Hydrological Aesthetics: The Material Agency of Liquid, Frozen and Atmospheric Water

An FGM-Informed Analysis of Architectural Envelopes

Architectural Design MArch. RC8

SN: 21058298

Theory Tutor: Dr. Ilaria Di Carlo

The Bartlett School of Architecture,

University College London

UCL THE BARTLETT

Contents

Abstract

Contemporary architectural envelopes collect, redirect and exclude water through waterproofing, drainage and environmental conditioning. These measures are essential for durability and comfort, yet their success often makes the facade appear dry, stable and self-contained, losing any meaningful dialogue with hydrology. In fact, water has not disappeared; it has merely been routed, stored and concealed from view. This dissertation returns water to the centre of architectural analysis, examining how it engages with architectural fabric across its liquid, frozen and atmospheric states through movement, accumulation, capillary action, phase changes and suspension as droplets. The spatial and sensory form of this relational material agency is what this study terms "hydrological aesthetics".

Three questions guide the inquiry. How does water interact with architectural matter? How might an FGM-informed analysis translate these interactions into design hypotheses regarding graded material distribution, and what are their technical limits? What contradictions arise when liquid, frozen and atmospheric water converge within the same envelope? Functionally graded materials (FGM) are adopted here as an analytical instrument rather than a validated facade technology. Their logic of spatially varying properties helps locate where an envelope might receive, redirect, store, resist or release water. Geometry, mechanical actuation and room-scale climate, however, belong to a broader field of spatial differentiation that exceeds FGM's material scope.

Six architectural and artistic projects are examined as sequences of material events rather than static products. The analysis asks: what enables water to act? What spatial and bodily effects follow? What infrastructures sustain or constrain these processes? Liquid water is analysed through movement and trace; frozen water through formation and duration; atmospheric water through humidity, fog and climatic mediation. The key finding is that problems arise at state transitions: a property that aids absorption, storage or evaporation in one state may become a source of frost damage, condensation or decay in another. The architectural proposition that emerges is a "selective hydrological threshold" across surface, depth and air, which renders selected water processes perceptible while safeguarding durability, health and environmental performance. These cases offer analytical speculation, not empirical validation of an FGM facade.

Keywords: hydrological aesthetics; architectural envelopes; water–material interaction; material agency; functionally graded materials; phase transitions; climatic mediation.

Introduction: Water as an Active Material Condition

A conventional building envelope is usually judged by whether the interior remains dry. Membranes, joints, sealants, insulation, drained cavities and mechanical systems regulate rainwater, pressure differentials, water vapour and temperature (Hutcheon, 1953, pp. 1–3; Ching, 2014, pp. 245–247; Hens, 2017, pp. 99–100, 201, 209, 223). Preventing ingress, condensation and mould growth is essential, but it does not remove water from the wider urban system. Instead, water is redirected through concealed networks of drainage, supply and treatment (Kaika, 2005, pp. 32, 46–50). The envelope appears self-contained because these movements remain out of view.

With climate change, this issue is impossible to ignore. Extreme heat, heavy rainfall and drought are changing in frequency and intensity (IPCC, 2021, pp. 8–10). These changes can alter the moisture performance and durability risks of particular building-envelope assemblies (Defo and Lacasse, 2021). Research has examined green façades, rainwater harvesting and evaporative cooling (Ottelé et al., 2011; Raimondi et al., 2023; Peeks and Badarnah, 2021). These approaches provide additional options, but this dissertation argues that they have not altered how the building edge is conceptualised. The issue is therefore not only technical but conceptual.

This is covered by a number of disciplines, with varying approaches to water. Sensory experience is not often addressed by building physics, which is more concerned with capillary transport and condensation (Künzel, 1995, pp. 17–20, 27–29). Atmosphere theory emphasises the relation between environmental qualities and bodily experience (Böhme, 1993, pp. 113–115). It says less about the technical systems that produce architectural atmospheres. Political ecology reveals how water infrastructures conceal the social and material relations that sustain apparently self-contained environments (Kaika, 2005, pp. 29, 46–50). These strands are not tied together with respect to the role of water.

Water is already involved in constructing and deconstructing through its relations with materials, climate and technical systems. It flows, seeps, crystallises, evaporates, condenses and redistributes heat (Hall and Hoff, 2022, pp. 47–52; Coussy, 2005, pp. 1689–1693; Künzel, 1995, pp. 27–29). It can darken rough, absorbing surfaces by reducing reflected light (Lekner and Dorf, 1988, pp. 1278–1280). Changes in moisture and temperature can also alter bodily movement. Water acts, but does not intend.

Hydrological aesthetics describes how this agency becomes perceptible through architectural form and bodily experience. Aesthetics is used here in the sense of *aisthesis*: perception through sight, touch, temperature, humidity, sound and bodily orientation (Böhme, 1993, pp. 114–116, 119). The term does not assign intention to water or romanticise material damage. According to Bennett, material agency is distributed across assemblages and registered through its effects (Bennett, 2010, pp. viii–ix, xvii). DeLanda shows how intensive gradients drive material processes, while critical thresholds mark qualitative transformations (DeLanda, 2013, p. 64). Perception, however, does not guarantee legibility. A stain may indicate the presence of moisture while obscuring its source. A fog field may intensify sensory experience while concealing its water and energy demands.

After examining water's actions, the study introduces FGM as an analytical tool. FGM allows composition, structure or properties to vary spatially within a component (Oxman, Keating and Tsai, 2011, p. 483; Grigoriadis, 2019, p. 160). The analysis asks where an envelope might receive, slow, redirect or exclude water. Slope, valves, refrigeration, airflow and room-scale climate also shape water behaviour but remain outside FGM's material scope.

The study is guided by three questions. First, how does water in its liquid, frozen and atmospheric states generate spatial, temporal and climatic effects? Second, how can these actions be transformed into design hypotheses for differentiated material distribution: where should gradients be applied, how steeply should properties change, and what should happen in neighbouring areas? What are the technical constraints? Third, what conflicts arise between the three states? Water comes first. Material gradients follow as analytical tools.

Four elements serve distinct roles. Hydrological aesthetics is the primary conceptual contribution, describing how water's actions become perceptible across spatial, bodily and cognitive registers. Material narrative is the comparative method, while FGM is a supplementary analytical tool. The selective hydrological threshold is the architectural proposition derived from comparison. Distinguishing these roles keeps water's actions analytically primary.

The methodology pairs six cases in three groups. Digital Water Pavilion and Teshima Art Museum compare programmed release with water emerging across a shaped floor. ICEHOTEL Winter and Eliasson's *Your mobile expectations: BMW H2R project* compare seasonal construction from harvested river ice with ice maintained by refrigeration. Blur Building and Cloudscapes compare fog exposed to changing weather with a cloud held within a controlled thermal section. The same questions are asked of each case. What makes water active? Where and how does it appear? Which systems enable or limit its operation?

The cases vary in scale, programme, duration and technical intensity and do not provide comparable data on water use, energy, maintenance or occupant response. The comparison is therefore conceptual, not a like-for-like performance evaluation. Analysis proceeds in three stages: documentation identifies mechanisms, interpretation examines their significance, and FGM-informed translation formulates questions for later modelling, testing or prototyping.

The framework is established in Chapter 2. Chapters 3–5 trace water's movement, freezing and evaporation. Chapter 6 summarises the cross-regime conflicts and develops the selective hydrological threshold. The conclusion restates the research questions, defines the contribution and identifies what remains to be tested. Figure 1 summarises this progression.

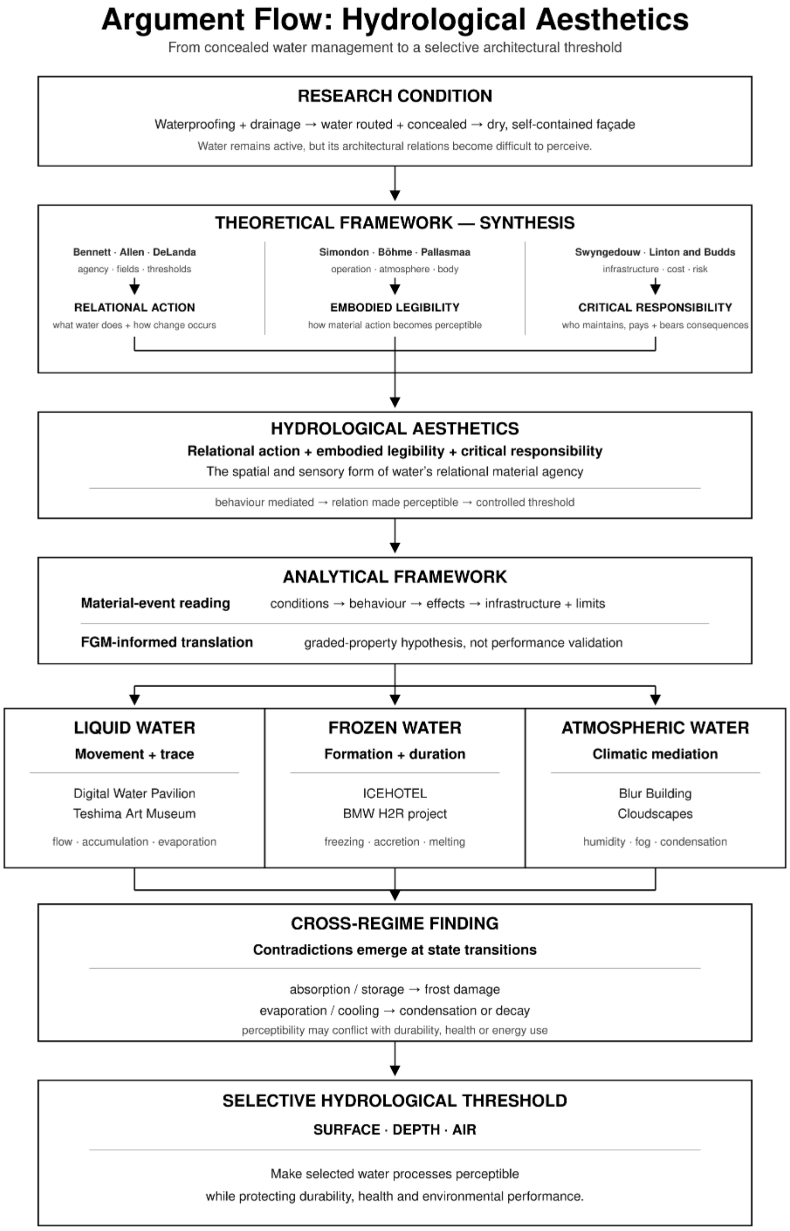

Figure 1. Argument flow from concealed water management to the Selective Hydrological Threshold. Source: Author.

2. Water's Material Agency and the FGM-Informed Framework

2.1 Relational Agency, Hydrological Aesthetics and Embodied Legibility

Water has agency here, but not intention. Its effects take shape through gravity, surface energy, pore geometry, temperature, humidity, airflow and technical systems. Through these relations, water moves, gathers, transfers heat and changes phase. Agency is not water's property alone. Following Bennett, it is distributed across human and nonhuman assemblages (2010, pp. viii–ix, xvii). Allen's field condition offers a spatial analogy: local interactions can form an order without a single governing geometry (1997, pp. 24-25). DeLanda shows how this field changes over time. Intensive differences drive processes, and thresholds produce a change in kind (2013, p. 64). Design enters these relations without mastering them. Opening a valve begins the release. Gravity, surface energy and airflow shape where the water goes next. FGM varies local material properties and shifts water's behaviour, but it does not fix the outcome.

Distributed agency cannot be seen on its own. It becomes perceptible in what water does: a wetting front advances through material, ice builds where water meets sub-zero conditions, and fog thickens or thins with airflow, humidity and droplet production. But none of these changes explains its own cause. The same darkening may come from rain, capillary rise, condensation or leakage. Simondon's techno-aesthetics helps explain why such changes matter aesthetically. For Simondon, aesthetic experience arises through use, action and contact with matter in transformation (2012, p. 3). In a water curtain, the flow itself matters. Falling water brings gravity, sound and bodily movement into one spatial event. A trace becomes hydrologically legible when it can be related to the material, climatic and technical conditions that made it.

Hydrological perception is both embodied and temporal. Böhme situates atmosphere between environmental qualities and human states (1993, pp. 114, 119). This bodily dimension also appears in Pallasmaa's account of the skin as a site of tactile and thermal perception (2024, p. 48). Water may therefore be sensed before it becomes visible. Fog reduces visual range and cold alters bodily movement. Flow, freezing and dispersal unfold at different rates, making duration part of perception. Such experience, however, offers only partial knowledge of the event. Visitors may encounter mist, cold or surface wetting without knowing the equipment, resource use and labour required to sustain these conditions. Two related methods address this gap. A phenomenological reading examines what a project makes perceptible without assuming a uniform bodily response. Critical reconstruction draws on drawings, technical records and operational evidence to identify how the experience is produced and maintained. Building physics clarifies its mechanisms and limits. Political ecology examines how labour, costs and risks are distributed.

Critical reconstruction also makes hydrological responsibility visible. Recognising water's agency does not absolve designers, owners or operators of responsibility. Water may cross boundaries or condense in unintended locations, while sustained moisture can enable mould growth and material decay (Hens, 2017, pp. 130–131, 171–172). Ownership, maintenance, infrastructure and access influence who is exposed and who pays. Political ecology treats water flows as socio-natural outcomes shaped by social, political, economic and infrastructural relations (Swyngedouw, Kaika and Castro, 2002, pp. 124–125; Linton and Budds, 2014, p. 170). Concealment forms part of this distribution. A dry surface may protect occupants while channelling runoff elsewhere, and mechanical fog may produce an intense atmosphere while shifting water, energy and maintenance costs. Hydrological aesthetics cannot resolve these problems, but it can expose where cost, labour and risk have been displaced.

On this basis, hydrological aesthetics is assessed through three criteria. First, a specific water behaviour must be architecturally mediated. Second, that mediation must reveal a relationship between water, matter, climate, infrastructure or the body. Third, if the event is to become an acceptable architectural proposition, it must remain within a controlled technical and environmental threshold that protects durability, health and environmental performance. The first two criteria identify hydrological aesthetics. The third distinguishes responsible mediation from uncontrolled damage or sensory spectacle. These criteria do not certify performance. Figure 2 summarises the progression from relational conditions and water action to perceptible effects, critical reconstruction and hydrological aesthetics.

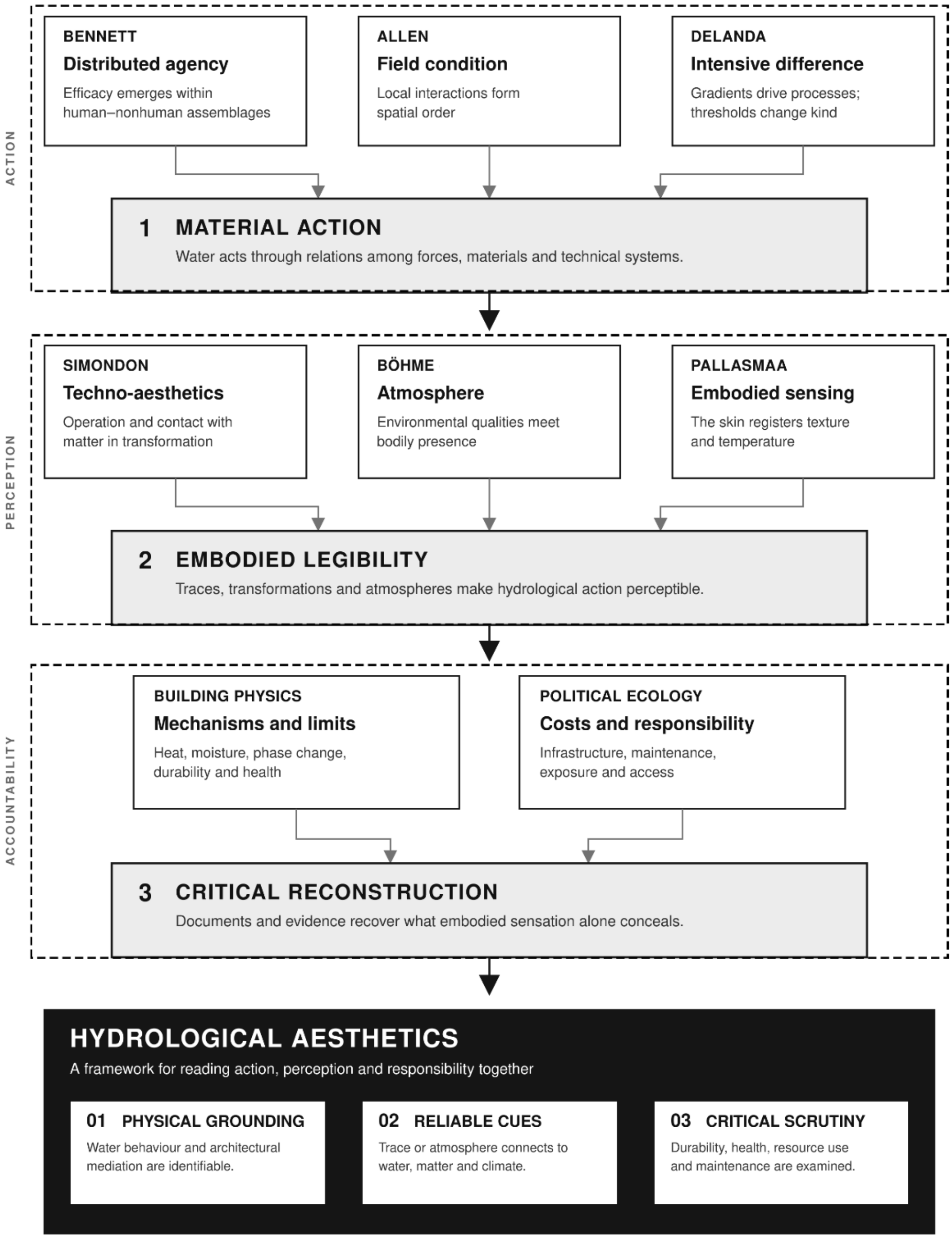

Figure 2. From hydrological conditions to hydrological aesthetics: a continuous analytical sequence. Source: Author, based on Bennett (2010), Allen (1997), DeLanda (2013), Simondon (2012 [1982]), Böhme (1993) and Pallasmaa (2024).

2.2 Liquid, Frozen and Atmospheric Modes of Agency

Liquid, frozen and atmospheric water are treated here not as a taxonomy of visual appearances, but as analytically distinct modes through which relational agency becomes materially and sensorially legible. None is inherently aesthetic: each becomes relevant to hydrological aesthetics only when architectural mediation reveals its operation and contains its consequences within an acceptable technical and environmental threshold.

Liquid water moves through gravity, surface tension and capillary action (Washburn, 1921, pp. 273–283; Hall and Hoff, 2022, pp. 47–52). These interactions become perceptible through changing paths and wet–dry boundaries. When architectural geometry and material variation make such relations legible, the liquid register becomes relational inscription: a trace connecting movement to the surface, material depth or technical system that conditions it. Figure 3 shows visible signs of rising damp produced by capillary moisture in historic masonry.

Figure 3. Visible signs of rising damp on a masonry wall in a lateral chapel of San Pietro in Vincoli, Rome. Source: Giaccone, Santamaria and Corradi (2020, Fig. 2b).

Frozen water acts when a thermal threshold is crossed. In porous materials, ice formation can generate pressure depending on saturation, pore structure, temperature and mechanical response (Fagerlund, 1977, p. 217; Scherer, 1999, p. 1347; Coussy, 2005, pp. 1689–1691). Freeze–thaw cycling may accumulate damage when material-specific thresholds are exceeded. Such damage may reveal water's action but is not an acceptable design medium. When formation, persistence and thaw remain controlled and legible, frozen water makes material time perceptible. Figure 4 compares the visible effects of repeated freeze–thaw cycling across concrete specimens with different compositions and water-to-binder ratios.

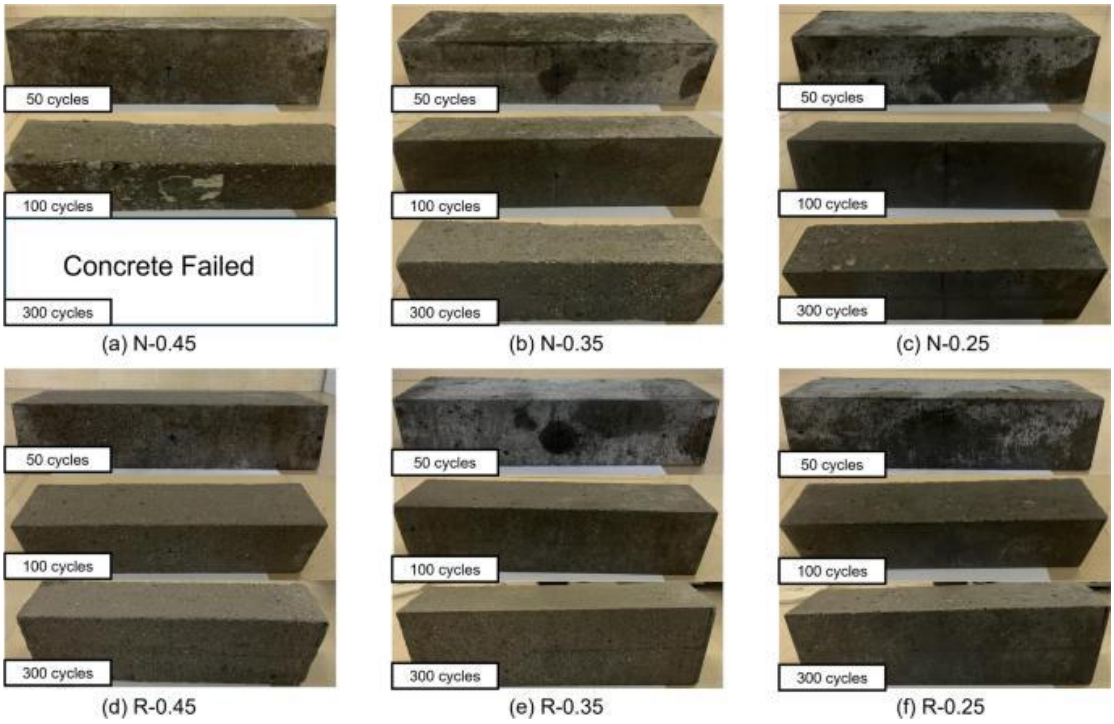

Figure 4. Surface appearance of natural-aggregate (N) and recycled-ceramic fine-aggregate (R) concrete with water-to-binder ratios of 0.45, 0.35 and 0.25 after 50, 100 and 300 freeze–thaw cycles. Source: Yang et al. (2026, Fig. 9).

Atmospheric water acts through vapour transport, latent heat exchange and suspended droplets. Vapour generally remains invisible, but evaporation, condensation and fog formation make its effects perceptible (Künzel, 1995, pp. 13–15, 28–30; Hens, 2017, pp. 16, 160–168). Fog droplets reduce visibility (Gultepe et al., 2007, pp. 1121–1125). In architectural space, this can compress perceived depth. Architectural atomisation can produce a comparable atmospheric field. Climatic mediation names these changes in heat exchange, visibility and bodily sensation across the surface–air interface. Figure 5 shows how increasing fog density reduces visibility within the same scene.

Figure 5. The same test scene under clear, medium-fog and dense-fog conditions. Source: Segonne and Duthon (2023, Fig. 6).

These modes are analytically distinct but materially coupled. Evaporation, condensation, freezing and thaw redistribute moisture and exchange heat (Hens, 2017, pp. 16, 166–168; Künzel, 1995, pp. 22–28). Their requirements can conflict. Capillary uptake may raise saturation and thereby increase freeze–thaw risk, while thermal conductivity and vapour resistance may shift condensation within an assembly (Fagerlund, 1977, p. 217; Hens, 2017, pp. 187–192). A property beneficial in one regime may create risk in another. Relational inscription, material time and climatic mediation provide the comparative registers for Chapters 3–5 and lead to the FGM-informed analysis in Section 2.3. Figure 6 maps these cross-regime relations.

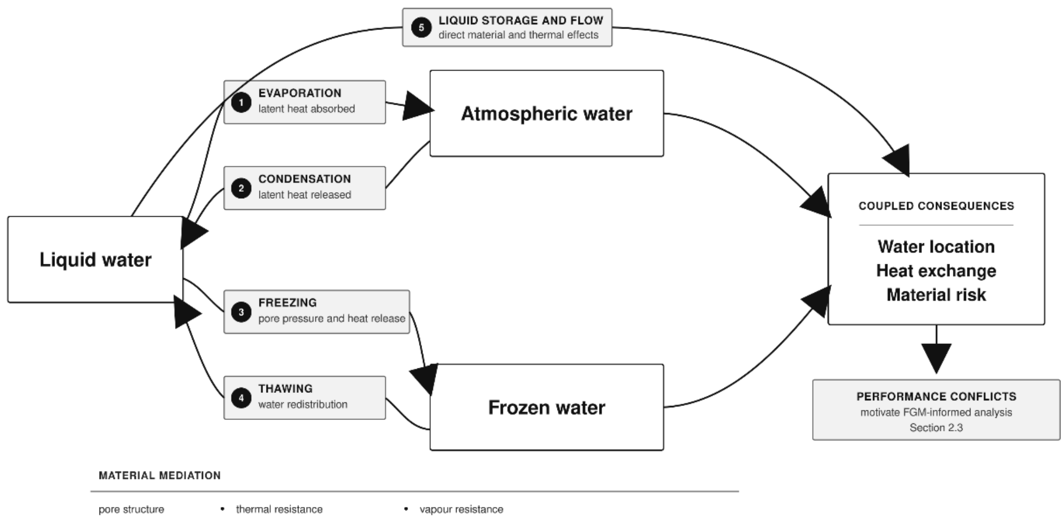

Figure 6. Coupled relations among liquid, frozen and atmospheric hydrological modes.
Source: Author.

2.3 FGM-Informed Analysis, Material Narratives and Evidential Limits

Functionally graded materials (FGM) refer to the controlled variation of composition, microstructure or performance within a single material component (Koizumi, 1997, p. 1). Conventional building envelopes typically distribute different functions across separate layers—cladding, membranes, insulation and structure—achieving overall performance through layered assembly. FGM offers a different approach, allowing selected material properties to vary locally within the component itself (Oxman, Keating and Tsai, 2011, pp. 483–484). It does not, however, by itself resolve assembly-scale requirements such as joints and drainage cavities. Water resistance may still depend on a protective layer within the complete envelope (Hens, 2017, p. 223).

Research on functionally graded rapid prototyping and flow-based fabrication has shown that computational tools can coordinate geometry with heterogeneous material deposition (Oxman, Keating and Tsai, 2011, p. 483; Duro-Royo, Mogas-Soldevila and Oxman, 2015, pp. 143–145). Grigoriadis argues that this shift from assumed uniformity to controlled variation directs architectural attention towards transitions and material behaviour (Grigoriadis, 2019, pp. 160–163). These studies demonstrate the feasibility of this material logic and its associated prototype-scale fabrication processes, but they do not yet establish the long-term hydrological performance of FGM in an envelope context.

In this thesis, FGM is deployed as an analytical lens rather than a ready-made construction system. Liquid water raises questions concerning wettability, pore geometry, permeability, temporary storage and drainage; frozen water introduces issues of saturation, thermal conductivity, heat capacity and mechanical accommodation; atmospheric water draws attention to surface temperature, vapour permeability, moisture buffering and sorption capacity (Hens, 2017, pp. 125–132, 170–180, 209–223). The purpose of FGM is to help locate where water creates different, and sometimes contradictory, performance demands—which property should vary, how quickly it should change, and what consequences this might have for adjacent regions. It does not assume that a continuous gradient will automatically resolve these conflicts.

Some conditions sit outside material variation. A slope can redirect a droplet. A valve can interrupt flow. Refrigeration can delay melting. Airflow carries moisture through space, while room-scale temperature fields affect relative humidity and condensation (Hens, 2017, pp. 143–168). FGM is therefore restricted here to property variation within the component. Geometry, discrete actuation, equipment and climatic fields remain part of the wider analysis. This boundary allows the cases to show where local variation may matter without treating them as evidence that FGM will perform as proposed.

Case analysis proceeds through what is termed here a “material narrative”: a sequential chain of events rather than a static image. It first identifies the climatic, material and technical conditions that enable water to act. It then follows the resulting movements, visible traces and phase changes, together with the perceptual positions they offer the body. It also considers devices that initiate, regulate or constrain the event, including pumps, drainage, refrigeration, sensors and maintenance systems. Pairing the cases reveals contrasting modes of mediation while preserving differences in scale and programme.

The findings generated through case comparison operate at distinct levels. Technical mechanisms are grounded in project documentation or technical evidence; interpretive analysis connects these mechanisms to spatial and sensory effects; FGM-informed translation restates observed behaviours as questions of local material variation. Any resulting hypothesis, however, would require modelling, experimentation or physical prototyping to be tested. These levels each have their own function and can complement one another, but they cannot substitute for one another—technical documentation does not guarantee reliable performance, and a persuasive interpretation does not constitute material validation.

FGM therefore translates water's actions into questions of spatial materiality without treating every difference as a gradient or analogy as evidence. It clarifies where architectural matter might guide, register or constrain an agency already at work. Water remains the subject of the research. Figure 7 distinguishes this translation from subsequent material validation.

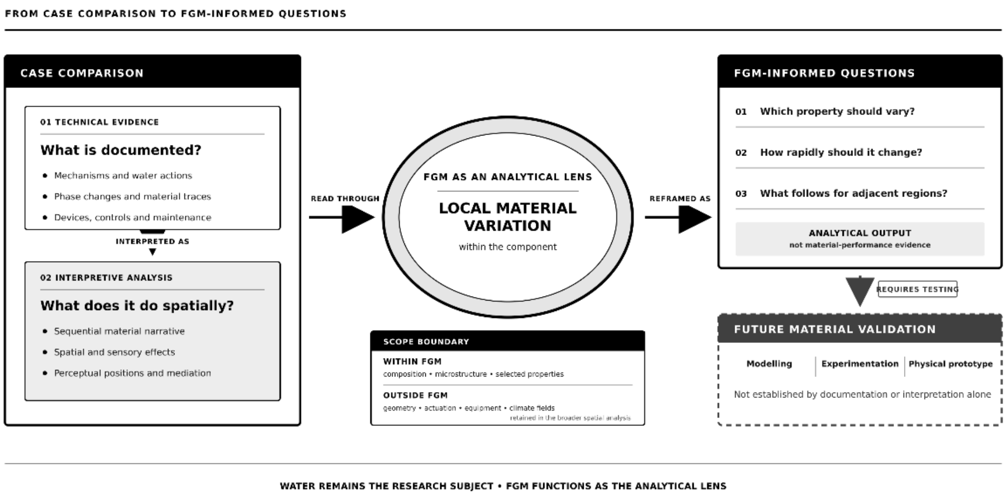

Figure 7. Scope and evidential levels of the FGM-informed analytical framework. Source: Author.

3. Liquid Water: Movement, Wetting and Relational Inscription

3.1 Liquid Agency, Field and Hydrological Responsibility

Liquid water is often the easiest state to observe because its movement and wetting can be seen directly. It falls, flows across surfaces and seeps into materials where pores, joints or openings permit. Typically, the building envelope controls this flow to preserve the integrity of the building and ensure the comfort of people inside (Ching, 2014, p. 224; Hens, 2017, pp. 130–131; Hutcheon, 1953, pp. 1–3). Control does not stop water from affecting the envelope. As it moves, water can reveal differences in materials and construction. It also changes the boundary between wet and dry areas and leaves visible traces. This process is described here as “relational inscription”.

Water flows down inclined planes. Surface tension and contact angle influence whether it beads, spreads or adheres to the surface. Capillary suction, viscosity and pore structure regulate moisture movement and its rate of transport within porous material (Washburn, 1921, pp. 273–283). At exposed surfaces, evaporation removes liquid water, while water vapour may subsequently be transported by diffusion (Künzel, 1995, pp. 14–20, 28–31; Hall and Hoff, 2022, pp. 241–257). Consequently, visible surface wetting does not necessarily identify where water entered the material.

This behaviour can be interpreted through Allen’s field condition concept (Allen, 1997, p. 24). A water path is created by interactions among local variations in slope, surface energy, pore structure, drainage and evaporation. Simondon similarly locates aesthetic significance in action and contact with matter rather than contemplation alone (Simondon, 2012, p. 3). A streak, reflection or wetting front is important because it shows relationships among forces, not because it functions as decoration. A wet surface becomes darker and may lighten as it dries. Repeated wetting makes this change visible over time. Similar traces can result from rain, rising damp, condensation or leakage, although the processes behind them differ.

Wetting can show how a material surface responds, but moisture does not always stay within the intended area. A visible trace may record this movement or indicate a problem. Persistent moisture can lead to mould growth and material decay (Hens, 2017, pp. 130–131). In concrete, freeze–thaw damage can occur when saturation exceeds a material-specific critical level before freezing (Fagerlund, 1977, p. 217). The design must therefore separate areas that can receive or hold water temporarily from those that require drainage or protection.

Water management is not only technical. It also involves political choices (Linton and Budds, 2014, p. 170). A dry façade does not make water disappear. Drainage sends it somewhere else, and the work and risk of managing it may fall unevenly across people and places (Swyngedouw, Kaika and Castro, 2002, pp. 125, 134). Sustainable drainage can slow, store, infiltrate or reuse runoff before discharge (Fletcher et al., 2015, pp. 527–533). Hydrological aesthetics can show these movements and the responsibilities attached to them, but it cannot replace engineering. A protected surface may depend on another location, infrastructure or group to manage water and its risks.

3.2 Commanded Flow and Conditioned Emergence

Figure 8 shows the Digital Water Pavilion, designed by Carlo Ratti Associati with collaborators from MIT for Expo Zaragoza 2008. Digitally controlled curtains of falling water formed its walls. In a recirculating system, water was pumped to the roof, released through digitally controlled valves, collected below and returned to the system (Richards, 2008; Yeste Navarro, 2018, p. 450). By interrupting individual streams, the valve system formed text, patterns and temporary passages.

Figure 8. Digital Water Pavilion with its digitally controlled water curtains in operation at Expo Zaragoza 2008. Source: Carlo Ratti Associati (2008).

The water curtain combined digital control with gravity-driven flow. Valve timing determined where streams were released or withheld, while released water fell under gravity (Richards, 2007). As Figure 9 shows, discrete streams formed a temporary surface, offering a limited analogy to Allen's field condition. Unlike Allen's emphasis on local interconnectivity, however, the valves remained centrally coordinated (Allen, 1997, p. 24).

Figure 9. Water curtains forming the perimeter of the Digital Water Pavilion. Source: Yeste Navarro (2018, p. 449, Figure 2); photograph credited to Lumiartecnia.

Falling water formed a spatial boundary in which sensor input and valve timing opened temporary passages, making access dependent on programmed intervals (Richards, 2007). The event depended on human movement, digital control, gravity and the movement of water. No element produced it alone, which reflects Bennett's account of distributed agency (2010, pp. viii–ix, xvii). Visitors encountered the falling water as a boundary, while the pumps, software and recirculation system that sustained it remained largely out of sight (Richards, 2007). The water was visible, but its infrastructure was not.

Teshima Art Museum, designed by Ryue Nishizawa with artist Rei Naito, consists of a low concrete shell containing Naito's *Matrix*. Water emerges from small holes in the floor, forms droplets, merges and flows across the surface throughout the day (Benesse Art Site Naoshima, 2019). Two large openings admit wind and changing light (Benesse Art Site Naoshima, n.d.). Surface tension helps maintain the droplets' form (Hall and Hoff, 2022, pp. 47–49), while the water-repellent floor surface shapes their variable movement (Gözen, 2023). Figure 10 presents the spatial setting of *Matrix* together with a close view of a droplet emerging from the floor.

Figure 10. Spatial setting and material behaviour in Teshima Art Museum: (left) the concrete shell, oval opening and wetted floor of Rei Naito's *Matrix*; (right) a water droplet emerging from the floor. Sources: (left) Benesse Art Site Naoshima (n.d.); (right) Benesse Art Site Naoshima (2019), photograph by Noboru Morikawa.

Water paths reveal surface differences that are not apparent when the floor is dry. Unlike the programmed curtain of the Digital Water Pavilion, water in *Matrix* follows no fixed pattern. The arrangement changes as droplets meet, coalesce and evaporate. Moving slowly across the floor, the droplets direct attention downward. Visitors follow their changing trajectories through proximity and duration. Figure 11 shows how they adjust their bodies to observe water close to the floor. The design establishes the conditions, while water produces variation through movement.

Figure 11. Visitors adjusting their posture and proximity to observe water traces across the floor of Rei Naito's *Matrix*, Teshima Art Museum. Photograph by Iwan Baan, 2010. Source: Loho (2024).

The two projects illustrate two ways of organising water. One uses programmed release, while the other relies on material conditions and gradual emergence. These arrangements produce different politics of control. In the first, command effects appear as openings in the water curtain, although circulation remains largely hidden. In the second, material processes become more prominent while institutional control is less visible.

In neither project is FGM used, but both show how local conditions organise liquid behaviour. Their comparison shifts attention from spectacle to the spatial distribution of control and material response. It raises questions about where water emerges, how far it moves and where its effects become visible. FGM extends this analysis by asking how graded envelope properties might differentiate these behaviours (Oxman, Keating and Tsai, 2011, pp. 483–484).

3.3 FGM-Informed Liquid Mediation

An FGM-informed envelope component would differentiate how water is received across its surface. It would guide water movement, make the material response observable and release moisture through defined drainage and drying paths. Different regions would perform distinct but materially connected functions.

At the exposed surface, surface energy and roughness would influence wettability and therefore whether water beads, spreads or remains as a visible wet trace. Within the component, pore-size distribution, pore connectivity and permeability, together with moisture state and exposure conditions, would affect penetration depth, redistribution and retention time (Künzel, 1995, pp. 20–24; Hens, 2017, pp. 209–224). Toward the interior, a lower-permeability region could limit inward moisture transfer, but would not by itself guarantee a dry inner face. The component would therefore require drainage and a defined outward drying path.

The component is conceived as a graded continuum rather than an assembly of discrete, homogeneous parts (Oxman, Keating and Tsai, 2011, pp. 483–484). One region could temporarily store water, while gradual changes in pore structure and permeability would guide it toward drainage. Visible traces would result from wetting, redistribution and drying within the material, rather than from an applied coating.

These material properties present conflicting requirements. Increasing connected porosity may increase temporary water storage, but may also extend the wetted depth. Evaporation still depends on available drying conditions. Lower permeability can reduce inward moisture movement, but it may also slow drying when retained water has no clear route out (Künzel, 1995, pp. 20–24; Hens, 2017, pp. 221–224). This is also a question of responsibility. Who decides which wetting processes are made visible, and who responds if water remains beyond the intended area? A rain trace may help the public see where water moves, while building operators need a clearer signal that inspection is required. Material gradients can assist with these tasks, but drainage and wider water infrastructure remain necessary.

The proposal works across three connected scales. At the surface, material variation shapes water's first contact and the traces left by wetting. Within the component, it affects storage, redistribution and drying. At envelope scale, these changes must connect with drainage, inspection and maintenance. Ignoring one scale may leave only a visual surface effect or allow water to accumulate outside the intended area.

The proposal still requires repeated exposure tests. These should record wetting-front depth, moisture distribution, drainage and drying over several cycles. The results need to distinguish an intended wetting path from leakage or material failure. Material tests alone cannot show whether users understand a visible trace. That question requires separate observation or user testing. Visual appearance cannot be used as proof of technical safety without monitoring data.

This FGM-informed analysis is a design proposition, not a validated façade system. It uses graded properties to relate visible surface traces to moisture storage, movement and release within the component. Drainage and maintenance remain necessary. For liquid hydrological aesthetics, the aim is selective control: some water processes may become visible, but exposure cannot be left unrestricted. The next chapter turns to frozen water, where retained moisture becomes more consequential through freezing and thawing.

4. Frozen Water: Crystallisation, Duration and Material Vulnerability

4.1 Frozen Agency, Intensive Thresholds and Material Time

Freezing does not stop water's movement entirely but reorganises its behaviour through ice formation, persistence and thaw. Changes in hardness, transparency and sound can make this phase transition perceptible. In porous materials, ice formation may generate internal pressure and deformation. Damage depends on saturation, pore structure, drainage and repeated freeze–thaw cycling rather than freezing alone (Fagerlund, 1977, pp. 217–229; Scherer, 1999, pp. 1347–1358; Coussy, 2005, pp. 1689–1718). How, then, might freezing register climatic duration without aestheticizing material damage?

DeLanda describes intensive difference through thresholds: gradual variation can produce a change in kind (2013, pp. 10–12). Freezing follows this pattern, but visible frost does not explain what happens below the surface. A temperature reading at or below 0°C is not enough to establish freeze–thaw risk. Pore water may remain unfrozen until the temperature falls further, and damage also depends on local saturation (Zhou, Derome and Carmeliet, 2017, pp. 285–286). A frost line can therefore record exposure to cold without diagnosing the material beneath.

Hill treats weather as an active part of architectural production (2012, pp. 2–5). Ingold describes weather as experienced through movement and breathing (2010, pp. S121–S122). In frozen spaces, climatic duration becomes tangible through cold, hardness and transparency. Freezing and thawing also affect movement and determine how long a space remains usable. The cases here concern large ice structures and mechanically maintained ice accretion. They are used to examine duration and dependency, not to test pore-scale durability or the feasibility of a frozen FGM system.

4.2 Seasonal Recurrence and Artificial Suspension

ICEHOTEL Winter is reconstructed annually beside the Torne River in Jukkasjärvi, Sweden. River ice is harvested, stored and assembled with snow to form guest rooms and shared spaces (ICEHOTEL). Water here is not a permanent material, but a temporary one. The cold, the light and the way sound travels all make the temperature tangible to the body. In spring, the structure melts and the water flows back into the river. Melting is part of the programme, so the ICEHOTEL is stable only for a season. It is not a permanent building. Weather determines how long the ice can last.

The cycle depends on climate and infrastructure. River ice must be harvested and stored, while reconstruction, maintenance and adjacent warm facilities support its operation (ICEHOTEL). Together, these systems turn seasonal cold into a recurring programme. Visitors encounter the finished architecture, while the labour and energy sustaining it remain less visible. Figure 12 contrasts the completed seasonal structure with the material-handling and construction infrastructure that enables its annual reconstruction.

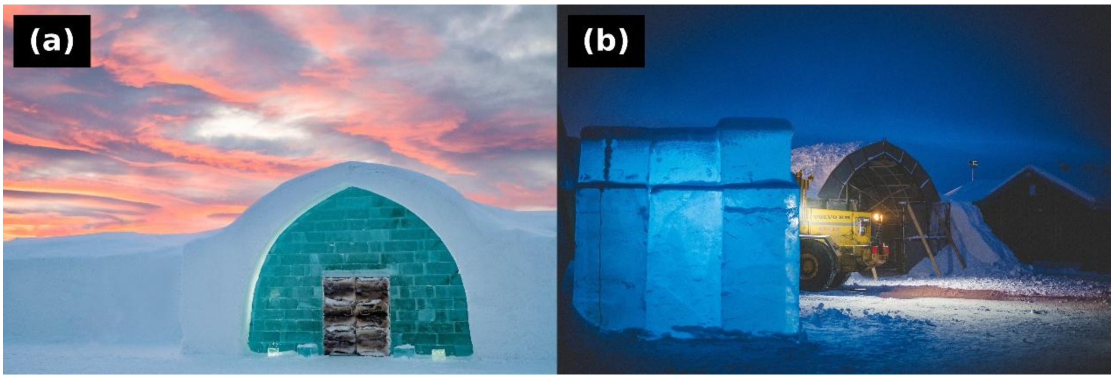

Figure 12. Seasonal form and supporting infrastructure at ICEHOTEL Winter: (a) the entrance to ICEHOTEL 35; (b) river-ice blocks and construction equipment at the site. Photographs by Asaf Kliger. Sources: ICEHOTEL .

Olafur Eliasson's Your mobile expectations: *BMW H2R project (2007)* retains the H2R chassis beneath a double-layer steel-and-mirror skin. Sprayed water freezes across this structure (Studio Olafur Eliasson, n.d.). Displayed at −10°C, accumulating ice thickens the frame, bridges openings and obscures the vehicle's profile (BMW Group, 2008). The form persists only within a maintained thermal environment. Figure 13 shows the accreted ice skin and visitors within the refrigerated exhibition space.

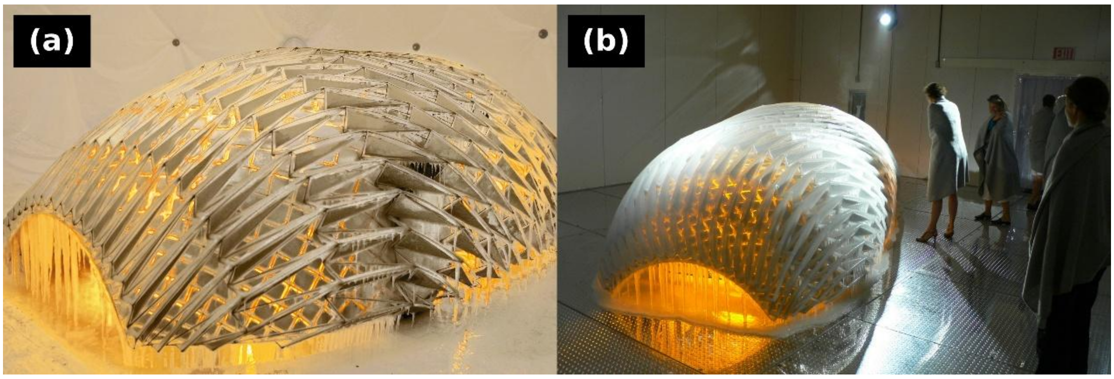

Figure 13. Ice accretion and bodily encounter in Olafur Eliasson's *Your mobile expectations: BMW H2R project* (2007): (a) ice formed across the steel-and-mirror skin; (b) visitors inside the refrigerated exhibition space. Photographs by Studio Olafur Eliasson. Source: Studio Olafur Eliasson (n.d.).

Simondon's techno-aesthetics connects aesthetic experience with technical operation, material transformation and bodily sensation (Simondon, 2012, pp. 2–3). In Eliasson's installation, refrigeration becomes perceptible through ice and visitors' experience of −10°C. ICEHOTEL Winter follows seasonal reconstruction, whereas the installation requires mechanical cooling during exhibition (BMW Group, 2008). These are different forms of thermal management, not an opposition between nature and technology. In both cases, frozen form depends on labour, energy and duration, raising questions about who sustains each thermal regime and at what cost.

4.3 FGM-Informed Frozen Mediation

An FGM-informed component would make freezing visible without exposing protected material to the phase-change event. The aim is a reversible, potentially legible trace rather than damage. Frost could register a thermal threshold in an exposed region. A drained transition would limit its water supply, while the inner region would remain outside the event. These are relations within a graded field, not separate wall layers (Allen, 1997, pp. 24–25). Surface wettability would influence water before freezing, but ice adhesion would require direct testing for the proposed material (Meuler et al., 2010, pp. 3100–3102, 3108). Pore structure and permeability would govern redistribution, while moisture state determines the water available to freeze (Coussy, 2005, pp. 1690–1691, 1709; Zhou, Derome and Carmeliet, 2017, pp. 286–287, 290). Thermal properties and cooling history would shape where and for how long freezing conditions occur (Coussy, 2005, pp. 1711–1715; Zhou, Derome and Carmeliet, 2017, pp. 287, 290). Matrix elasticity would influence how freezing pressure becomes deformation, so compliance would require testing (Coussy, 2005, pp. 1689–1691, 1706–1708). DeLanda's intensive difference clarifies the sequence: temperature may change gradually until it crosses a threshold and the material changes state (2013, pp. 63–64).

These requirements do not always work together. Greater connected porosity may hold enough water for frost to appear, but at higher saturation it also leaves more water able to freeze. Thermal resistance may delay freezing in one area and move the freezing front into another. This trade-off must be tested after thaw as well as during icing, since a surface that retains water may also drain slowly. A monitored or replaceable area could serve as the recording surface, while the protected material remains outside the intended phase-change zone. After thawing and drying, the trace should disappear. Any permanent change would count as a failure.

The three regions distribute vulnerability and maintenance responsibilities by defining where phase change is permitted or excluded and who must respond when saturation exceeds the intended range. These technical and political decisions determine which regions are protected or replaceable and where maintenance labour is required. A visible frost region should support inspection, but maintenance personnel also need access and authority to respond. The proposal can work only if the trace is reversible and inspectable, and the affected region accessible and repairable. Testing should track wetting, freezing, thawing and drying across cycles. Linked moisture, thermal and mechanical data must distinguish reversible phase change from material damage. Separate perception tests must establish whether users understand the trace.

5. Atmospheric Water: Vapour, Droplets and Climatic Mediation

5.1 Atmospheric Agency, Field Conditions and Environmental Limits

Viewed through atmospheric water, the building envelope is not simply a surface but an interface that exchanges heat and moisture with the surrounding air. Water vapour remains invisible, whereas fog and cloud make atmospheric water perceptible through suspended droplets or ice particles. This atmospheric regime involves vapour movement, humidity shifts, droplet formation, suspension, dispersion and deposition.

Evaporation absorbs heat as liquid becomes vapour. Condensation releases latent heat when air becomes saturated or a surface falls below the local dew-point temperature (Künzel, 1995, pp. 13–15, 25–31; Hens, 2017, pp. 267–272, 278–282). Atomisation forms droplets without a phase change. In buildings, droplet size, nozzle position, airflow and humidity affect evaporation, cooling and unwanted wetting (Farnham et al., 2011, pp. 228–238; Ulpiani, 2019). At system scale, these processes connect climatic conditions, equipment, space and occupancy (Stojanovic et al., 2023, pp. 100–119). These interactions can be read through Allen's field condition (Allen, 1997, p. 24). Whether produced by weather or maintained mechanically, the atmospheric field extends beyond a single surface.

'Climatic mediation' describes the aesthetic experience of atmospheric water. Böhme locates atmosphere between environmental qualities and bodily states (1993, pp. 114–116, 122–125). Pallasmaa emphasises perception through touch and temperature (2024, pp. 33–35, 48–50). Suspended droplets can shorten sightlines. Evaporation may cool the air or a material surface and change how the space feels. Surface condensation appears as droplets or a thin film of water. Studies of outdoor misting combine environmental measurements with user surveys. They record changes in local thermal conditions, thermal sensation and perceived comfort (Wong and Chong, 2010, pp. 2671–2677; Desert, Naboni and Garcia, 2020, pp. 10–15). In *Interior Weather*, Philippe Rahm uses temperature, relative humidity and light to organise space (Canadian Centre for Architecture).

Atmospheric water makes a threshold visible. Temperature and humidity may change slowly, yet condensation appears abruptly once local conditions reach saturation. DeLanda's account of intensive difference helps describe this shift from gradual variation to a change in kind (2013, p. 64). Making such a threshold perceptible, however, does not justify unhealthy humidity or discomfort that occupants cannot avoid. Comfort is socially shaped (Shove, 2003, pp. 43–44, 65–66), and responses vary between occupants and contexts (Arens et al., 2010, pp. 5, 10; Nicol, Humphreys and Roaf, 2012, pp. 23–25). Thermal variation may contribute to architectural experience only where health and ordinary use remain protected. A cool or disorienting atmosphere can be felt immediately, but perception alone does not reveal the water, energy and maintenance needed to sustain it. The political question is who defines acceptable comfort. It also matters whether occupants can alter the condition or must endure it through routine use.

5.2 Weather-Responsive Fog and Regulated Condensation

Blur Building, designed by Diller + Scofidio for Swiss Expo 2002, drew water from Lake Neuchâtel, filtered it and forced it through approximately 35,000 high-pressure nozzles. A meteorological sensing system adjusted the output in response to wind, temperature and humidity (Diller Scofidio + Renfro, n.d.). The atomised droplets remained suspended briefly, while the fog's boundary shifted continuously as changing weather dispersed or concentrated them.

Visitors entered a field of fog rather than observing a façade from outside. Sightlines shortened, other bodies receded into the mist, and the environment was encountered bodily rather than primarily through distant vision (Diller Scofidio + Renfro, n.d.). High-pressure atomisation produced the fog, while meteorological feedback and changing weather continually reshaped its boundary and sensory effects. Its political significance lies in this separation: visitors could choose whether to enter, but the pumps, filtration, water use and maintenance remained largely out of view and under institutional control. The project therefore made weather bodily perceptible without making the resources and responsibilities sustaining it equally legible. Figure 14 shows how the fog obscures the structure while drawing its access route and visitors into a shifting atmospheric field.

In *Cloudscapes*, Transsolar and Tetsuo Kondo Architects organised the 2010 installation as a vertical thermodynamic section. Cool, dry air occupied the lower zone, warm, humid air formed the middle zone, and hotter, dry air remained above (Transsolar, n.d.; Tetsuo Kondo Architects, n.d.). When the middle layer reached saturation, water vapour condensed into visible droplets.

The resulting cloud registered this threshold by making the boundary between adjacent climatic fields perceptible.

A ramp took visitors below, through and above the cloud layer. Depth came from climatic difference rather than partitions. As visitors moved through the stratified air, the environmental system sustained the conditions in which the cloud formed (Transsolar, n.d.; Tetsuo Kondo Architects, n.d.). Read through Simondon's techno-aesthetics (2012, pp. 2–5), heating, cooling, humidification and airflow were not neutral support. Their operation produced the section through which bodies moved. Blur Building presents an open field negotiated with weather, while Cloudscapes constructs and maintains a controlled field. Both show atmospheric water acquiring architectural significance through relations among air, apparatus and body, while the supporting resources remain less perceptible. Figure 15 shows visitors moving below, through and above the suspended cloud layer in Cloudscapes.

Figure 14. Blur Building enveloped by mechanically produced fog at Swiss Expo 2002, Yverdon-les-Bains, Switzerland. Designed by Diller + Scofidio. Photograph by Norbert Aepli (2002). Source: Wikimedia Commons.

Figure 15. Visitors moving through the ramp and suspended cloud layer of *Cloudscapes* at the 2010 Venice Architecture Biennale. Designed by Transsolar and Tetsuo Kondo Architects. Photograph by Fulvio Spada (2010). Source: Wikimedia Commons.

5.3 FGM-Informed Atmospheric Mediation

An FGM component cannot produce Blur's fog field or sustain Cloudscapes independently. It can only modify the boundary where air and material meet. Local thermal properties would affect surface temperature and therefore condensation risk. Wettability and texture would affect whether condensate spreads, remains pinned or drains (Hens, 2017, pp. 279–282; Gulfam and Chen, 2022, pp. 1–5, 16). Further into the component, vapour permeability, hygroscopicity and moisture-storage capacity would affect transmission and buffering (Hens, 2017, pp. 273, 282–284). These variations could allow controlled wetting at the surface, temporary storage through a transition region and reduced inward transfer at the protected side. The regions would remain connected, following Allen's emphasis on local connections (1997, p. 24). Each would respond to adjacent properties and to the thermal and moisture conditions at its boundaries (Hens, 2017, pp. 267, 273). The gradient alters one boundary within a larger atmospheric field. It does not regulate that field by itself.

The same distribution creates trade-offs. Hygroscopic buffering can moderate short-term humidity changes, but it does not alter steady-state conditions (Hens, 2017, pp. 288–289). Increasing vapour resistance may restrict inward movement but also reduce drying capacity, depending on climate and assembly design (Geving and Holme, 2013, pp. 47–49). Cooling a surface can make dew visible, but the resulting condensate still has to be collected and drained (Hens, 2017, pp. 279–282, 299–301). An evaporative façade can provide cooling only while water remains available and has a safe route out of the system (Eisenbarth et al., 2022, pp. 16–18). FGM can locate these conflicts within the component. It cannot resolve them. Performance still depends on climate, use and maintenance at a particular site.

Atmospheric hydrological aesthetics emerge when moisture and heat become perceptible through interactions among surface, air and body. Wind, pressure, indoor stratification, equipment and occupation extend beyond the material component, so gradients mediate only part of this experience. Decisions about comfort and control are also institutional. A temporary exhibition and a daily workspace carry different obligations concerning who can adjust or leave the environment and whose health takes priority. FGM can influence thermal, hygroscopic and drainage conditions at the exchange point, but the wider atmospheric system also requires sensors, environmental controls, ventilation and operational judgement. Testing must therefore combine material experiments with hygrothermal analysis, airflow simulation, comfort assessment and resource evaluation. Atmospheric water exposes the limits of material-centred design because it continues to act after leaving the component.

6. Across Regimes: Field, Threshold and the Selective Hydrological Threshold

6.1 Coupled Transitions and Cross-Regime Conflict

The previous chapters separated water into liquid, frozen and atmospheric regimes to make the analysis manageable. Water processes, however, do not remain within these categories. Rain reaches a surface, enters pores and later evaporates or freezes. Vapour condenses, while ice melts and returns to the cycle. Read as a field condition, the building envelope extends across surface, depth and air through local connections (Allen, 1997, p. 24). DeLanda (2013, pp. 10–12) further shows that crossing a critical threshold can change system behaviour. FGM may modify some of these local conditions by varying material properties across a component, but it cannot control the entire field. Geometry, mechanical systems, climate and maintenance continue to shape water behaviour.

Continuity across the three water regimes creates conflicts for FGM. A property that works in one condition can cause a problem in another. Connected porosity may redistribute moisture, but retained water can raise freeze–thaw risk once susceptible cementitious materials exceed critical saturation (Fagerlund, 1977, pp. 217–229). Surface roughness may slow or pin droplets, making traces visible but leaving moisture behind (Gulfam and Chen, 2022, pp. 1–5, 16). Thermal conductivity and vapour resistance alter temperature and vapour-pressure profiles. This may shift condensation within an assembly (Hens, 2017, pp. 187–192). No property is positive or negative in itself. Its effect depends on how much water is present, how quickly it moves, where it accumulates and how long it remains.

Water-related processes unfold at different rates. Wetting can be rapid. Drying can be slow. Saturation may require sustained exposure. A frost event may leave no immediate visible damage, although deterioration in concrete can accumulate across repeated freeze–thaw cycles (Fagerlund, 1977, pp. 217–229). Mechanically generated mist may form quickly while depending on continuous pumping and control (Ulpiani, 2019). A hydrological event therefore cannot be judged by immediate perception alone. Its supporting systems and longer timescales must also be considered.

Table 6.1 should be read as a map of relationships rather than a technical specification. Material properties interact, and their effects vary with climate, season, orientation, programme and maintenance. FGM helps turn these interactions into design questions, but it cannot replace design judgement. Designers and operating institutions must still decide which conflicts are acceptable, which performance criteria take priority and which risks are unacceptable within the protected interior.

Table 6.1. Cross-regime implications of selected material properties.

Material property	**Liquid water**	**Frozen water**	**Atmospheric water**
Porosity	Absorption, temporary storage and drying.	Saturation and freeze-thaw risk.	Moisture buffering and evaporation, with dampness risk.
Permeability	Transfer towards storage or drainage.	Supply of water to colder depth.	Vapour movement and moisture accumulation.
Surface area and roughness	Slower runoff and legible wetting.	Ice adhesion and accretion.	Evaporation and condensate collection.
Thermal response	Drying rate and surface temperature.	Freezing-front location and duration.	Condensation risk and evaporative cooling.
Retention	Prolonged inscription and moderated runoff.	Water available for crystallisation.	Humidity buffering with biological-growth risk.

Source: Author's synthesis from the comparative analysis.

6.2 Selective Legibility, Responsibility and the Architectural Proposition

Based on the analysis above, the following architectural proposal can be formulated: a “selective hydrological threshold.” The idea behind this threshold is not to make water visible everywhere across a building surface. Rather, it asks a series of selective questions. Where can water be received? Where can it be temporarily stored? Where must it be taken away promptly? Where should it be kept out? Rainfall can be recorded on a surface. Frost formation can be recorded in a replaceable zone while protected areas remain frost-free. The effects of evaporation and condensation might be observed at an interface between material and air. But certain conditions cannot be negotiated. Drainage must remain functional, and the interior and other protected zones must remain safe. In this context, “selectivity” refers to decisions about where water goes, how long it remains and which effects are acceptable.

The four main roles of the threshold are to receive water, make its presence and duration legible, release it before risk increases, and connect visible changes to an appropriate response. Not all these tasks have to be performed by the material itself. Some may be supported by material gradients. Others may depend on joints, cavities, sensors or maintenance procedures. FGM can address local material variation, but it remains only one part of a larger system. Hydrological behaviour is also shaped by geometry, airflow, equipment and infrastructure. The critical issue is coordination, not technological novelty. A graded component would not work as intended unless it operated with drainage, climate control, inspection and long-term maintenance.

On the one hand, architecture can provide a better understanding of water. On the other, water can provide a way of understanding architecture. The first works through designed spatial experience. People experience movement, temperature, humidity, condensation and changes in material surfaces through their bodies. The second is critical reconstruction. It examines drawings and technical documents alongside the systems hidden behind the experience, including pumps, storage tanks, refrigeration, sensors, labour and institutional structures. These methods should not be treated as mutually exclusive. A visible trace must be connected to a verifiable mechanism, but technical documentation should not diminish bodily experience. The hydrological threshold is therefore material and political. It determines what becomes visible, where it appears, who can perceive it and how long it remains visible.

The question “legible to whom?” is therefore crucial. Different readers require different kinds of information. A public rainwater path could communicate storage and release without displaying precise measurements. A maintenance worker might need a more specific signal indicating when inspection is required before moisture reaches a vulnerable area. This signal can be reliable without being visually dominant. Selective legibility does not mean making every process visible. It means connecting the appropriate signal to its intended reader and action. Aesthetics and instrumentation need not conflict, but perception must remain connected to process and consequence. Seeing alone is not enough.

The proposal remains theoretical. Existing case studies provide precedents for some of its technical mechanisms. Comparative interpretation examines spatial and bodily effects, while FGM-informed analysis identifies possible relationships between material properties and water behaviour. However, any claim about performance requires modelling, material characterisation and prototype testing.

Several practical questions remain for future research. Do users interpret the signals as intended? Are costs and maintenance requirements realistic across the service life? Is the system's water and energy use environmentally sustainable? Technical and interpretive validation are distinct, but the proposal requires both. Prototype testing must assess safety, legibility and maintainability. The proposal must then be evaluated under normal institutional conditions, not only in a temporary exhibition.

7. Conclusion

This study began with a simple observation: despite its technical sophistication, the building envelope often treats water primarily as something to be kept out. The preceding chapters have examined this limitation and explored water as an active participant in architectural processes. Three lines of argument run through the dissertation. Each corresponds to one of the research questions, and together they point towards a different way of understanding the relationship between architecture and water.

The first line of argument concerns what water does. Liquid water reorganises surfaces and boundaries through movement and wetting. Frozen water gives thermal duration a temporary material form through crystallisation and thaw. Atmospheric water reshapes bodily perception and climatic conditions through humidity, vapour, suspended droplets and latent heat. These are interconnected processes across water's changing states. In each case, water acts through relationships among geometry, materials, climate and institutions. These conditions shape its behaviour, but water also participates in forming the conditions around it.

The second line of argument poses a more pragmatic question: what might an architectural response be? In an FGM-informed approach, wettability, porosity, permeability, thermal response and mechanical compliance become locally variable design parameters distributed across a component. This use of FGM is diagnostic rather than prescriptive. It helps identify where water might be received, retained, made perceptible, redirected or excluded. Material gradients cannot resolve every conflict. Design judgement remains necessary because hydrological behaviour also depends on geometry, airflow, weather and active control systems. The cases illustrate possible mechanisms rather than demonstrate the practical performance of an FGM façade.

The third argument emerges from conflicts among the three water regimes. These regimes provide analytical categories, but actual water processes overlap and transform. Evaporation occurs from a wet surface. Vapour condenses. Retained moisture freezes. Ice melts and returns to the cycle. The main analytical finding is therefore that a material property may be advantageous under one condition and disadvantageous under another. Connected porosity may support absorption and redistribution, but retained water can increase freeze–thaw risk in susceptible porous materials. Thermal resistance may improve interior surface temperatures while relocating condensation risk within an assembly. Retention may extend the visibility of a trace while prolonging dampness. A material property's role changes with water volume, rate of movement, location, duration and climate. Relational inscription, material duration and climatic mediation offer three registers for reading these connected processes architecturally. They do not replace analysis of physical behaviour. They help interpret its architectural significance.

The thesis proposes a selective hydrological threshold operating across surface, depth and air. This threshold specifies which water processes become visible, where, to whom and for how long. At the same time, it must limit processes that could compromise durability, health or performance. But the threshold is not only material. It is also institutional. The distribution of material properties must be coordinated with drainage, climate control, inspection and maintenance. Responsibility must be explicit when risk or cost shifts between users, maintenance teams and institutions.

The argument has clear evidential limits. The six cases are atypical, and several are short-term projects with uneven documentation. They do not provide comparable evidence on durability, water use, energy consumption, maintenance requirements or occupant responses. The performance of particular material distributions or manufacturing methods cannot therefore be established through theoretical comparison alone. The framework instead identifies what should be tested next.

A next step would be to construct an FGM-informed prototype that tests interactions among liquid, frozen and atmospheric water under defined climatic and maintenance conditions. The research must also ask whether occupants, designers and maintenance teams interpret the signals as intended. This question cannot be answered by theory alone. It requires performance testing, environmental monitoring and evaluation with intended users.

Reference List

Hutcheon, N.B. (1953) *Fundamental Considerations in the Design of Exterior Walls for Buildings*. DBR Technical Report No. 13 (NRCC 3057). Ottawa: National Research Council Canada. Available at: https://nrc-publications.canada.ca/eng/view/object/?id=e03a98e6-9755-42d8-a9ea-f8b34680bded

Ching, F.D.K. (2014) *Building Construction Illustrated*. 5th edn. Hoboken, NJ: Wiley.

Hens, H. (2017) *Building Physics: Heat, Air and Moisture: Fundamentals and Engineering Methods with Examples and Exercises*. 3rd edn. Berlin: Ernst & Sohn. https://doi.org/10.1002/9783433608548

Kaika, M. (2005) *City of Flows: Modernity, Nature, and the City*. New York: Routledge.

IPCC (2021) 'Summary for Policymakers', in Masson-Delmotte, V. et al. (eds) *Climate Change 2021: The Physical Science Basis*. Cambridge: Cambridge University Press, pp. 3–32. https://doi.org/10.1017/9781009157896.001

Defo, M. and Lacasse, M.A. (2021) 'Effects of climate change on the moisture performance of tallwood building envelope', *Buildings*, 11(2), 35. https://doi.org/10.3390/buildings11020035

Ottelé, M., Perini, K., Fraaij, A.L.A., Haas, E.M. and Raiteri, R. (2011) 'Comparative life cycle analysis for green façades and living wall systems', *Energy and Buildings*, 43(12), pp. 3419–3429. https://doi.org/10.1016/j.enbuild.2011.09.010

Raimondi, A., Quinn, R., Abhijith, G.R., Becciu, G. and Ostfeld, A. (2023) 'Rainwater harvesting and treatment: State of the art and perspectives', *Water*, 15(8), 1518. https://doi.org/10.3390/w15081518

Peeks, M. and Badarnah, L. (2021) 'Textured building façades: Utilizing morphological adaptations found in nature for evaporative cooling', *Biomimetics*, 6(2), 24. https://doi.org/10.3390/biomimetics6020024

Künzel, H.M. (1995) *Simultaneous Heat and Moisture Transport in Building Components: One- and Two-Dimensional Calculation Using Simple Parameters*. Stuttgart: Fraunhofer IRB Verlag. https://doi.org/10.24406/publica-fhg-288145

Böhme, G. (1993) 'Atmosphere as the fundamental concept of a new aesthetics', *Thesis Eleven*, 36(1), pp. 113–126. https://doi.org/10.1177/072551369303600107

Hall, C. and Hoff, W.D. (2022) *Water Transport in Brick, Stone and Concrete*. 3rd edn. Boca Raton, FL: CRC Press. https://doi.org/10.1201/9780429352744

Coussy, O. (2005) ‘Poromechanics of freezing materials’, *Journal of the Mechanics and Physics of Solids*, 53(8), pp. 1689–1718. https://doi.org/10.1016/j.jmps.2005.04.001

Lekner, J. and Dorf, M.C. (1988) ‘Why some things are darker when wet’, *Applied Optics*, 27(7), pp. 1278–1280. https://doi.org/10.1364/AO.27.001278

Bennett, J. (2010) *Vibrant Matter: A Political Ecology of Things*. Durham, NC: Duke University Press.

DeLanda, M. (2013) *Intensive Science and Virtual Philosophy*. London: Bloomsbury Academic.

Oxman, N., Keating, S. and Tsai, E. (2011) ‘Functionally graded rapid prototyping’, in Bártolo, P.J. et al. (eds) *Innovative Developments in Virtual and Physical Prototyping*. London: CRC Press, pp. 483–489. https://doi.org/10.1201/b11341-78

Grigoriadis, K. (2019) ‘Computational blends: The epistemology of designing with functionally graded materials’, *The Journal of Architecture*, 24(2), pp. 160–192. https://doi.org/10.1080/13602365.2019.1578074

Allen, S. (1997) ‘From object to field’, *Architectural Design*, 67(5–6), pp. 24–31.

Simondon, G. (2012) ‘On techno-aesthetics’, translated by A. De Boever, *Parrhesia*, 14, pp. 1–8. Available at: http://www.parrhesiajournal.org/parrhesia14/parrhesia14_simondon.pdf

Pallasmaa, J. (2024) *The Eyes of the Skin: Architecture and the Senses*. 4th edn. Chichester: Wiley. https://doi.org/10.1002/9781394200702

Swyngedouw, E., Kaika, M. and Castro, E. (2002) ‘Urban water: A political-ecology perspective’, *Built Environment*, 28(2), pp. 124–137. Available at: https://www.jstor.org/stable/23288796

Linton, J. and Budds, J. (2014) ‘The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water’, *Geoforum*, 57, pp. 170–180. https://doi.org/10.1016/j.geoforum.2013.10.008

Washburn, E.W. (1921) ‘The dynamics of capillary flow’, *Physical Review*, 17(3), pp. 273–283. https://doi.org/10.1103/PhysRev.17.273

Fagerlund, G. (1977) ‘The critical degree of saturation method of assessing the freeze/thaw resistance of concrete’, *Matériaux et Construction*, 10(4), pp. 217–229. https://doi.org/10.1007/BF02478693

Scherer, G.W. (1999) ‘Crystallization in pores’, *Cement and Concrete Research*, 29(8), pp. 1347–1358. https://doi.org/10.1016/S0008-8846(99)00002-2

Gultepe, I., Tardif, R., Michaelides, S.C., Cermak, J., Bott, A., Bendix, J., Müller, M.D., Pagowski, M., Hansen, B., Ellrod, G., Jacobs, W., Toth, G. and Cober, S.G. (2007) ‘Fog research: A review of past achievements and future perspectives’, *Pure and Applied Geophysics*, 164, pp. 1121–1159. https://doi.org/10.1007/s00024-007-0211-x

Koizumi, M. (1997) ‘FGM activities in Japan’, *Composites Part B: Engineering*, 28(1–2), pp. 1–4. https://doi.org/10.1016/S1359-8368(96)00016-9

Duro-Royo, J., Mogas-Soldevila, L. and Oxman, N. (2015) ‘Flow-based fabrication: An integrated computational workflow for design and digital additive manufacturing of multifunctional heterogeneously structured objects’, *Computer-Aided Design*, 69, pp. 143–154. https://doi.org/10.1016/j.cad.2015.05.005

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D. and Viklander, M. (2015) ‘SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage’, *Urban Water Journal*, 12(7), pp. 525–542. https://doi.org/10.1080/1573062X.2014.916314

Richards, P. (2008) ‘MIT Digital Water Pavilion makes a splash in Spain’, *MIT News*, 11 June. Available at: https://news.mit.edu/2008/zaragoza-tt0611

Yeste Navarro, I. (2018) ‘Digital Water Pavilion’, *Artigrama*, 33, pp. 445–452. https://doi.org/10.26754/ojs_artigrama/artigrama.2018338291

Richards, P. (2007) ‘MIT architects design building with “digital water” walls’, *MIT News*, 10 July. Available at: https://news.mit.edu/2007/mit-architects-design-building-digital-water-walls

Benesse Art Site Naoshima (2019) ‘Experiencing Teshima Art Museum’s Special Morning Viewing Program (April 14, 2019)’, 4 June. Available at: https://benesse-artsite.jp/en/story/20190604-1176.html

Benesse Art Site Naoshima (n.d.) ‘Teshima Art Museum’. Available at: https://benesse-artsite.jp/en/art/teshima-artmuseum.html

Gözen, J.E. (2023) ‘MATRIX: Rei Naito and William Gibson hallucinating the Posthuman’, *Journal of Global Pop Cultures*, August. Available at: https://www.journalofglobalpopcultures.com/issues/the-natures-of-pop/matrix-rei-naito-and-william-gibson-hallucinating-the-posthuman

Zhou, X., Derome, D. and Carmeliet, J. (2017) ‘Hygrothermal modeling and evaluation of freeze-thaw damage risk of masonry walls retrofitted with internal insulation’, *Building and Environment*, 125, pp. 285–298. https://doi.org/10.1016/j.buildenv.2017.08.001

Hill, J. (2012) *Weather Architecture*. London: Routledge.

Ingold, T. (2010) ‘Footprints through the weather-world: Walking, breathing, knowing’, *Journal of the Royal Anthropological Institute*, 16(s1), pp. S121–S139. https://doi.org/10.1111/j.1467-9655.2010.01613.x

ICEHOTEL (n.d.) ‘The Story of ICEHOTEL’. Available at: https://www.icehotel.com/the-story

Studio Olafur Eliasson (n.d.) ‘Your mobile expectations: BMW H2R project, 2007’. Available at: https://olafureliasson.net/artwork/your-mobile-expectations-bmw-h2r-project-2007/

BMW Group (2008) ‘Olafur Eliasson – Your mobile expectations: BMW H2R project’, 29 May. Available at: https://www.press.bmwgroup.com/austria/article/detail/T0031216DE/olafur-eliasson-your-mobile-expectations%3A-bmw-h2r-project-das-16-bmw-art-car

Meuler, A.J., Smith, J.D., Varanasi, K.K., Mabry, J.M., McKinley, G.H. and Cohen, R.E. (2010) ‘Relationships between water wettability and ice adhesion’, *ACS Applied Materials & Interfaces*, 2(11), pp. 3100–3110. https://doi.org/10.1021/am1006035

Farnham, C., Nakao, M., Nishioka, M., Nabeshima, M. and Mizuno, T. (2011) ‘Study of mist-cooling for semi-enclosed spaces in Osaka, Japan’, *Procedia Environmental Sciences*, 4, pp. 228–238. https://doi.org/10.1016/j.proenv.2011.03.027

Ulpiani, G. (2019) ‘Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts’, *Applied Energy*, 254, 113647. https://doi.org/10.1016/j.apenergy.2019.113647

Stojanovic, D., Vujovic, M., Ding, Y. and Katic, M. (2023) ‘Context-aware module for evaporative cooling in the outdoor built environment’, *International Journal of Architectural Computing*, 21(1), pp. 100–119. https://doi.org/10.1177/14780771221095307

Wong, N.H. and Chong, A.Z.M. (2010) ‘Performance evaluation of misting fans in hot and humid climate’, *Building and Environment*, 45(12), pp. 2666–2678. https://doi.org/10.1016/j.buildenv.2010.05.026

Desert, A., Naboni, E. and Garcia, D. (2020) ‘The spatial comfort and thermal delight of outdoor misting installations in hot and humid extreme environments’, *Energy and Buildings*, 224, 110202. https://doi.org/10.1016/j.enbuild.2020.110202

Canadian Centre for Architecture (n.d.) ‘Philippe Rahm “Interior Weather” installation records’. Available at: https://www.cca.qc.ca/en/archives/395999/philippe-rahm-interior-weather-installation-records

Shove, E. (2003) *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. Oxford: Berg.

Arens, E., Humphreys, M.A., de Dear, R. and Zhang, H. (2010) ‘Are “class A” temperature requirements realistic or desirable?’, *Building and Environment*, 45(1), pp. 4–10. https://doi.org/10.1016/j.buildenv.2009.03.014

Nicol, F., Humphreys, M. and Roaf, S. (2012) *Adaptive Thermal Comfort: Principles and Practice*. London: Routledge.

Diller Scofidio + Renfro (n.d.) ‘Blur Building’. Available at: https://dsrny.com/project/blur-building

Transsolar (n.d.) ‘Cloudscapes’. Available at: https://transsolar.com/publications/exhibitions/cloudscapes

Tetsuo Kondo Architects (n.d.) ‘Cloudscapes’. Available at: https://www.tetsuokondo.jp/project/bnl.html

Gulfam, R. and Chen, Y. (2022) ‘Recent growth of wettability gradient surfaces: A review’, *Research*, 2022, 9873075. https://doi.org/10.34133/2022/9873075

Geving, S. and Holme, J. (2013) ‘Vapour retarders in wood frame walls and their effect on the drying capability’, *Frontiers of Architectural Research*, 2(1), pp. 42–49. https://doi.org/10.1016/j.foar.2012.12.003

Eisenbarth, C., Haase, W., Blandini, L. and Sobek, W. (2022) 'Potentials of hydroactive lightweight façades for urban climate resilience', *Civil Engineering Design*, 4(1–3), pp. 14–24. https://doi.org/10.1002/cend.202200003

List of Figures

Figure 11. Visitors adjusting their posture and proximity to observe water traces across the floor of Rei Naito's *Matrix*, Teshima Art Museum. Photograph by Iwan Baan, 2010. Source: Loho (2024). Available at: https://observer.com/2024/01/photographer-iwan-baan-architecture/

Figure 12. Seasonal form and supporting infrastructure at ICEHOTEL Winter: (a) the entrance to ICEHOTEL 35; (b) river-ice blocks and construction equipment at the site. Photographs by Asaf Kliger. Source (a): ICEHOTEL . Available at: https://www.icehotel.com/the-story
Source (b): ICEHOTEL. Available at: https://www.icehotel.com/sustainability

Figure 13. Ice accretion and bodily encounter in Olafur Eliasson's *Your mobile expectations: BMW H2R project* (2007): (a) ice formed across the steel-and-mirror skin; (b) visitors inside the refrigerated exhibition space. Photographs by Studio Olafur Eliasson. Source: Studio Olafur Eliasson (n.d.). Available at: https://olafureliasson.net/artwork/your-mobile-expectations-bmw-h2r-project-2007/

Figure 14. Blur Building enveloped by mechanically produced fog at Swiss Expo 2002, Yverdon-les-Bains, Switzerland. Designed by Diller + Scofidio. Photograph by Norbert Aepli (2002). Source: Wikimedia Commons. Available at: https://commons.wikimedia.org/wiki/File:20020717_Expo_Yverdon_23.JPG

Figure 15. Visitors moving through the ramp and suspended cloud layer of *Cloudscapes* at the 2010 Venice Architecture Biennale. Designed by Transsolar and Tetsuo Kondo Architects. Photograph by Fulvio Spada (2010). Source: Wikimedia Commons. Available at: https://commons.wikimedia.org/wiki/File:Cloudscapes,_Transsolar_%26_Tetsuo_Kondo_Architects,_Architecture_Biennale_(5177886133).jpg

Bibliography

Allen, S. (1997) ‘From object to field’, *Architectural Design*, 67(5–6), pp. 24–31.

Arens, E., Humphreys, M.A., de Dear, R. and Zhang, H. (2010) ‘Are “class A” temperature requirements realistic or desirable?’, *Building and Environment*, 45(1), pp. 4–10. https://doi.org/10.1016/j.buildenv.2009.03.014

Benesse Art Site Naoshima (n.d.) ‘Teshima Art Museum’. Available at: https://benesse-artsite.jp/en/art/teshima-artmuseum.html

Benesse Art Site Naoshima (2019) ‘Experiencing Teshima Art Museum’s Special Morning Viewing Program (April 14, 2019)’, 4 June. Available at: https://benesse-artsite.jp/en/story/20190604-1176.html

Bennett, J. (2010) *Vibrant Matter: A Political Ecology of Things*. Durham, NC: Duke University Press.

BMW Group (2008) ‘Olafur Eliasson – Your mobile expectations: BMW H2R project’, 29 May. Available at: https://www.press.bmwgroup.com/austria/article/detail/T0031216DE/olafur-eliasson-your-mobile-expectations%3A-bmw-h2r-project-das-16-bmw-art-car

Böhme, G. (1993) ‘Atmosphere as the fundamental concept of a new aesthetics’, *Thesis Eleven*, 36(1), pp. 113–126. https://doi.org/10.1177/072551369303600107

Canadian Centre for Architecture (n.d.) ‘Philippe Rahm “Interior Weather” installation records’. Available at: https://www.cca.qc.ca/en/archives/395999/philippe-rahm-interior-weather-installation-records

Carlo Ratti Associati (2008) ‘Digital Water Pavilion’. Available at: https://carlorattiassociati.com/project/digital-water-pavilion/

Chen, J., He, Z., Chen, S., Nguyen, P.M.V., Liu, J. and Xu, H. (2025) ‘Study on freeze-thaw damage of surface and pore structure of steam cured concrete’, *Scientific Reports*, 15, 22594. https://doi.org/10.1038/s41598-025-06958-y

Ching, F.D.K. (2014) *Building Construction Illustrated*. 5th edn. Hoboken, NJ: Wiley.

Coussy, O. (2005) ‘Poromechanics of freezing materials’, *Journal of the Mechanics and Physics of Solids*, 53(8), pp. 1689–1718. https://doi.org/10.1016/j.jmps.2005.04.001

Defo, M. and Lacasse, M.A. (2021) ‘Effects of climate change on the moisture performance of tallwood building envelope’, *Buildings*, 11(2), 35. https://doi.org/10.3390/buildings11020035

DeLanda, M. (1995) ‘Uniformity and variability: An essay in the philosophy of matter’, paper presented at *Doors of Perception 3: On Matter*, Netherlands Design Institute, Amsterdam, 7–11 November. Available at: https://archives.doorsofperception.com/doors3/transcripts/Delanda.html

DeLanda, M. (2013) *Intensive Science and Virtual Philosophy*. London: Bloomsbury Academic.

Desert, A., Naboni, E. and Garcia, D. (2020) ‘The spatial comfort and thermal delight of outdoor misting installations in hot and humid extreme environments’, *Energy and Buildings*, 224, 110202. https://doi.org/10.1016/j.enbuild.2020.110202

Diller Scofidio + Renfro (n.d.) ‘Blur Building’. Available at: https://dsrny.com/project/blur-building

Duro-Royo, J., Mogas-Soldevila, L. and Oxman, N. (2015) ‘Flow-based fabrication: An integrated computational workflow for design and digital additive manufacturing of multifunctional heterogeneously structured objects’, *Computer-Aided Design*, 69, pp. 143–154. https://doi.org/10.1016/j.cad.2015.05.005

Eisenbarth, C., Haase, W., Blandini, L. and Sobek, W. (2022) ‘Potentials of hydroactive lightweight façades for urban climate resilience’, *Civil Engineering Design*, 4(1–3), pp. 14–24. https://doi.org/10.1002/cend.202200003

Fagerlund, G. (1977) ‘The critical degree of saturation method of assessing the freeze/thaw resistance of concrete’, *Matériaux et Construction*, 10(4), pp. 217–229. https://doi.org/10.1007/BF02478693

Farnham, C., Nakao, M., Nishioka, M., Nabeshima, M. and Mizuno, T. (2011) ‘Study of mist-cooling for semi-enclosed spaces in Osaka, Japan’, *Procedia Environmental Sciences*, 4, pp. 228–238. https://doi.org/10.1016/j.proenv.2011.03.027

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D. and Viklander, M. (2015) ‘SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage’, *Urban Water Journal*, 12(7), pp. 525–542. https://doi.org/10.1080/1573062X.2014.916314

Geving, S. and Holme, J. (2013) ‘Vapour retarders in wood frame walls and their effect on the drying capability’, *Frontiers of Architectural Research*, 2(1), pp. 42–49. https://doi.org/10.1016/j.foar.2012.12.003

Giaccone, D., Santamaria, U. and Corradi, M. (2020) ‘An experimental study on the effect of water on historic brickwork masonry’, *Heritage*, 3(1), pp. 29–46. https://doi.org/10.3390/heritage3010003

Gözen, J.E. (2023) ‘MATRIX: Rei Naito and William Gibson hallucinating the Posthuman’, *Journal of Global Pop Cultures*, August. Available at: https://www.journalofglobalpopcultures.com/issues/the-natures-of-pop/matrix-rei-naito-and-william-gibson-hallucinating-the-posthuman

Grigoriadis, K. (2019) ‘Computational blends: The epistemology of designing with functionally graded materials’, *The Journal of Architecture*, 24(2), pp. 160–192. https://doi.org/10.1080/13602365.2019.1578074

Gulfam, R. and Chen, Y. (2022) ‘Recent growth of wettability gradient surfaces: A review’, *Research*, 2022, 9873075. https://doi.org/10.34133/2022/9873075

Gultepe, I., Tardif, R., Michaelides, S.C., Cermak, J., Bott, A., Bendix, J., Müller, M.D., Pagowski, M., Hansen, B., Ellrod, G., Jacobs, W., Toth, G. and Cober, S.G. (2007) ‘Fog research: A review of past achievements and future perspectives’, *Pure and Applied Geophysics*, 164, pp. 1121–1159. https://doi.org/10.1007/s00024-007-0211-x

Hall, C. and Hoff, W.D. (2022) *Water Transport in Brick, Stone and Concrete*. 3rd edn. Boca Raton, FL: CRC Press. https://doi.org/10.1201/9780429352744

Hens, H. (2017) *Building Physics: Heat, Air and Moisture: Fundamentals and Engineering Methods with Examples and Exercises*. 3rd edn. Berlin: Ernst & Sohn. https://doi.org/10.1002/9783433608548

Hill, J. (2012) *Weather Architecture*. London: Routledge.

Hutcheon, N.B. (1953) *Fundamental Considerations in the Design of Exterior Walls for Buildings*. DBR Technical Report No. 13 (NRCC 3057). Ottawa: National Research Council Canada. Available at: https://nrc-publications.canada.ca/eng/view/object/?id=e03a98e6-9755-42d8-a9ea-f8b34680bded

ICEHOTEL (n.d.) ‘The Story of ICEHOTEL’. Available at: https://www.icehotel.com/the-story

Ingold, T. (2010) ‘Footprints through the weather-world: Walking, breathing, knowing’, *Journal of the Royal Anthropological Institute*, 16(s1), pp. S121–S139. https://doi.org/10.1111/j.1467-9655.2010.01613.x

IPCC (2021) 'Summary for Policymakers', in Masson-Delmotte, V. et al. (eds) *Climate Change 2021: The Physical Science Basis*. Cambridge: Cambridge University Press, pp. 3–32. https://doi.org/10.1017/9781009157896.001

Kaika, M. (2005) *City of Flows: Modernity, Nature, and the City*. New York: Routledge.

Koizumi, M. (1997) 'FGM activities in Japan', *Composites Part B: Engineering*, 28(1–2), pp. 1–4. https://doi.org/10.1016/S1359-8368(96)00016-9

Künzel, H.M. (1995) *Simultaneous Heat and Moisture Transport in Building Components: One- and Two-Dimensional Calculation Using Simple Parameters*. Stuttgart: Fraunhofer IRB Verlag. https://doi.org/10.24406/publica-fhg-288145

Lekner, J. and Dorf, M.C. (1988) 'Why some things are darker when wet', *Applied Optics*, 27(7), pp. 1278–1280. https://doi.org/10.1364/AO.27.001278

Linton, J. and Budds, J. (2014) 'The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water', *Geoforum*, 57, pp. 170–180. https://doi.org/10.1016/j.geoforum.2013.10.008

Loho, P. (2024) 'Iwan Baan is breaking through architecture's leading lines', *Observer*, 10 January. Available at: https://observer.com/2024/01/photographer-iwan-baan-architecture/

Meuler, A.J., Smith, J.D., Varanasi, K.K., Mabry, J.M., McKinley, G.H. and Cohen, R.E. (2010) 'Relationships between water wettability and ice adhesion', *ACS Applied Materials & Interfaces*, 2(11), pp. 3100–3110. https://doi.org/10.1021/am1006035

Nicol, F., Humphreys, M. and Roaf, S. (2012) *Adaptive Thermal Comfort: Principles and Practice*. London: Routledge.

Ottelé, M., Perini, K., Fraaij, A.L.A., Haas, E.M. and Raiteri, R. (2011) 'Comparative life cycle analysis for green façades and living wall systems', *Energy and Buildings*, 43(12), pp. 3419–3429. https://doi.org/10.1016/j.enbuild.2011.09.010

Oxman, N., Keating, S. and Tsai, E. (2011) 'Functionally graded rapid prototyping', in Bártolo, P.J. et al. (eds) *Innovative Developments in Virtual and Physical Prototyping*. London: CRC Press, pp. 483–489. https://doi.org/10.1201/b11341-78

Pallasmaa, J. (2024) *The Eyes of the Skin: Architecture and the Senses*. 4th edn. Chichester: Wiley. https://doi.org/10.1002/9781394200702

Peeks, M. and Badarnah, L. (2021) 'Textured building façades: Utilizing morphological adaptations found in nature for evaporative cooling', *Biomimetics*, 6(2), 24. https://doi.org/10.3390/biomimetics6020024

Raimondi, A., Quinn, R., Abhijith, G.R., Becciu, G. and Ostfeld, A. (2023) 'Rainwater harvesting and treatment: State of the art and perspectives', *Water*, 15(8), 1518. https://doi.org/10.3390/w15081518

Richards, P. (2007) 'MIT architects design building with "digital water" walls', *MIT News*, 10 July. Available at: https://news.mit.edu/2007/mit-architects-design-building-digital-water-walls

Richards, P. (2008) 'MIT Digital Water Pavilion makes a splash in Spain', *MIT News*, 11 June. Available at: https://news.mit.edu/2008/zaragoza-tt0611

Scherer, G.W. (1999) 'Crystallization in pores', *Cement and Concrete Research*, 29(8), pp. 1347–1358. https://doi.org/10.1016/S0008-8846(99)00002-2

Segonne, C. and Duthon, P. (2023) 'Qualification of the PAVIN fog and rain platform and its digital twin for the evaluation of a pedestrian detector in fog', *Journal of Imaging*, 9(10), 211. https://doi.org/10.3390/jimaging9100211

Shove, E. (2003) *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. Oxford: Berg.

Simondon, G. (2012) 'On techno-aesthetics', translated by A. De Boever, *Parrhesia*, 14, pp. 1–8. Available at: http://www.parrhesiajournal.org/parrhesia14/parrhesia14_simondon.pdf

Stojanovic, D., Vujovic, M., Ding, Y. and Katic, M. (2023) 'Context-aware module for evaporative cooling in the outdoor built environment', *International Journal of Architectural Computing*, 21(1), pp. 100–119. https://doi.org/10.1177/14780771221095307

Studio Olafur Eliasson (n.d.) 'Your mobile expectations: BMW H2R project, 2007'. Available at: https://olafureliasson.net/artwork/your-mobile-expectations-bmw-h2r-project-2007/

Swyngedouw, E., Kaika, M. and Castro, E. (2002) 'Urban water: A political-ecology perspective', *Built Environment*, 28(2), pp. 124–137. Available at: https://www.jstor.org/stable/23288796

Tetsuo Kondo Architects (n.d.) 'Cloudscapes'. Available at: https://www.tetsuokondo.jp/project/bnl.html

Transsolar (n.d.) 'Cloudscapes'. Available at: https://transsolar.com/publications/exhibitions/cloudscapes

Ulpiani, G. (2019) ‘Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts’, *Applied Energy*, 254, 113647. https://doi.org/10.1016/j.apenergy.2019.113647

Washburn, E.W. (1921) ‘The dynamics of capillary flow’, *Physical Review*, 17(3), pp. 273–283. https://doi.org/10.1103/PhysRev.17.273

Wong, N.H. and Chong, A.Z.M. (2010) ‘Performance evaluation of misting fans in hot and humid climate’, *Building and Environment*, 45(12), pp. 2666–2678. https://doi.org/10.1016/j.buildenv.2010.05.026

Yang, Y., Chen, B., Liang, S., Liu, F., Yang, W., Xie, R., Zhu, Y., Guo, W., Wang, H. and Jiang, S. (2026) ‘Effect of recycled ceramic fine aggregate (RCFA) on strength and durability of concrete with varying water-to-binder ratios’, *International Journal of Concrete Structures and Materials*, 20, 33. https://doi.org/10.1186/s40069-026-00913-5

Yeste Navarro, I. (2018) ‘Digital Water Pavilion’, *Artigrama*, 33, pp. 445–452. https://doi.org/10.26754/ojs_artigrama/artigrama.2018338291

Zhou, X., Derome, D. and Carmeliet, J. (2017) ‘Hygrothermal modeling and evaluation of freeze-thaw damage risk of masonry walls retrofitted with internal insulation’, *Building and Environment*, 125, pp. 285–298. https://doi.org/10.1016/j.buildenv.2017.08.001