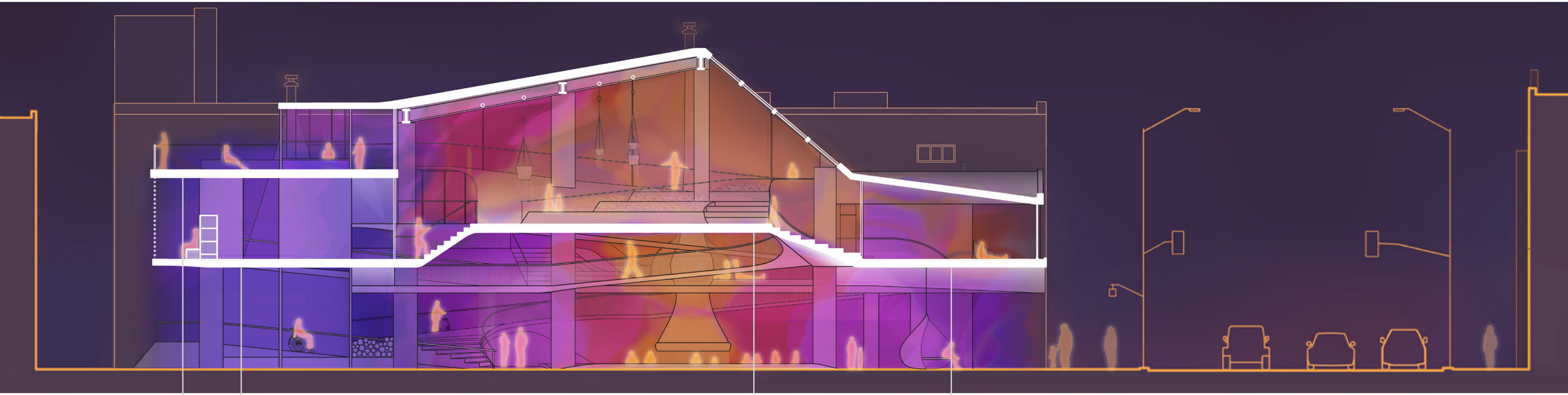


Figure 5.5 Thermal Longitudinal Section 2: West Face.

SAUNA *Inside - Platform Level 5*

Elements: wood burning sauna stove, heat transfer from the cooking area

Thermal Flora: wood enclosed space, glazed roof, seating

Experience: A small enclosed room has a sauna stove located on a central wall. When not in use, the seats in the room can still be warm if the cooking elements are being used below. The roof of the space is open to the base of a glazed bottom pool of water, allowing light to filter in through the thermal pool.

ROOFTOP LOUNGE *Outside - Platform Level 6*

Elements: heat transfer from the sauna and cooking area, sun exposure and covered areas

Thermal Flora: semi-enclosed thermal pool, heated seating, balcony

Experience: Located directly above the sauna, a shallow thermal pool provides a foot bath and seating area. The thermal pool is semi-enclosed to retain heat in the water. Part of the rooftop has seating that is covered overhead and other areas which are not. The seating located directly above the cooking patio is slightly warmer when the cooking area is in use. The rooftop lounge offers the most exposure to the elements and can be a cool space on a windy day.

SUN BATHING *In-Between - Platform Level 3, 4*

Elements: sun

Thermal Flora: glazing, operable shading screens, seating

Experience: Shifting between glazed windows and perforated panels, the sun bathing area uses solar gain to accumulate heat within the space. Reclined seats face the street, allowing one to watch the activity outside. If the space becomes too warm, operable screens can bring air flow into the space or reduce the solar gain. The thermal mass of the wall for the water bathing area can also provide radiant heat into the space after sun exposure.

GREENHOUSE *In-Between - Platform Level 5, 6*

Elements: sun, heat transfer from the fire

Thermal Flora: planter beds, hammocks

Experience: With suspended plants in the summer and planter beds, the greenhouse remains operational in the winter by transferring heat from the central fire to the planter beds. Hammocks are hung amongst the plants for a place to unwind within a green space. Being the greenhouse is two levels, the upper level will be slightly warmer and humid due to the decreased ceiling height.

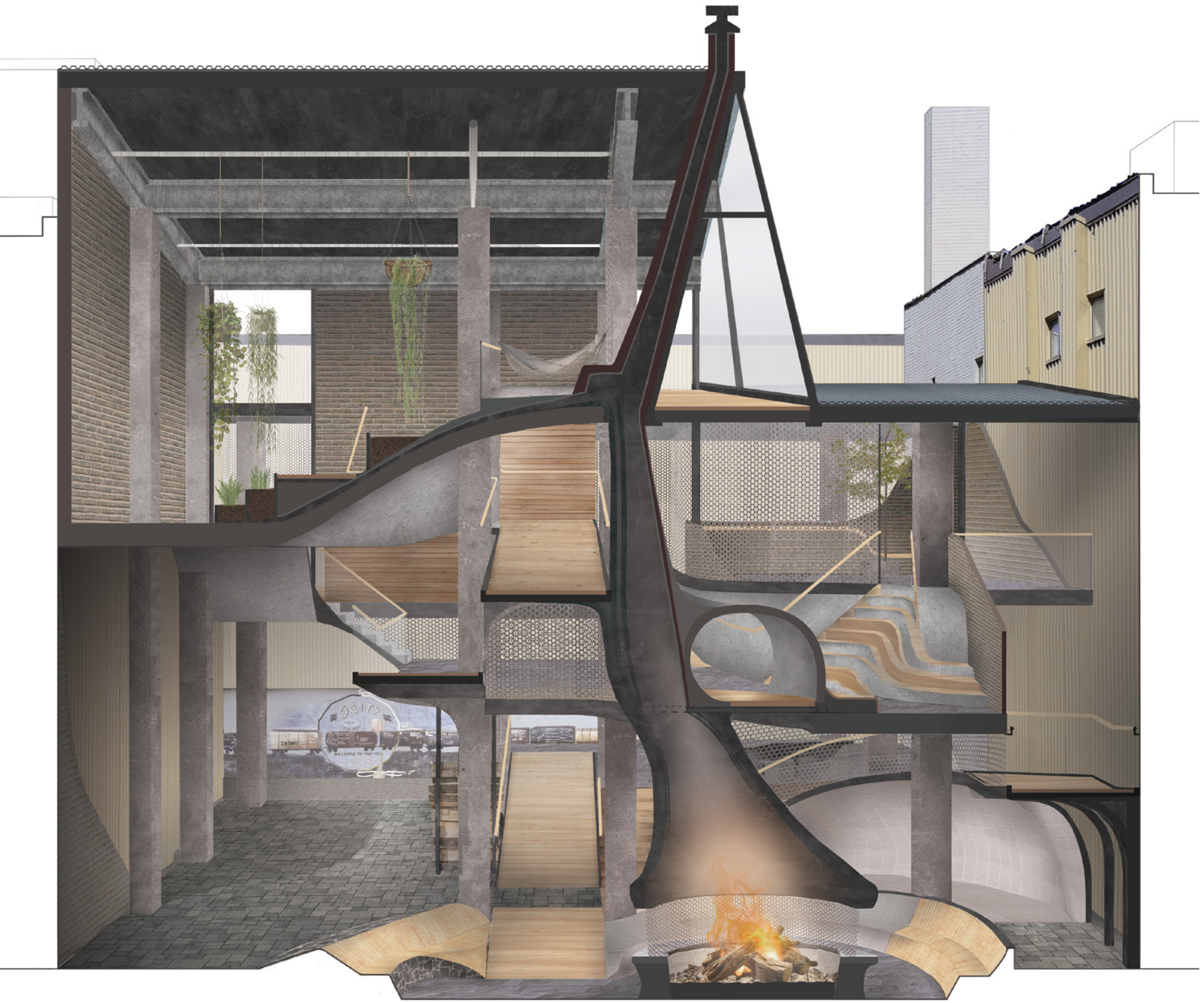


Figure 5.6 Cross Section A: Render.

Cross-Section A

The fire is the primary heat source provided centrally in the thermal garden. The following sections delineate the ways of directing thermal energy to support different programmed spaces and thermal qualities.

Detail A.1: Fire Pit

The thermal energy given off by a fire is mostly convective heat, hence the hearth is located below ground level and the seating is situated at different intervals from the fire to adjust radiant thermal comfort.

Detail A.2: Chimney, Rest Area, Circulation

As the heat rises and travels through the flue of the chimney, air gaps between the insulated steel structure are also heated. The heated air, within the walls of the chimney, delivers heat to the circulation and resting areas surrounding the stack. A domed nook and raised platform provide places to sit or lay down amongst the heated surfaces. The radiant heat rising from the fire pit below provides heat to the circulation spaces that are above.

Detail A.3: Heat Exchange

At the highest level, the chimney travels through the greenhouse. The chimney makes a bend to allow the convective air to accumulate in the cavity and warm the heat transfer fluid. With smoke collecting in the cavity, there is a smoke shelf to prevent the smoke travelling back down. The chimney in the greenhouse transitions to a masonry structure, to prevent the air from cooling too fast as it makes its way to the vent. The bricks allow the convective heat to be absorbed slowly and radiated back into the greenhouse.

Detail A.4: Planter Bed Heat Transfer

To sustain the plants in the winter, the planter beds are heated. Thermal energy is provided from the fire to warm the heat transfer fluid, and subsequently warm the soil beneath the plants. Soil, having a high moisture content and density, can retain the transferred heat for a long period of time if the fire is used consistently.

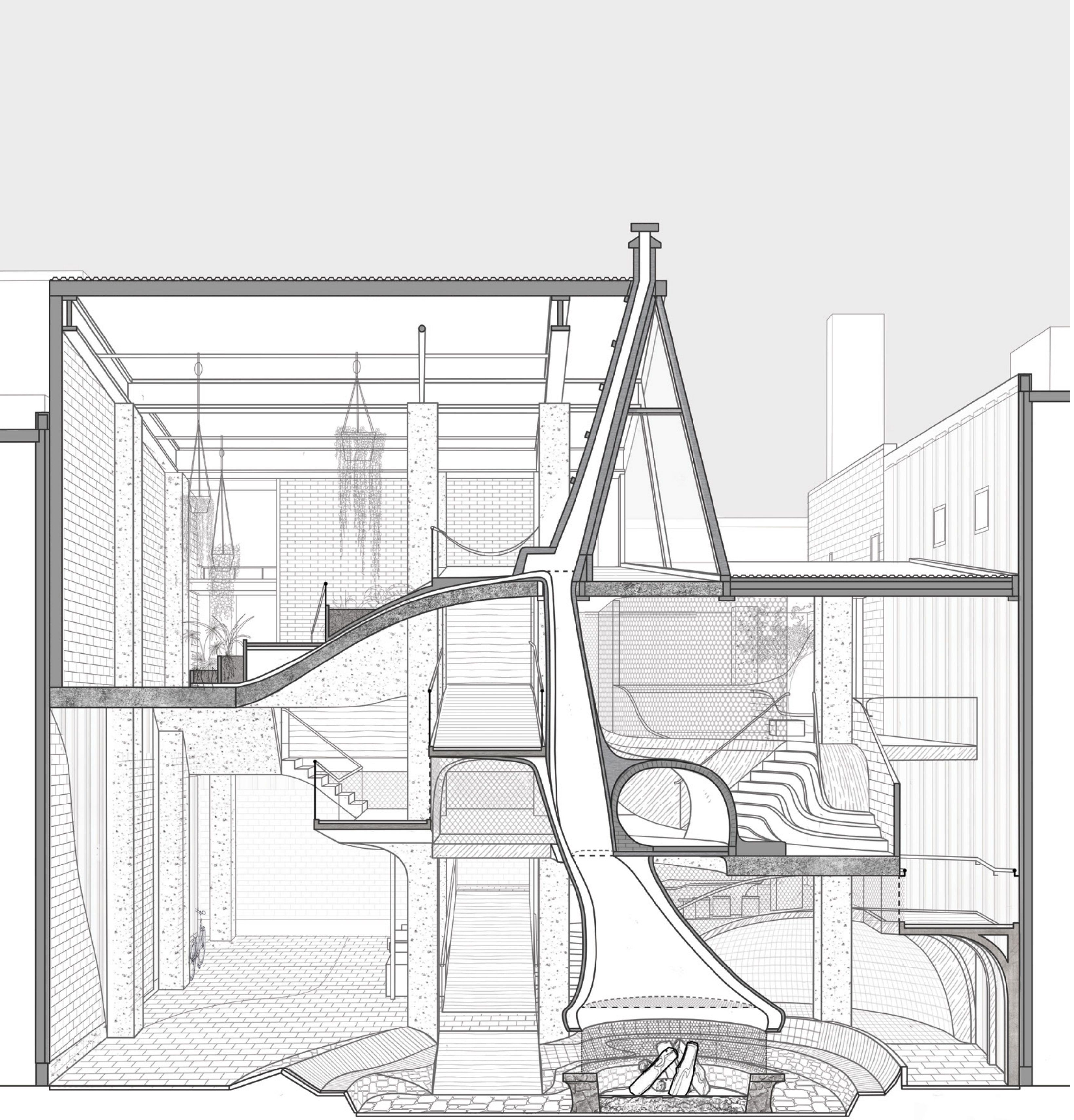


Figure 5.7 Cross Section A: Technical.

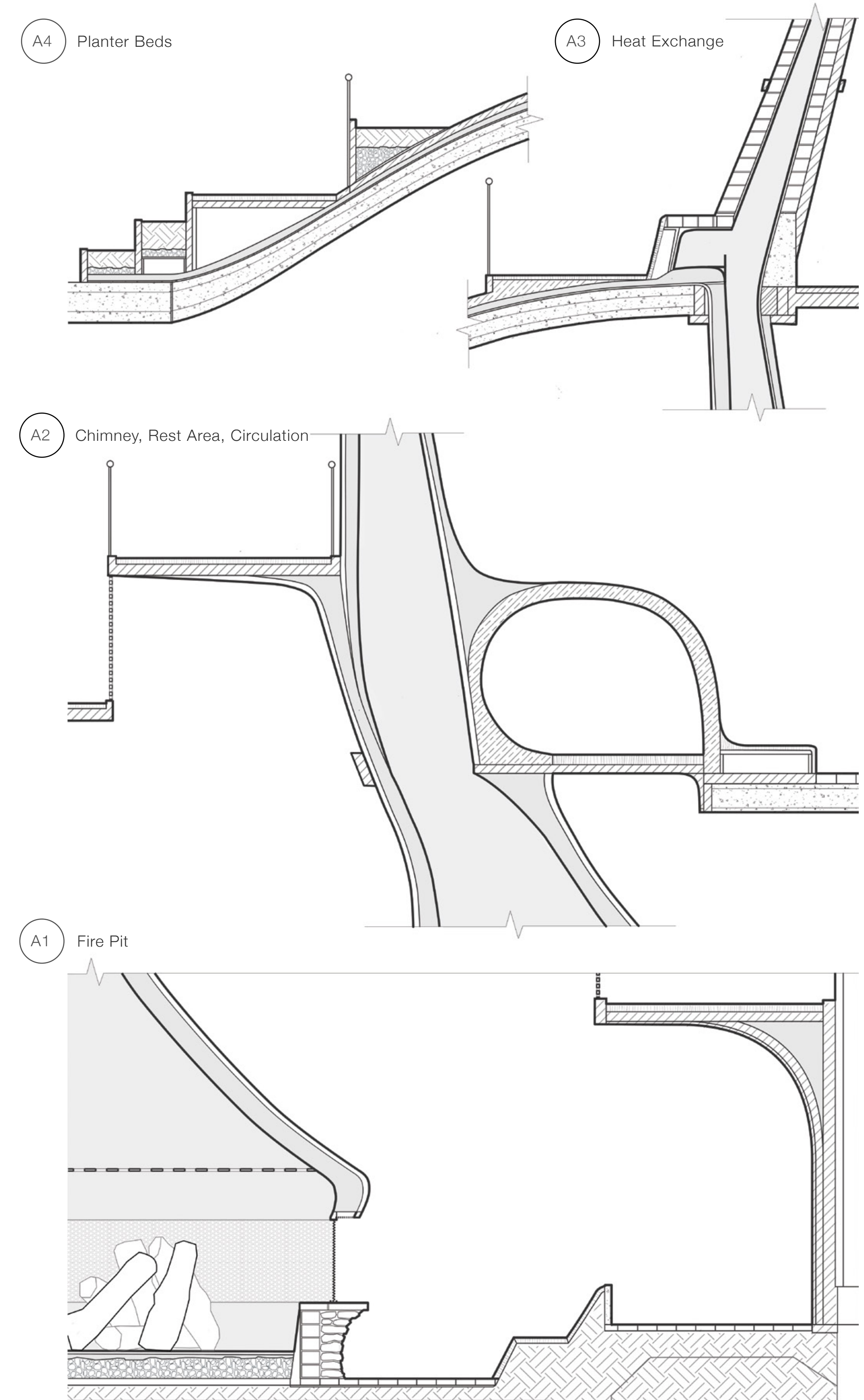


Figure 5.8 Cross Section A: Technical Details.

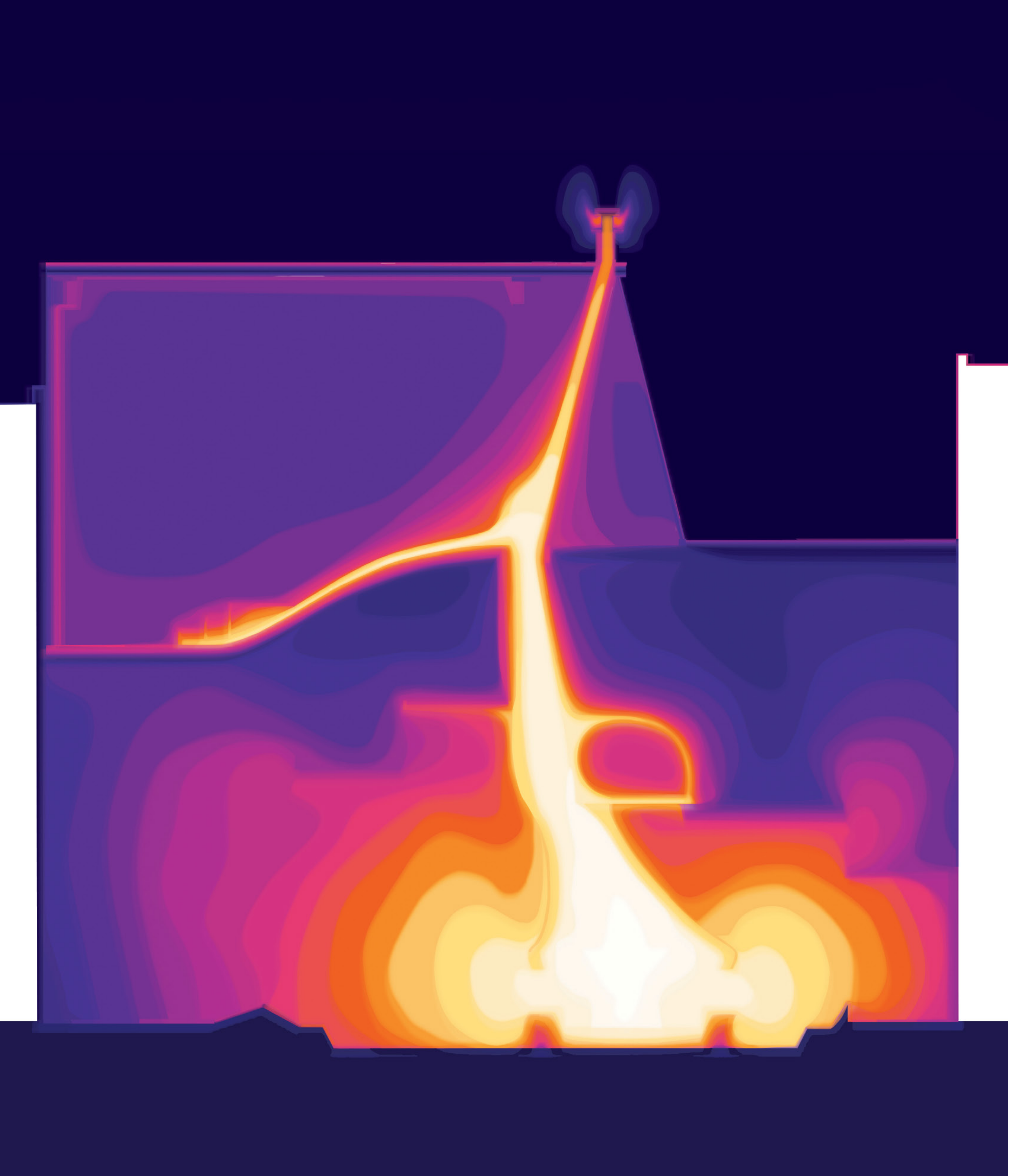


Figure 5.9 Cross Section A: Thermal.

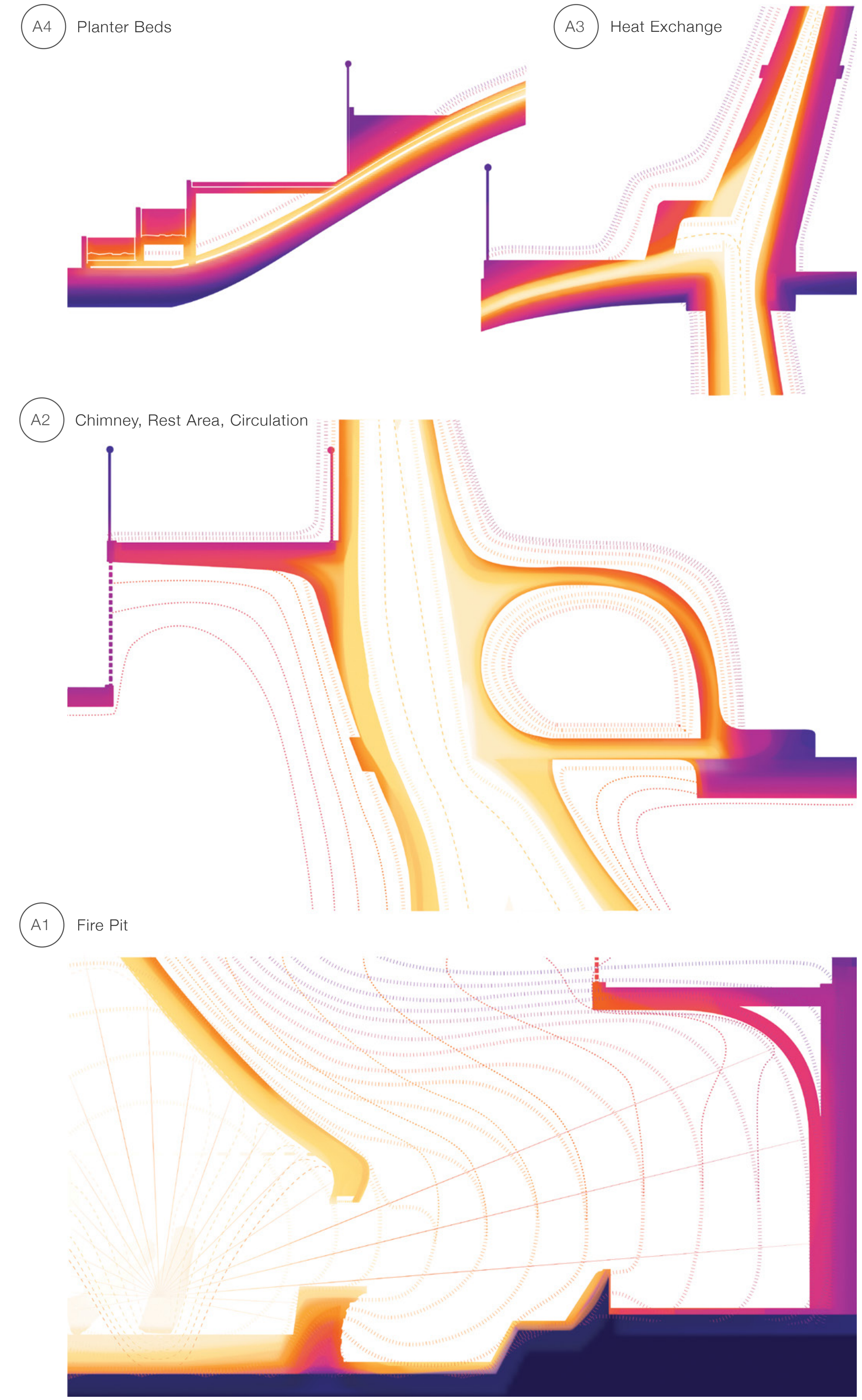


Figure 5.10 Cross Section A: Thermal Details.

Figure 5.11 Cross Section B: Perspective Render.

Cross-Section B

Within the thermal garden there are secondary heat sources provided in concurrence to the fire. The following sections delineate the ways of directing smaller sources of thermal energy to support different programmed spaces and thermal qualities.

Detail B.1 Cooking and Seating

The cooking patio has several cooking elements including a wood-fired grill, oven and cooktop. When in use, the heat will radiate into the eating area, warming the seating on the side facing the cooking elements. A majority of the heat will also rise into the chimney vent, travelling through the walls of the sauna, and then outside to the rooftop lounge. At moments along the chimney, the flue transitions in material, allowing some heat to be absorbed into the adjacent space. Metal was used to enclose air gaps and conductively heat beneath the seating in both the sauna, and exterior roof lounge area.

Detail B.2 Sauna and Thermal Pool

The sauna contains a wood fired stove, which is burned beneath a bed of rocks. The rocks absorb the thermal energy from the fire and radiate the resulting heat into the space. Due to the sauna being a small and enclosed space, the room will obtain a high temperature, especially at the ceiling level of the room. To make use of the hot air rising in the sauna, a shallow pool of water acts as the ceiling, providing a thermal pool to the platform above. The thermal pool further makes use of the heat by using a coil heat exchanger wrapped around the stove pipe to heat the water as hot air rises through the pipe.

Detail B.3 Exhaust Energy Dump

The east building facade, enclosing the site to the thermal garden, has several exhaust vents located at the rear of the site. Expelling humid warm air, a tunnel space was formed with perforated panels to allow the heat to dissipate into the circulation path. Being there is a limit to the length of exhaust vents, partially enclosing the air space surrounding the vent was the most viable option to make use of the energy dump.

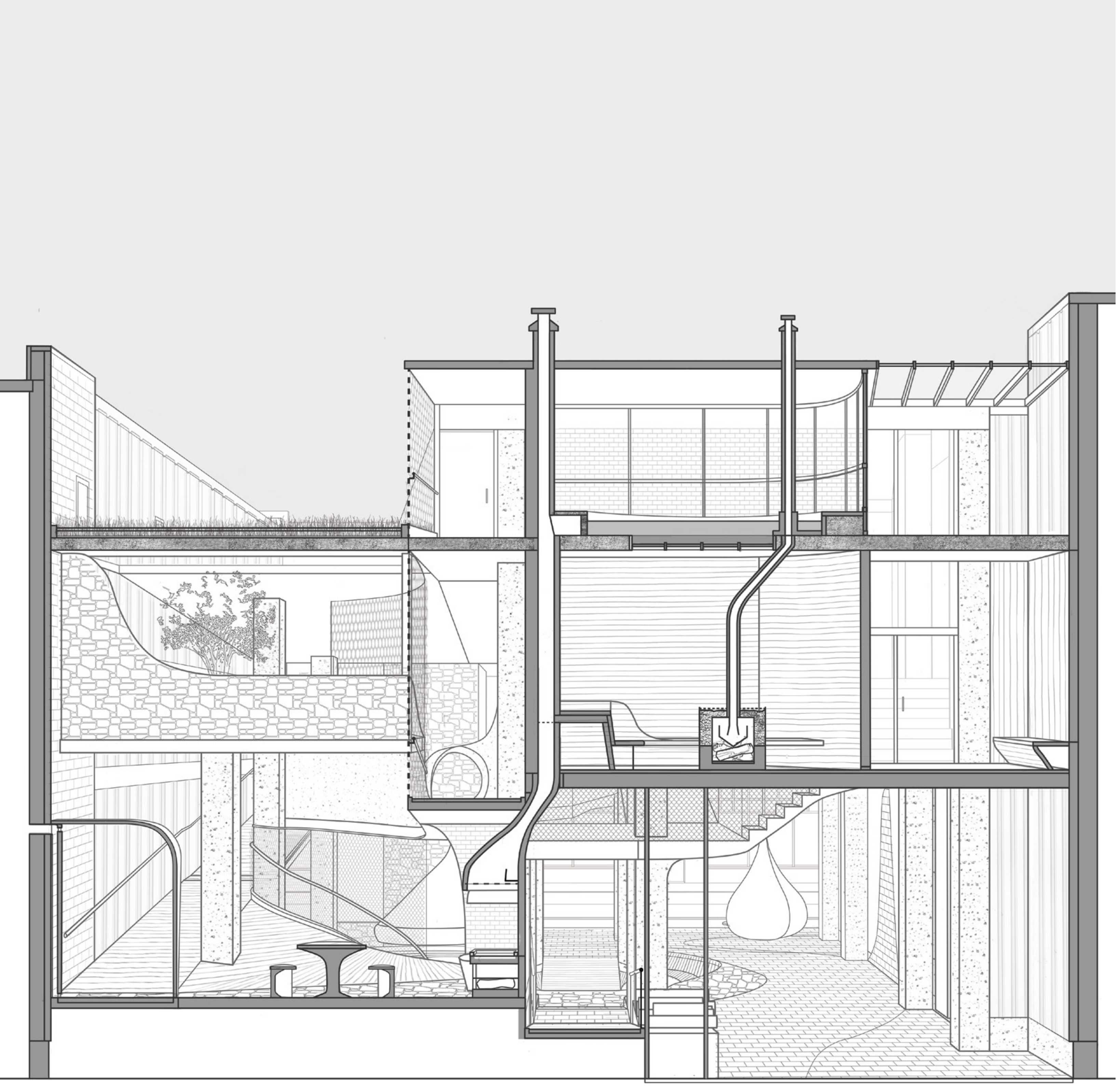


Figure 5.12 Cross Section B: Technical.

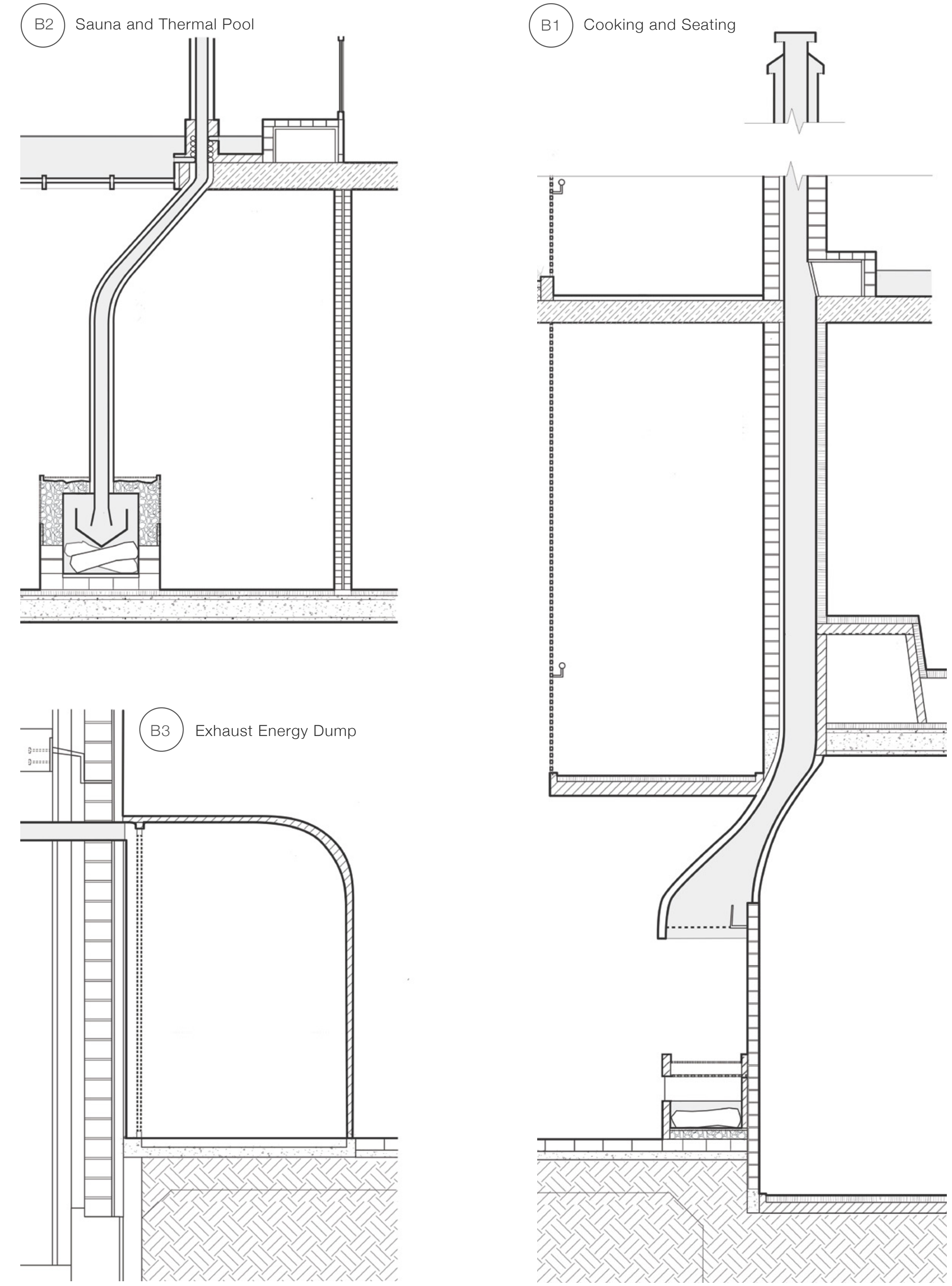


Figure 5.13 Cross Section B: Technical Details.

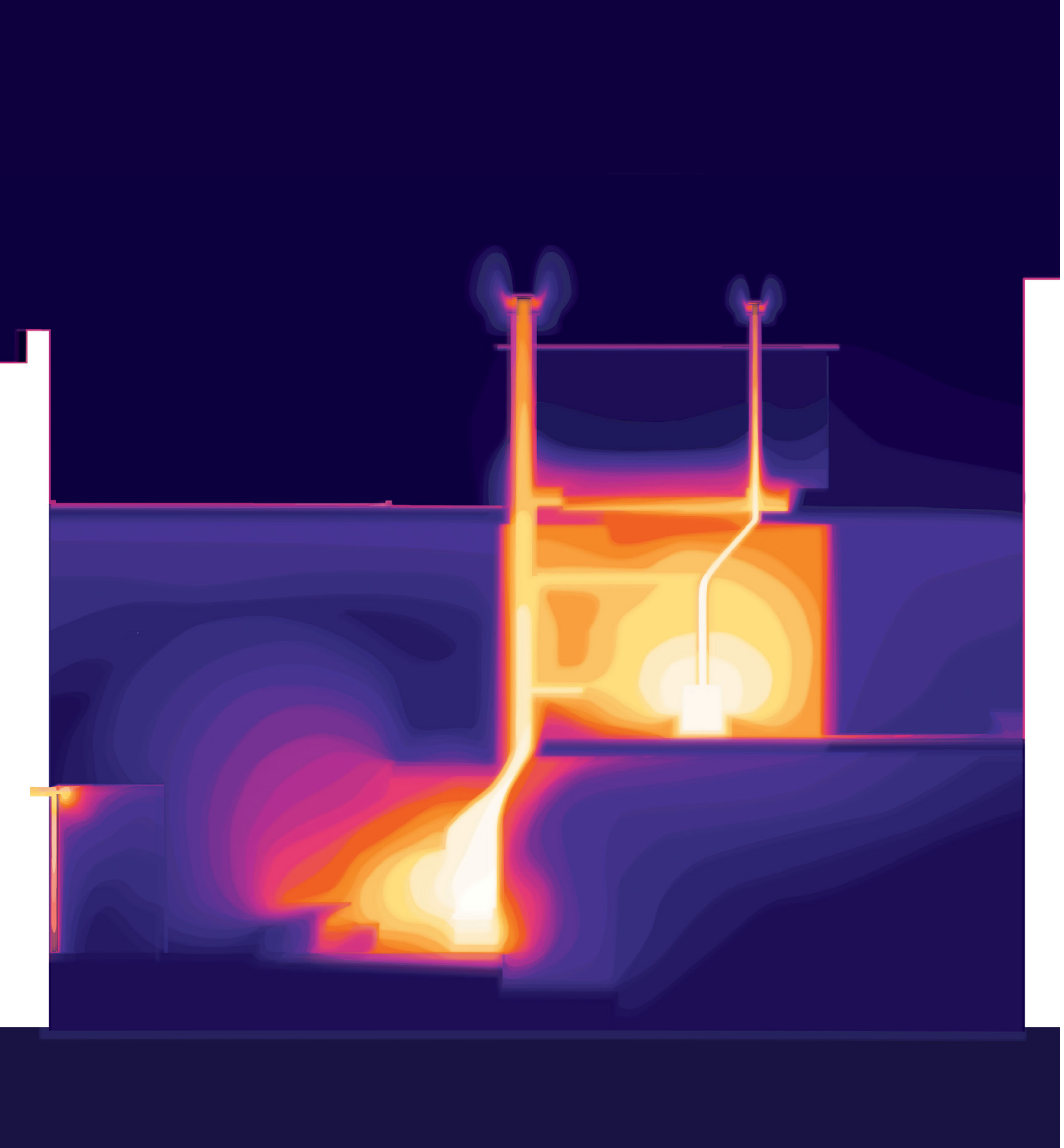


Figure 5.14 Cross Section B: Thermal.

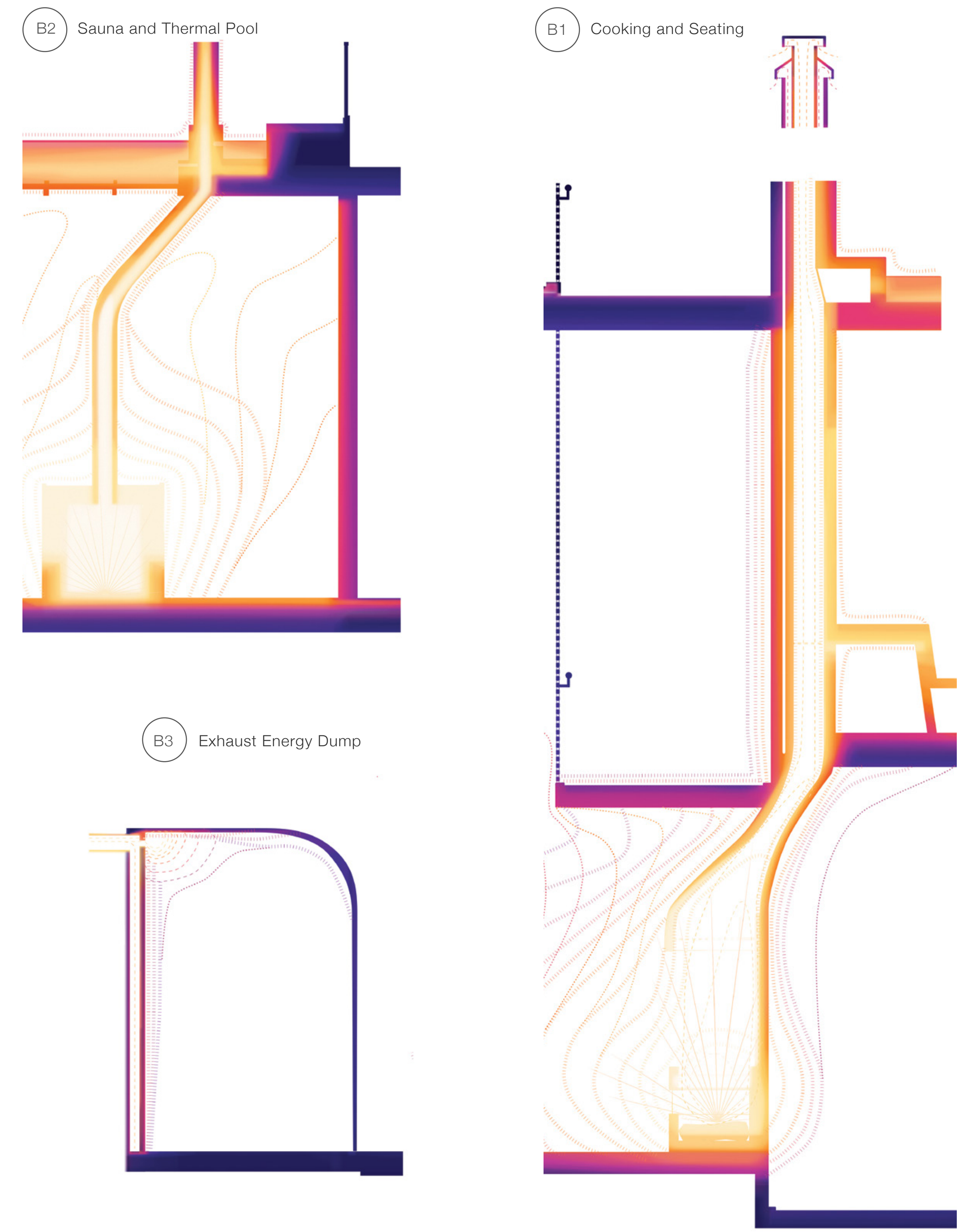


Figure 5.15 Cross Section B: Thermal Details.

102 Stamatis Zografos, *Architecture and Fire: A Psychoanalytic Approach to Conservation* (UCL Press, 2020), 88.

Figure 5.16 Perspective Render of the Hearth Space.

This thesis uncovered:

How thermodynamic space
defines the zone between the inside and outside,
and the ways this can sensually enhance the experience of exterior conditions
in order to engage symbiotic connections and synesthetic perceptions,
between ourselves and the urban environment.

CONCLUSION

Within architecture, thermal imaging cameras are typically not used in the design application of thermodynamic space. The process of using the thermal imaging camera, investigated thermodynamics as an architectural aesthetic that could be applied to sustainable design practices for urban space, especially in northern climates. The method of visually seeing the presence of thermal phenomena in unsuspecting places, recognized the ergonomic potential of 'felt' experiences for architectural application. Experiments assessed different thermodynamic and architectural factors affecting the states of heat transference between the scales of the meteorological, architectural and the physiological. Discoveries made between each scale were subsequently applied to the next set of experiments until an architectural strategy could be obtained, recognizing the implications of social and thermal interactions for comfort and well-being. The thermal palette thus became a visual means to express the *thermal* into an aesthetic that could be experienced by the body; through the thermal qualities of spatial convective forms, radiant material selection, and conductive places of direct engagement with the body. Being able to visually understand thermal energy through thermal imaging, influenced a new culture of experiencing energy phenomena through a balance of activity, refined form and associative materials.

The role of thermodynamics within the threshold zone, between the inside and outside, encouraged investigation into the potentials of this energetic presence for a public experienced architecture.
The intention is for the body to become more thermally sensitive and attune to 'felt sensations' of microclimates, allowing one to use the comprehended associations to perceive other spaces of comfort within the urban environment. The thermal garden emerged as the architecture to support a program of a socially inclusive culture surrounding the thermal; where urbanized vertical conditions could make use of passive convective heating and cooling strategies, and be an operable public space in the northern winter climate. Having the program of the thermal garden be influenced by fire, brought sensually and thermally gratuitous public spaces for interactions within microclimate programming, engaging more primal sensuous needs towards the generated activities. With the presented approach to thermodynamics, contradictions in architecture can be acknowledged through the development of a flexible thermal milieu; catering to both the artistic and technical, iconic and performative, cultural and technological.

In contribution to architecture, there should be a re-awakened perspective on thermodynamics, where it is not just considered in terms of efficiency, but also the felt, experiential qualities. Thermal image documentation and experimentation reinvestigated approaches of applying technology for thermodynamics and architectural application. With regards to spaces of physiological comfort, current simulation technologies have difficulty in merging the correlation between the social and thermal experience with building science. When there is an open dialogue between the body and the architecture, a bona fide thermal design application can be brought down to the scale of the body and the program of space. Insight into the power of the *thermal*, steps away from the visually aesthetic, and focuses in on the 'felt senses'; where 'Sensual Building Systems' can bring a thermal tectonic aesthetic to architecture through form and material appropriation, derived from the photographed experimentation, and crafting 'felt' experiences as a result.

Figure A1.1: Thermal Images Series 1 - Nature and the City, Body and the Elements, Thresholds, Ornament.

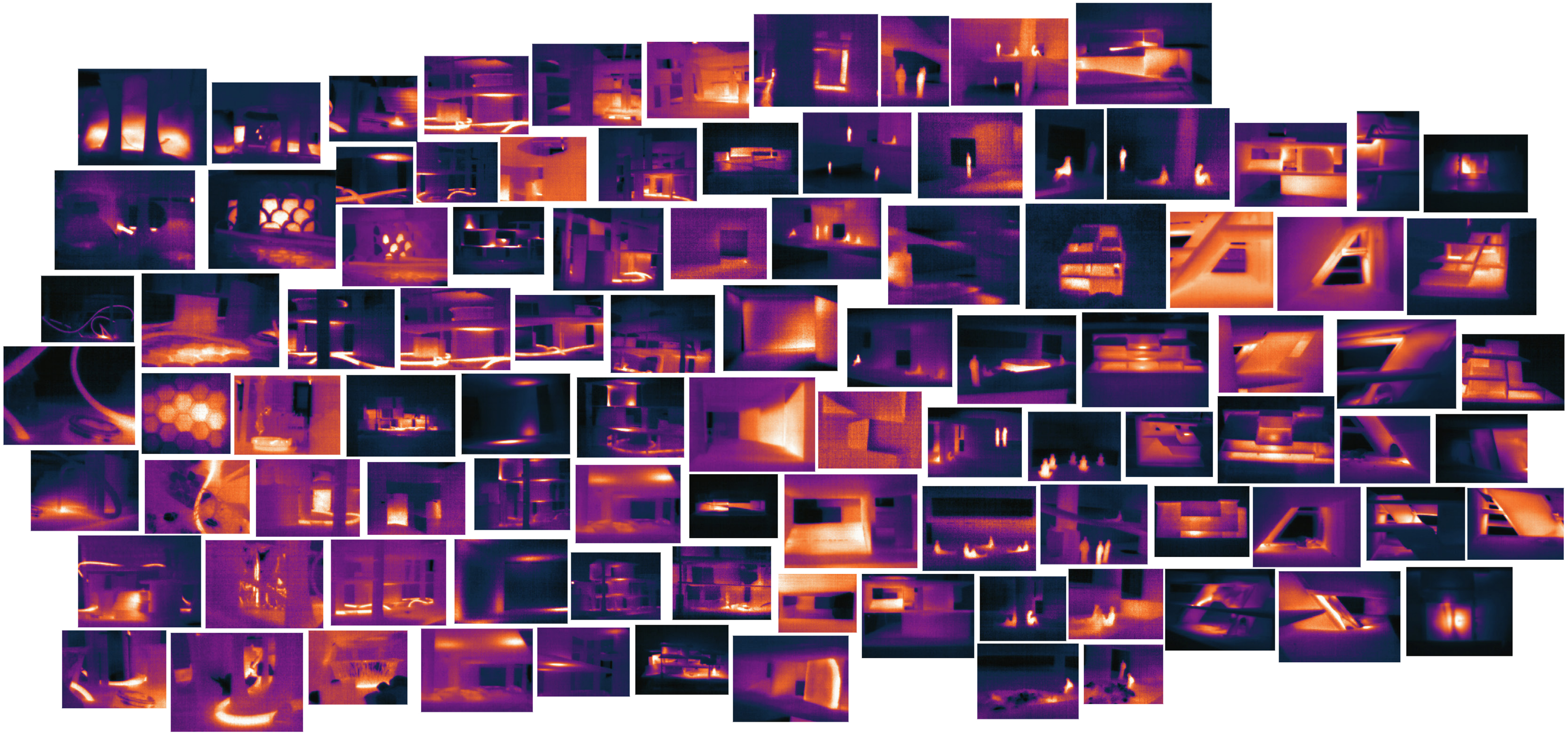


Figure A1.2: Thermal Images Series 2 - Material Objects and Form, Tectonics, Activity, Inhabitation, Form and Fire.

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