⑦ Architecture in making

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In this chapter, we argue that the desired qualities of the future *smart living lab* building are not a scientific challenge but rather a human and social one. Moreover, we posit that partial qualities linked to use, experimentation, environmental performance and context are only relevant when incorporated in the overall quality we call architecture. Their implementation depends on the capacity of various actors to get involved in a learning-by-doing process that leaves room for their divergent interests and the creation of shared values.

A research programme dedicated to the conception and realization of a building is rather rare. The *smart living lab*'s future building (SLB)[24] has given us the opportunity to explore and identify ways of influencing and supporting the process of its future construction. Fulfilling initial expectations is a key challenge when it comes to the design and realization of a building. In the case of the SLB, this challenge is paramount. In addition to the expectations of the politicians and citizens of Fribourg, the SLB must also meet the requirements of researchers in terms of its energy performance so as to serve as a research subject/object and to be a comfortable place for everyday activities. Like the goals for the project, the risks are equally high. The findings of the research programme presented in this book will be included in the design brief. The SLB vision, which is also part of the brief, states that the SLB should be “the architectural transposition of use value. It should offer a sensorial experience, connect and reassure people. It should be resilient to new uses and technology, as well as to the loss of obsolete ones... The building's performance assessment should be addressed globally and from cradle to grave. It should consider all embodied and operative impacts related to material and energy consumption, including all components in the perimeter of the building's envelope”[25].

Given the gap between academic research and practice, we must ask ourselves whether the designers, jury and builders will be able to understand and respond to this challenge? Given the SLB's role as a precursor, will the legal framework—with its myriad norms and procedures—allow for its realization? The SLB vision also states that the building “should be ready for incremental growth and the redefinition of uses”. While we understand that the SLB must be designed so as to be capable of constant evolution, we wonder how this will be compatible with contemporary Swiss culture, which expects well-finished, almost perfect buildings. The SLB process involves an array of actors including politicians, administrators, researchers from various disciplines, architects, engineers and an independent jury and builders, among others. Each speaks a different language and has a different way of thinking, which limits their collaboration capacities. Is the SLB yet another attempt to build the Tower of Babel [Figure 7.1]?

There are two ways of looking at the Tower of Babel metaphor. The first is pessimistic and announces the failure to meet expectations. The second, which is optimistic, serves as a basis for our thesis: the future *smart living lab* building should be an open process wherein stakeholders strive to develop a shared understanding of the objectives and qualities and to enact them. This chapter aims to offer a conceptual framework that will facilitate collaboration between the actors during the actual process: how do actors understand the concept of architectural quality? What are their roles? How do they interact?

24 This chapter is the result of an applied research project called “Architectural Quality and the Building Realization Process” developed between 2015 and 2016 by the TRANSFORM Institute.

25 Excerpt from the “Vision of the *smart living lab* building” by the Scientific Committee, March 2017.

Fig. 7.1 The Tower of Babel. A metaphor for the failure of an overly ambitious plan to reach the heavens as just before God confused the builders' language (Pieter Brueghel the Elder)

In the first subchapter, we clarify the main actors' understanding of "architectural quality," which is essential for the collaboration process. For users, architecture is a building's overall quality translated into an atmosphere, an emotion triggered by their transaction with physical factors. Habits and social relationships in a work environment also contribute to the atmosphere of a place. The analogy between user comfort and atmosphere supports the idea of using a comprehensive approach to the former. For architects, architecture is also the overall quality of a building, which is known as "wholeness." To understand how architects attempt to create "wholeness," we will briefly describe "design thinking" which is their core activity and mainly qualitative. As aesthetic theories of architecture are less accessible to the public due to their specific language, we have chosen to illustrate it using several examples of well-known buildings.

In the second subchapter, we will present a theoretical framework for understanding the building realization process. In real situations versus imaginary/idealized processes, the stakeholders have different interests and understandings of the notion of architectural quality. A building's quality clearly depends on the quality of the interaction between actors. Actors are able to come to an agreement not by following legal procedures but by adhering to social norms (Epron 1981), which is a learning process (Bicchieri 2014). This means that the design phase should be conceived in such a way as to allow for the mediation of actors' divergent interests — a learning-by-doing process wherein shared values are forged.

In the final subchapter we will argue that, in order to materialize the vision of the future *smart living lab* building evoked in this introduction, collaboration is essential. We will likewise highlight the critical issues for the SLB process based on the conclusions of the previous subchapters.

The complexity of the research project required a hybrid approach combining a literature review, the framing of theoretical notions, case studies, interactions with the main *smart living lab* actors in the preparation for the actual process, and practical experiments with students in two *Joint Master of Architecture* studios at the HEIA Fribourg.

7.1 Architecture as quality

Architectural quality is a controversial notion, whose origin lies in the double meaning of the notion of quality itself. In philosophy, quality is considered as an attribute or characteristic feature of an object (Cargile 1995) (objective meaning). However, quality can also be interpreted as value (subjective meaning). For example, Jean-François Bordron considers quality as a value we can attribute to acts, objects and relationships (Bordron 2011), whereas Van der Voordt emphasizes the subjective point of view: "Quality is the extent to which a product fulfils the requirements set for it" (Van der Voordt and Wegen 2005). If we transpose these views to a building, it seems obvious that the latter has both "objective" (as a physical object) and "subjective" features based on how we judge it. Aware of this duality, Biau and Lautier stress that is difficult to reach a consensus on the definition of architectural quality (Biau and Lautier 2009). An architectural object has multiple facets; it is an object of use that can be described as functional and / or symbolic, but is also a work of art that "escapes functional comparisons." The debate on the definition of architectural quality is perpetual and crosses all historical periods.

7.1.1 Architectural quality: a lack of consensus

Many attempts have been made to define architectural quality. In their book "Architecture in Use: An Introduction to the Programming, Design and Evaluation of Buildings," Van der Voordt and Wegen (Van der Voordt and Wegen 2005) distinguish two ways of understanding architectural quality based on a thorough analysis of these definitions. The first, which is predominant in architectural discourse, is associated with perceptual qualities, cultural values and symbolic meanings. The second and more common understanding of quality defines it as a synthesis of form, function and technique. Based on these two definitions, Van der Voordt and Wegen propose another that integrates the four major sub-qualities: functional, aesthetic, technical and economic. Functional qualities refer to how spaces are adapted to users' activities ("usability") based on their organization and layout. Aesthetic qualities are linked to the atmosphere of a building and its potential to evoke meaning, which could ultimately give it cultural value. Technical qualities relate to the degree to which a building's physical properties respond to measurable requirements (structure, envelope, technical installations, energy performance, healthy indoor climate, etc.). Efficient use of financial resources and rate of return define the economic qualities. One might observe that the first three groups of sub-qualities are an updated version of the classical Vitruvian Triad, *firmitas, utilitas, venustas* (solid, useful, beautiful).

All of these definitions illustrate the fact that a building has qualities. However, the main question—that of the definition of architectural quality—remains open. Van der Voordt and Wegen talk about the synthesis and integration of these sub-qualities as a prerequisite for achieving architectural quality. However, it is not clear here who does the synthesizing and the integrating. Coming back to the idea of quality as a subjective topic, and to its dependency on fulfilling the requirements set for it, we understand that the definition of architectural quality cannot be sought in a general way; we must address it relative to the subject that produces or evaluates it. Simply put, functional and aesthetic qualities are the concern of users, historians and theoreticians. Technical qualities concern users, building owners and public administrations. Economic qualities concern investors.

We shall see how these different actors identify and evaluate these groups of sub-qualities and in what ways they are concerned by their integration.

7.1.2 User experience: pervasive quality

Regarding the architectural quality of existing buildings, it would seem that the user is the main actor of reference. In this case, we essentially consider users who occupy and utilize a building in a more or less regular way. Visitors to a building can also be included in this group, but their interest in the building is more focused. The former group performs various activities and has social relationships with other people there.

To understand how we experience a place and how quality emerges, we will take a detour through the works of John Dewey[26]. At the beginning of his article "Qualitative Thought," Dewey states that "quality lies at the heart of human experience" (Eldridge 2016) and that our ways of thinking are conditioned by the world we live in, which is primarily qualitative (Dewey 1925–1953). This means that human beings and the environment are constantly in transaction, which changes them mutually. Dewey calls this transaction an "experience," a key concept of his philosophy. According to him, our experience of reality in the fullest sense[27] is not the accumulation of distinct perceptions; rather, its origin is a "situation," a dialectical event between specific physical, biological, social and cultural conditions and the physical setting. In problematic or indeterminate situations, we tend to make connections between the different experienced elements through an "experimental inquiry," and thus transform the situation into a unified whole (Dewey 1938).

Furthermore—and this is the key point for understanding quality and architectural quality from a user's perspective—Dewey argues that a "single pervasive quality" shapes our experience by creating unity (Dewey 1925–1953). This means that we do not analyse distinct sub-qualities and then combine them; on the contrary, we have an "emotion," "impression" or "hunch" of a dominating quality in an overall situation. This emotion is the basis for subsequent thought (Dewey 1925–1953). For Dewey, this unity of pervasive quality is at once emotional, practical and intellectual (Dewey 1934). In his book "The Meaning of the Body: Aesthetics of Human Understanding," Mark Johnson claims that Dewey's understanding of experience and pervasive quality is still relevant today, and that problematic situations and the grasping of qualities even serve as the basis for scientific thinking (Johnson 2007). Tucker confirms the role of feelings and emotions in all aspects of cognition based on recent developments in brain studies (Tucker 2007). At the same time, some argue

26 John Dewey (1859–1952) was an American philosopher, psychologist, Georgist and educational reformer whose ideas have been influential in education and social reform.

27 For Dewey, "an experience is one in which the material of experience is fulfilled or consummated" (Eldridge 2016). He distinguishes it from inchoate experiences, wherein we are distracted and do not complete our course of action.

that real experiences are becoming less important in our ever-expanding digital environment. However, while our everyday tools have changed dramatically, the way we interact with the world around us is the same. The topicality of Dewey's ideas has been confirmed in the past twenty years through the key notion of user experience (UX), which was developed by specialists in ergonomics of human system interactions. The ISO 9241-210 standard specifies that emotions and behaviours are the crux of user experience throughout any process. It is worth noting that the description of UX design as a process (Interaction Design Foundation 2018) is similar to Dewey's understanding of experience. While comparing the uses of a computer and a building might seem implausible, they are both complex systems (Heylighen 2010). In fact, the conceptual basis of software design is actually architectural thinking (Perry and Wolf 1992).

Pervasive quality as atmosphere

Although Dewey does not specifically consider architecture and its qualities, we can easily discern this link through his notions of "situation" and "experience," which actually describe users' interaction with the built and natural environments. In his article "From pervasive quality to situated atmospheres," Jean-Paul Thibaud argues that the "pervasive quality" defined by Dewey is the equivalent of what we call "atmosphere" (Thibaud 2004). His description of atmosphere illustrates this analogy: an atmosphere is experienced and felt as opposed to perceived or thought. Pervasive quality (or atmosphere), he continues, can be defined as "affective tone,"[28] a term that has both objective and subjective meaning (Thibaud 2004). In this sense, the way a user experiences a place is like an aesthetic experience. However, both Dewey and Thibaud specify that there is only a difference of degree, and not of nature, between the aesthetic experience of a work of art and the experience of an everyday situation. Among the many contemporary scholars who support Dewey's concept of "continuity of aesthetic experience with normal processes of living," we find the already-cited philosopher Mark Johnson, who argues that these aspects of meaning-making are all fundamentally aesthetic (Johnson 2007).

Pallasmaa also argues for the relevance of Dewey's concept of experience in architecture and the parallel between "pervasive quality" and atmosphere in his article "Space, place and atmosphere. Emotion and peripheral perception in architectural experience" (Pallasmaa 2014). Following Dewey, he states that architectural quality results not only from visual perception but from a sensorial fusion of countless factors, i.e. an atmosphere. Pallasmaa uses the work of Peter Zumthor as an outstanding example of architecture that creates atmospheres. Zumthor himself is specific: for him, architectural quality is atmosphere (Zumthor 2006). The conceptualization of atmosphere as a key element of architecture is relatively recent. The most developed contribution comes from Gernot Böhme, another

28 "Tonalité affective" in French, "Stimmung" in German: Martin Steimann thoroughly analysed the notion of Stimmung in an architectural perspective (Lucan, Marchand, and Steinmann 2003). Another relevant example is given by Sylvain Malfroy (Malfroy 2010).

of Pallasmaa's references. While Böhme does not base his thinking on Dewey, his understanding of atmosphere as the result of experience—a "mindful physical sensation" that we can describe as elation or depression, openness, entrapment, etc.—is similar (Böhme 2013).

Atmosphere and habit: a shared experience

If experience and pervasive quality depend on an individual's transaction with a physical setting (a place), we might infer that quality is purely subjective and, as such, impossible to analyse. Nevertheless, Dewey, Thibaud and Böhme again show us that atmospheres can be shared and, moreover, contribute to social relations. As we have seen, Dewey considers pervasive quality not as an end in itself but rather a basis for further analysis, thought and development, and hence a driver of future action. Thibaud also states that our body's actions are elicited by an atmosphere, as evident in our expressions: an atmosphere can stimulate or appease, captivate or bring us down, transport or paralyze us (Thibaud 2004). Though Dewey and Thibaud offer a detailed description of the emotional dimension of an experience, they do not distinguish it from the intellectual and practical realms. A meaningful experience is fundamentally linked to action in a physical setting.

Habit is the link between individual experience and social relationships, according to Dewey and Thibaud. For Dewey, habit is acquired through past experience and directs future ones (Dewey 1921). Going further, he claims that individual habits and social customs are interdependent because they are formed in a similar way (Dewey 1921). This means that we develop our behavioural habits through exposure to other actors and that, in turn, individual habits contribute to social patterns. Thibaud makes the link between Dewey's notion of habit and atmosphere. He explains that, despite the fact that different people do not experience a given atmosphere in the same way, it can nonetheless be defined as a shared experience when it is generated by a collective dynamic. A situation can be experienced as tense or relaxed, conflicting or consensual, strange or familiar (Thibaud 2004).

Atmosphere and comfort

Going further, we argue that atmosphere is not only a relevant concept for our everyday lives, but that it should be considered in conjunction with the notion of user comfort. As we have seen, Dewey's discourse focuses on the notion of pervasive quality in meaningful experiences. However, such events are quite rare, as everyday life is largely comprised of casual experiences. These "inchoate experiences," as Dewey calls them, are incomplete and express diffuse feelings (Dewey 2005). However, that does not hinder our transaction with a given environment or impact our feelings towards it. Pallasmaa argues that our interaction with a place is influenced by countless factors (Pallasmaa 2014), and that the diffuse, general ambience of a given setting determines our feelings towards it. Böhme calls these countless factors "generators of atmosphere" and divides them in three interdependent groups (Böhme 2015). In the first group he includes the configuration of materials, spatial proportions, the aging of materials, how materials relate beetween each other and to a place, rhythms, light, etc. Synesthetic[29] properties that affect several senses form the second group. The third group consists of social characteristics.

29 Sensation produced in one modality when a stimulus is applied to another modality, as when hearing a certain sound induces the visualization of a certain colour.

Exploring the notion of comfort, we find that it is similar to the notions of experience and atmosphere. For De Looze et al., who developed the De Dear and Brager thermal adaptive model (De Dear and Brager 1998), comfort is subjective; it is a reaction to an environment and is affected by physical, physiological and psychological factors (De Looze et al 2003). Vischer outlines three dimensions of comfort: physical, psychological and functional (Vischer 2004). Ortiz et al. describe the way users attempt to establish comfort. In order to find a stable state when stress appears, users either manipulate the environment or adapt their behaviour under the influence of emotions and attitudes (Ortiz et al 2017). Though we find different terms in all of these descriptions, the overall meaning is the same: our experience of the environment is subjective and our transaction with (or reaction to) physical factors generates emotions / atmospheres that have an impact on how we behave, which, in turn, is conditioned by habit. This points to the fact that comfort is ultimately a feeling, a qualitative notion, and that quantitative factors—temperature, humidity, natural and artificial light, acoustics—which are often studied separately, should be approached in a global way.

7.1.3 Design thinking: in search of quality

So far, we have discussed architectural quality from a user's perspective. We will now explore architectural design, the way architects imagine buildings by trying to bring out quality.

For a long time, designing architecture was seen as a purely creative activity without conceptualization. In the past fifty years, scientific researchers have nevertheless attempted to show "how designers design." The most accurate example of this is the concept of "design thinking." Its basis lies in the works of several researchers: Herbert Simon in the sciences (Simon 1969), Robert McKim in design engineering (McKim 1973) and Bryan Lawson in architectural design (Lawson 1980). The most significant development in this area can be found in Peter Rowe's book, "Design Thinking," (Rowe 1986) where he investigates several theoretical and practical positions to reveal an underlying structure of inquiry common to all design.

Rowe considers heuristic reasoning based on Herbert Simon's "bounded rationality," as a key element of design thinking. Heuristic reasoning is a process wherein the steps necessary for solving "wicked problems" are not known beforehand. The final decision, the solution, is made only once the line of reasoning has been completed (Rowe 1986). Rowe considers the type of problems characteristic to architectural design as "wicked problems," resuming and developing Churchman's (Churchman 1967) and Rittel's (Rittel 1972) concept. "Wicked problems" do not have a definitive formulation or an explicit basis for ending the problem-solving activity. The solutions proposed for wicked problems are not necessarily correct or incorrect (Rowe 1986). Lawson points this out that, given that problem formulation and idea generation (solution) are intertwined in heuristic reasoning (Lawson 2009).

In order to describe the architect's position as regards these "wicked problems," Rowe uses Merleau-Ponty's concept of situation (Merleau-Ponty 1962), wherein an individual is totally immersed in a problem and identifies him or herself with it in order to understand it (Rowe 1986). Rowe argues that various aspects of the design process can be considered as "problematic situations," as architects must overcome their novelty and make sense of them. During the design process, they simultaneously reflect and act (Schön 1987). The architect selects the information and explores and identifies seemingly relevant themes for a given situation. He or she thus begins with a "move" that, following development and evaluation, is partially reformulated (Schön 1987). This first "move" is essential to the process, as it expresses an idea in sketch form, a specific type of hypothesis that enables architects to give shape to their ideas and thus fulfil their main role. This iterative, incremental approach preserves and takes advantage of the ambiguous nature of the design situation (Plattner et al 2011).

Nowadays, the use of computers challenges this traditional design process. In his chapter "Intention to Artifact," Bernstein discusses the potential of Building Information Modelling (BIM) for integrating design, production and project management into a single digital workflow. In the case of "parametric design," architects, aided by computers, systematically generate formal alternatives. According to Schumacher, architects no longer manipulate forms but rather scripts[30] (Schumacher 2012). We could argue that this does not change their traditional role, as it is they who design the scripts that lead to formal operations and decide when computer-generated forms actually become architecture. Moreover, architectural design and software design are similar. Fred Brooks (Brooks 1975) suggests that the architecture of a software system reflects an overall vision, and that software architects must assume the role of "vision keeper" and preservers of "conceptual integrity." Software design is quality-driven, as put forth in the concept of user experience (ISO 9241-210 2015) mentioned earlier. The similarity between the two also lies in their use of an identical, incremental, iterative approach for dealing with the complexity of a given situation. The foundations of architectural design and software design are based on the same

30 In Digital Technology, a script is "an executable section of code that automates a task." (www.dictionary.com)

heuristic reasoning. Thus does Bernstein use Rowe's definition to show that parametric design is "generated only through the 'heuristic reasoning' of scripting" (Bernstein 2012).

To summarize the characteristics of design thinking—a problematic situation, the combination of reflection and action, an iterative approach and various media—we can conclude that design thinking is by and large qualitative.

7.1.4 Global and partial architectural qualities

What is the quality architects look for? As we saw previously with Van der Voordt and Wegen, in an attempt to solve the client's "wicked problem," architects try to design buildings that integrate functional, aesthetic, technical and economic qualities. Many architects use the term "wholeness" to describe the result of this integration (Herzog & de Meuron 2006, Zumthor 1996). What this wholeness (Johnson 1994) means and how it can be achieved is a permanent debate that has followed architectural discourse throughout its history, with terms like unity, harmony between parts, coherence, identity, character, integrity, presence and "universal" or "contingent" beauty [31]. Instead of entering this endless theoretical debate, we prefer to move forward in our understanding of the "perceptual qualities, cultural values and symbolic meanings" that comprise aesthetic qualities (Van der Voordt and Wegen 2005) by using examples of famous buildings.

Van der Voordt and Wegen use the controversial Jewish Museum in Berlin [Figure 7.2], designed by Daniel Libeskind, as an example of emphasis on symbolic meaning. The oppressive atmosphere of the Holocaust is generated by a series of architectural devices (a puzzling path, dead ends and the black ceiling) (Van der Voordt and Wegen 2005). In contrast, Costello argues that this symbolic meaning is linked to "visitors' experience as dialogic interaction" (Costello 2013). The experience is anything but comfortable, just as Libeskind intended it (Libeskind 2015). Visitors agree. Referring to the Garden of Exile [Figure 7.3] with its pillars emerging at oblique angles, Howard Jacobson says: "Nothing is as it should be here. Every perspective nauseates us. The ground won't stay still and the sky itself appears displaced" (Jacobson 2007). Combining these two perspectives confirms Dewey's idea that feeling and meaning are correlated. The spatial configurations and materiality of the Jewish Museum generate an atmosphere, in this case one of discomfort, nausea, disorientation and panic, and in this way express "the oppressive atmosphere of the Holocaust."

At the Museum Insel Hombroich [Figures 7.4, 7.5] in Neuss, Germany, the combination of art, architecture and nature is designed to enhance the visitor's experience. Sculptor Erwin Heerich and landscape architect Bernhard Korte created a series of pavilions and landscapes that form an unusual setting for art exhibition. The

31 In November 2014, the British Royal Academy held a debate on the question "Is beauty an essential consideration in architecture?" https://www.royalacademy.org.uk/article/debate-is-beauty-an-essential-consideration-in-architecture. This debate was held in a way that echoes the 17th century "Quarrel of the Ancients and the Moderns."

Fig. 7.2 Jewish Museum Berlin: the openings of the zinc-clad facade evoke a body full of scars

Fig. 7.3 The Garden of Exile, with its pillars emerging at oblique angles, creates a sensation of nausea

Fig. 7.4 Museum Insel Hombroich: A framed natural landscape seen from inside

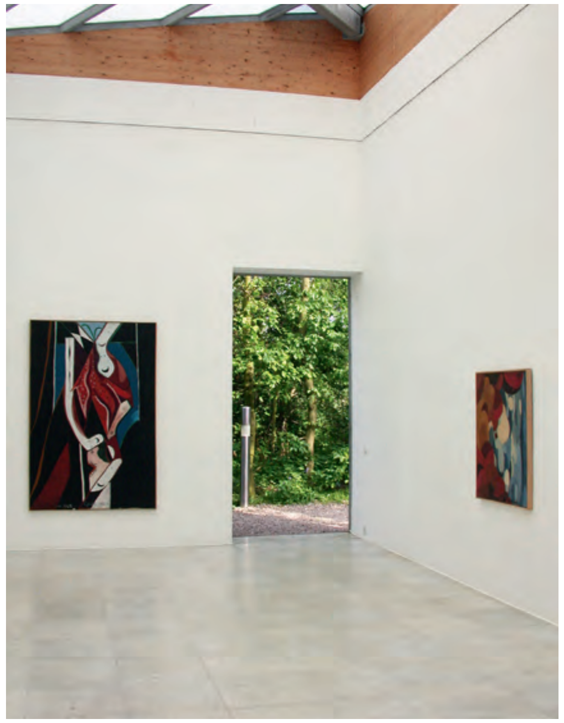

Fig. 7.5 Museum Insel Hombroich: The works of art are exhibited without any information

Fig. 7.6 Bruder Klaus Field Chapel: Traces of burned trunks used to cast the reinforced concrete walls

Fig. 7.7 Bruder Klaus Field Chapel: A monolith that dominates the landscape

Fig. 7.8 The Barcelona Pavilion: Absence of use that leaves the pavilion open to interpretation

outdoor climate pervades the interior of the door-less pavilions, without air conditioning or artificial light. Visitors experience the works in a direct way, as they are exhibited without title or author to emphasize the experience of the work itself.

Presence is the global quality that Peter Zumthor also seeks. For him, a building should "not represent anything, just being" (Zumthor 2010) and thus elicit feelings through its spaces and materiality. The Bruder Klaus Field Chapel Figures 7.6, 7.7 he designed on a farm near Wachendorf in Germany is a compelling example. With its open roof and lack of plumbing, bathroom, running water or electricity, visitors are exposed to natural elements, which heightens the experience of the interior atmosphere. Zumthor says that despite his attempts to avoid "premature meaning" during the design process, meaning, ultimately, is unavoidable (Zumthor 2013). This might very well be the case, for the Bruder Klaus Field Chapel is a monolith that sits on the edge of a field, or, as Simon Unwin argues, "the erect monolith stands at the origins of architecture" (Unwin 2016). It is an archetype that can have many meanings—marking a place, indicating an alignment with some cosmic event, dominating a landscape, embodying the power of a religious creed, partaking in a picturesque composition or evoking stories about distant pasts and peoples (Unwin 2016). Intentionally or unintentionally, Zumthor's Chapel might convey some of these meanings[32].

32 Unwin gives several 20th- and 21st-century examples of architecture that "allude[d] to the standing stone and employ[ed] its timeless architectural powers" and shows that they are mainly in relation to religion.

Historians and architecture critics play a major role in giving meaning to architecture. Looking at one of the most analysed and debated works in architecture, the Barcelona Pavilion Figure 7.8 designed by Mies van der Rohe, the many interpretations and theories "explain less about what Mies made than they do about what others have made of his making" (Dodds 2005). Their analysis is anything but neutral, as Godber shows by using two opposing interpretations (Godber 1998). While Giedion sees it as "standing quiet but firm in its enlightened modernity, as night descended around it" (Giedion 1954), José Quetglas considers the pavilion's "useless, silent, marmoreal vacant qualities" as premonitory of Prussian militarism. Giedion and Quetglas' words illustrate that, in this case as well, meaning comes after feeling (Quetglas 1988).

These examples allow us to conclude that architecture is nothing other than the global quality of a building. Paradoxically or not, architecture is an adjective. However, a building must also have what we can call "partial qualities" such as stability, health, security, accessibility, energy efficiency, fire safety, an outdoor view, etc. These qualities, which concern all users, are expressed in standards and norms and are, as such, a mandatory part of building design.

We find similarities when we compare an architect's position relative to a building's architectural quality and to that of its users. The "pervasive quality" of a building or a place felt by users is global, as is the architectural quality the architect aims to create. Both are the result of similar processes, as both users and architects face problematic situations to which they attempt to ascribe meaning and, thus, live an experience. Users' experiences take place in a physical setting that they feel as a whole, while the architect's experience reflects his or her total immersion in the subject, framework and means. John Dewey already made this parallel between the user's position versus that of the architect. For him, the perceiver's activities are comparable to those of the creator (Leddy 2016). We can better understand this relationship if we consider the link between Dewey's key concepts (experience, situation and pervasive quality) and those of architectural theorists. Rowe's description of design thinking is based on Herbert Simon's heuristics, which draws on Dewey's pragmatic tradition (Barone et al 1997) and Merleau-Ponty's notions of "experience" and "situation" (likewise borrowed from Dewey) (Gibson 2016). In the late twentieth century, Jonathan Hill clearly expressed the same understanding. For him, architecture is produced by the architect through design, and by users through inhabitation and use. Hence, even users play a creative role (Hill 1998). This may explain Pallasmaa's observation that even buildings that are not designed by an architect can provoke "a sensorially rich and pleasant atmosphere," (Pallasmaa 2014). It is users' inhabitation that turns a "specific materiality, scale, rhythm, colour or formal theme with variations" into an atmosphere Figure 7.9.

Taking into account the previous reasoning, we can conclude that architectural quality—like emotion—is context-sensitive, plural (relative to the many individuals who experience it), both global (the building as a whole) and local (the spaces that comprise the building), processual (linked to the daily interaction of users and places) and a continuum between positive (quality, in common language) and negative (unacceptable constraints) extremes.

7.2 In search of an agreement

Architects and users are not the only actors who make architecture. The realization of a building always entails a series of phases involving different stakeholders: a client formulates a brief outlining the qualitative and quantitative requirements. Based on this, designers (architects, engineers and other specialists) create a concept and schematic design that (for public buildings) is then submitted for competition. Architects then must develop all the constructive aspects that one or several construction companies will build, and that users will then occupy. Sometimes, a building's life cycle continues with its transformation. In other cases, its life ends with its demolition and possible recycling or reuse of some of its parts. This generic description of the architectural process highlights its key phases: a brief that establishes the objectives and criteria for evaluation, several actors/stakeholders performing various tasks using their own methods, means/tools and a schedule of activities.

Fig. 7.9 Users appropriating a public space to create a popular atmosphere in the Vallon neighbourhood, Lausanne

7.2.1 The building realization process

In most countries, the building realization process is regulated by a procedural framework that is strongly influenced by specific laws and practices. For example, comparing building procedures in the United Kingdom[33] and Switzerland[34], we can distinguish five similar phases:

1) Exploration
2) Programme and requirements
3) Design
4) Commissioning and construction
5) Use and management

However, what none of these procedures takes into account is how the various actors behave during this process, or how each one's role is goal-oriented according to their appraisal of the situation (Wilson and Shpall 2016). Frankfurt mentions that actors identify themselves with a desire while performing (Frankfurt 1998). This desire can be intentional, goal-oriented or subconscious, which leads us to the concept of agency. Agency is an actor's capacity to act in a given environment. For Doucet and Cupers, transposing the concept of agency to architecture raises a number of important questions (Doucet and Cupers 2009), for instance, how many agents should we take into account? How do they operate? Most importantly, why and with what purpose do agents perform their tasks? As we saw earlier, a building's qualities seem to be the obvious, generic answer to the last question. In this respect, Biau and Lautier underline that working with "quality actors" during the realization process is a prerequisite for architectural quality, and that actors' interactions are decisive to the quality of the result (Biau and Lautier 2009).

To emphasize the roles of actors, Tombesi organizes the workflow based on the output of each work stage (Tombesi 2012). He links each of these outputs with an actor, user, client, professional, builder or manufacturer, highlighting the importance of iteration during certain stages, which reflects how actors collaborate. Tombesi claims that design can not only provide answer to a given problem, but can also help in formulating "ways to organize the necessary means to achieve such a solution" (Tombesi 2012). Tombesi therefore proposes an analytical framework that shows the "multi-faceted, socially heterogeneous nature of design in buildings" (Tombesi 2012). This framework specifies several groups of categories that must be determined[35] and that define "a system of design production" (Tombesi 2012). Further on, he argues that, based on this framework, the design should and can be treated as a "complex network of sub-domains, specialized design contributions as well as negotiated practices" (Tombesi 2012). Here, he raises a critical question: "Who should design the project (and not simply the building)?" Without answering it directly, he suggests that use of digital infrastructures could be one way to design projects (Tombesi 2012).

33 RIBA Plan 2013 and the Generic Design and Construction Process Protocol Model, BIM Enabled MEP Coordination Process, IDP: Integrated design process.

34 SIA, KBOB/IPB Standard.

35 The groups of categories Tombesi proposes are:
1. Project definition and control: procurement, operations and coalition
2. Building opportunity generation: goals, stakeholders and resources
3. Building scope formulation: programme, spatial/visual, performance and specification
4. Building manufacturing: materials/systems, tectonics and fabrication
5. Building erection: testing, assembly and site
6. Building use and maintenance: use, maintenance and change

While these arguments in favour of a comprehensive design approach of the construction process are compelling, their transfer to practice is problematic. In reality, the construction process is an ad-hoc effort that involves public and private actors. The latter are obliged to respect the legal framework that defines their rights and obligations but not the way they interact, which is based on culturally- established common models. It is therefore difficult to imagine them engaging in a design process in which their roles are questioned and redefined. First and foremost, this would entail understanding the meaning of design in general and the design process more specifically. However, as we have seen, these complex concepts require at the very least basic architectural knowledge that most actors do not have. The implementation of a theoretically-based design process must bridge the gap between scientific knowledge and practice—in other words, a long-term objective.

7.2.2 Builders' and architects' analogue positions

In his somewhat older but nonetheless relevant book, Epron stresses that the act of building cannot be an ideal process, as it is always the result of a "circumstantial and non-systematic encounter between heterogeneous elements belonging to five domains" (Epron 1981): the architectural doctrine, the architectural institutions to which the professionals involved belong, the economy and/or political structure, the technical aspects of the building process (objects, elements and procedures) and the education system.

After thoroughly analysing historical building processes, Epron identifies their characteristic features, which are similar to those of design thinking discussed above. As building activity is "situated," the builder must define the problem to be solved, as "the terms of constructive problems are not given" (Epron 1981). Consequently, Epron defines building activity as "the art of formulating problems" and considers technical problems as "the mediation by which building activity is related to its conditions" (Epron 1981). As the characteristics of a given context do not emerge in an objective way, the builder must begin by formulating a hypothesis and choosing methods. To formulate this hypothesis, the builder, like the designer, must refer to his or her knowledge of construction and construction processes, which provides him or her with a set of solutions. Construction activities usually involve several builders whose positions differ depending on their role, the task at hand and the course of their actions. As such, these positions are inevitably "conflicting" (Epron 1981).

The building process is a place for discussion of these conflicting positions. During these discussions, the builder tries to either maintain conditions that favour his or her position, or change them in order to gain an advantage (Epron 1981). Tense on-site discussions between architects and builders is but one obvious example. This helps us in understanding why the building process cannot be completely rationalized and should instead be understood as "a patient or authoritarian search for an agreement between the participants" (Epron 1981). Epron's main point here is that the actors are less united by respect of legal norms and standards than by their adherence to a social norm, what Epron calls "rule." Bicchieri offers a new argument in favour of Epron's understanding by showing that social norms do not result from planning but rather from unforeseen interactions between individuals (Bicchieri 2014). He points out that the creation of social norms is a learning process through which actors "internalize the common values embodied in the norms." The potential conflict between individual desires and collective goals can be resolved only if they succeed in establishing a common value system (Wilson and Shpall 2016) through cooperation.

This means that conflict between actors' values and interests occurs within both the design and building processes, and that the decisions made are the outcome of this conflict. The design and building processes mediate divergent interests, and the debates to which they give rise actually have to do with how each understands architectural quality. The building owner (the client) also plays a decisive role in this debate. The client, as Biau and Lautier show, seeks the "quality of the thing sold" (Biau and Lautier 2009) in conjunction with the needs and desires of its users. For the owner, architectural quality is a combination of price, uses, technical quality and comfort. As we have seen, architects also search for a compromise between the client's requirements and their own way of understanding and approaching architectural quality.

7.3 Collaboration for shared qualities

In this final subchapter, we will compare the reasoning and conclusions discussed previously in light of the SLB case in order to identify critical issues and to make recommendations for addressing them.

Generally speaking, the fact that different actors have different perceptions of architectural qualities combined with the desired innovative, experimental nature of the SLB supports the hypothesis presented in the introduction: the need for its realization to be an open process. Consistency can only be guaranteed when actors and stakeholders engage in a learning process and share their points of view.

7.3.1 The involvement of actors

Actors' and stakeholders' involvement in this kind of iterative approach affords them the opportunity to find optimal solutions through the mediation of their different or even divergent interests. Involving users in the design process is an almost commonplace procedure in urban planning in Switzerland. However, the former are seldom involved in the architectural design process. As the other chapters of this book demonstrate, the *smart living lab* building is exemplary in this sense. Surveys on users' preferences and levels of satisfaction regarding working conditions in the Blue Hall, the "user environment" experiment and the involvement of researchers and laboratory directors in defining the vision for the building are examples of user involvement in preparation for the future design brief. The involvement of the *smart living lab* researchers throughout the entire process was essential for several reasons. To begin, they were able to take part in the materialization of their vision. It also gave them an opportunity to offer their expertise in various domains. Finally, as future users, they helped to define their preferred atmospheres.

First critical issue: the gap between the atmosphere proposed by designers and what users actually experience

This first issue is critical in the sense that there is always a gap between the atmosphere proposed by designers and what users actually experience. The interior perspectives, which are usually drawn in the preliminary design stage, offer only partial information regarding the future setting and lack both the effects of environmental factors (light, temperature, ventilation, noise, etc.) and social interactions, which are key factors for generating atmospheres.

As we saw, actors' adherence to social norms is necessary for reaching an agreement. For example, involving construction companies at an early stage could allow the builder to enter into the negotiations. The "Alliance Contracts in Australia" is an example of one such attempt to create a legal consensus between actors to align commercial interests with project outcomes (Noble 2010).

7.3.2 Initial stage

By looking at several cases[36], we learned that most important decisions are made in the initial stages. As we saw earlier, the definition of the "wicked problem" sets the tone for the rest of the process. This corresponds to the formulation of the preliminary design brief, which establishes the objectives and the programme. For the SLB, the objectives were expressed in the aforementioned "Vision of the *smart living lab* building." However, they are ambiguous in nature and open to interpretation. Moreover, they are not easily understood by designers because of the inherent complexity of academic language.

36 Case studies: Blue Hall in Fribourg, NEXT 21 Complex project in Osaka City (Japan), Research Center ICTA-ICP · UAB and Media-ICT building CZFB in Barcelona, Sino-Italian Ecological and Energy Efficient Building, Tsinghua University, Europa Building in Brussels and NEST in Dübendorf.

Second critical issue: translation of the vision into operational objectives

The second critical issue is translating the vision into operational goals. The brief should be generic in order to give designers ample room to interpret the problematic situation and, at the same time, formulate innovative solutions. In light of the previous discussion, we would like to suggest that the objectives expressed in the Vision could be divided into four simple groups of qualities linked to use, experimentation, environmental performance and context. However, approaching them globally, which is necessary for reaching the main objective, i.e. the sought-after architectural quality, raises design issues. Environmental performance objectives, for instance, are specific relative to other performance objectives because of their quantitative nature: "The building will have to reach the objectives of the SIA Energy Efficiency Path guidelines (SIA 2040)." Their inclusion in the preliminary design brief might be problematic because the evaluation of these objectives depends on a high level of architectural detail that is not available in the preliminary design. We recommend translating them into qualitative requirements, which must be integrated into an environmental concept and correlated with the overall architectural concept. The legal obligation to respect comfort norms—which is part of the usability objectives category—is problematic in the case of the SLB. The norms consider an "average" user and ignore the subjective nature of comfort and its link with atmosphere described above. The study of comfort in office environments in correlation with energy consumption is currently one of the research themes of the *smart living lab*. Again we encounter the paradox presented in the introduction: the fact that the SLB is intended to embody qualities that require entirely new know-how.

Third critical issue: programme definition

Defining a programme is the problematic third critical issue. The *smart living lab*, the research centre that will occupy the building, is not a homogenous entity but rather a horizontal union of researchers from three institutions. Although currently operating in a temporary building[37], the *smart living lab* is a young academic consortium whose collaboration has only just begun. As such, it is still not clear how the researchers from various institutions and laboratories will work together, nor where the various research groups wish to be located. If they have separate spaces, how and where will they exchange ideas? Most importantly, how do they understand the *smart living lab* and its building? We propose that the programme be defined in a generic way so as to give the designers the freedom to interpret the given problematic situation and formulate innovative solutions accordingly. User involvement in the preliminary design stage could provide the necessary feedback for this.

37 Since 2015, the Blue Hall, which is located in the blueFACTORY site, next to its future location, has been home to the *smart living lab.*

7.3.3 Preliminary design stage

All of the previous considerations led to the idea of defining an iterative brief that would allow for a gradual attunement of users' requirements and designers' responses. However, the legal procedure is usually sequential, which as such does not favour an iterative approach. As the SLB is a publicly-funded building, its design stage must respect the rules of public markets. In other words, the preliminary design must be chosen by open competition, which makes involving actors in the co-construction of the design impossible.

Fourth critical issue: type of procedure

This raises a fourth critical issue: that of implementing a procedure that facilitates collaboration between users, stakeholders, designers and experts. For this, we suggest transposing the "Parallel Studies Commission" model (in French "Mandat d'études parallèles – MEP"). An approach often used in Switzerland for urban design competitions, MEP are useful in projects that require a direct dialogue between an expert panel and participants, as in the SLB case. However, even in this case, the decision is ultimately made by an independent jury.

Fifth critical issue: jury selection

The fifth critical issue is the jury selection. The jury should be selected based on the SLB's objectives. In other words, its members should have skills in the areas of use, experimentation, energy efficiency and architecture. At this point it is important to come back to the actors'—in this case, the jury members'—subjective view of architectural quality; this means that the organizers of the MEP must clearly present their intentions to the jury members to allow for a comprehensive understanding of the SLB case.

Sixth critical issue: decision-making procedure

The sixth critical issue is how the jury makes its decision. Based on the interpretation of architectural quality presented here, the evaluation process cannot depend on an "averaging" of partial qualities (i.e. checklist), as some might give rise to contradictory situations. For example, concerning the experimental aspect, the vision states that the building "should be designed for incremental growth and redefinition of use." Hence, the designers must provide technical and construction solutions that will allow for this type of transformation. However, transforming part of a building is likely to affect users' typical behaviour and comfort. Consequently, adequately assessing the situation should take the form of a critical debate between jury members that considers both the qualities desired for the SLB and the jury members' points of view (Hanrot 2005). Their decision at the end of the preliminary design stage is critical.

Seventh critical issue: targeting architectural and life cycle environmental qualities

One particular aspect of the SLB project is linked to the goal of creating a building that has both architectural and lifecycle environmental qualities. This is a seventh critical issue, as buildings that are environmentally performant tend to lack architectural qual-

Fig. 7.10 A clinical atmosphere reigns in the offices of the 2226 Building

ities and lead to user discomfort (Ortiz et al 2017). One of the main reasons for this is the idea that environmental performance is merely a technical issue, which leads to myriad high-tech devices and systems and ultimately stereotypical solutions imposed by various standards and labels. However, as we have already seen with Epron, the technical problem is not an objective one, as the act of building is always circumstantial and depends on a specific context and the available resources. Complying with the requirements of a "green" label is not enough to create sustainable architecture if the building is not conceived of as a whole, in other words, if environmental objectives are not considered relative to other objectives. The fact that the architectural concept is often developed prior to the environmental concept is another reason buildings often lack both architectural and environmental qualities.

Eighth critical issue: lack of collaboration between architects and engineers

The eighth critical issue is usually a result of architects' and engineers' failure to collaborate during the design process. We can resume this long-debated issue by highlighting the fact that their approaches and thinking as regards design differ greatly. Architects have an incremental, iterative approach that focuses on qualitative aspects, whereas engineers solve "well-defined" problems that generally target a building's quantitative aspects. Of course, architects work on quantitative aspects as well. By defining a building's spaces, they position and dimension its material elements (structure, partitions, envelope, equipment, etc.). In reality, there is an intrinsic connection between qualitative and quantitative architectural elements, as Bordron argues is the case for the relationship between quality and quantity in general (Bordron 2011). This means that environmental engineers should also work on qualitative aspects and, most importantly, that the architectural and environmental concepts should be developed simultaneously. The collaboration between Jürgen Stoppel and Lars Junghans (Baumschlager Eberle Architekten) in the initial stage of the design process for the "2226" building Figure 7.10 in Lustenau, Austria, is a notable example of this. This passive building—which has neither a heating nor a cooling or ventilation system—uses the thermal inertia of its thick walls made of efficient bricks (Baumschlager Eberle 2017).

As mentioned at the beginning of the chapter, the discussions regarding architectural quality and the building realization process cannot and do not provide definitive answers. For better or for worse, real architectural processes are open to unforeseen events. Instead, these discussions offer a framework and a set of questions that, in the case of the *smart living lab*'s future building, will hopefully improve a shared understanding and facilitate collaboration between the actors involved. How can we ensure collaboration? How can we implement a legal procedure to facilitate it? How can we create shared qualities? How can we involve designers and important decision makers in this adventure? How will designers and other actors materialize the SLB vision into an actual building with architectural qualities and atmospheres that will stimulate interdisciplinary exchanges between researchers? How will architects and engineers work together to develop coherent architectural and environmental concepts? How to involve all of the stakeholders throughout the entire process? These are the challenges designers, decision makers and users will face from this point on. Ultimately, an optimistic interpretation of the Babel tower metaphor hinges on collaboration that itself depends on creating trust and mutual respect between actors. This is not so much a scientific challenge as a human and social one that is rarely met in practice.

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References

Baumschlager Eberle Architekten. 2013. "2226 / Baumschlager Eberle Architekten." ArchDaily. November 26, 2013. http://www.archdaily.com/451653/2226-be-baumschlager-eberle/.
Jessica Mairs. 2015. "Architecture Should Not Be Comforting Says Daniel Libeskind." Dezeen. November 19, 2015. https://www.dezeen.com/2015/11/19/ daniel-libeskind-architecture-should-not-be-comforting-memorials-ground-zero-masterplan-jewish-museum-berlin/.
Gili Merin. 2013. "Peter Zumthor: Seven Personal Observations on Presence In Architecture." ArchDaily. December 3, 2013. http://www.archdaily.com/452513/peter-zumthor-seven-personal-observations-on-presence-in-architecture/.
The Interaction Design Foundation. Accessed December 6, 2018. "What Is User Experience (UX) Design?" https://www.interaction-design.org/literature/topics/ux-design.
Barone, David F., James E. Maddux, and Charles R. Snyder. 1997. "Social Cognitive Psychology." The Plenum Series in Social/Clinical Psychology. Boston, MA: Springer US. https://doi.org/10.1007/978-1-4615-5843-9.
Bernstein, Phil. 2012. "Digital Workflows in Architecture: Design–Assembly–Industry." Edited by Scott Marble. Vol. Intention to Artifact. Birkhäuser Basel.
Biau, Véronique, François Lautier, Réseau activités et métiers de l'architecture et de l'urbanisme, Plan urbanisme construction architecture (France), and Architecture et maîtres d'ouvrage (Association), eds. 2009. "La qualité architecturale: acteurs et enjeux." 1re éd. *Cahiers Ramau* 5. Paris: RAMAU, Réseau activités et métiers de l'architecture et de l'urbanisme: Editions de la Villette.
Bicchieri, Cristina, and Ryan Muldoon. 2014. "Social Norms." In *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta, Spring 2014. Metaphysics Research Lab, Stanford University.https://plato.stanford.edu/archives/spr2014/entries/social-norms/.
Böhme, Gernot. 2015. "Constructing Atmospheres: Test-Sites for an Aesthetics of Joy." Edited by Margit Brünner. Vol. Atmosphere as an Aesthetic Concept. AADR – Art, Architecture, Design Research. Baunach: Spurbuchverl.
Böhme, Gernot. 2013. "Atmosphere as Mindful Physical Presence in Space – PDF." Accessed June 19, 2018. http://docplayer.nl/23311131-Atmosphere-as-mindful-physical-presence-in-space.html.
Bordron, Jean-François. 2011. "Trois ordres de la valeur selon la qualité, la quantité et la relation." *Semen. Revue de sémio-linguistique des textes et discours*, no. 32 (October): 35–52.
Brooks, Frederik. 1975. "The Mythical Man-Month" Reading, Mass: Addison Wesley. *Essays on Software Engineering.*
Cargile, J. 2005. "The Oxford Companion to Philosophy." Edited by Ted Honderich. 2nd ed. Vol. Qualities. Oxford; New York: Oxford University Press.
Chevrier, Jean-François. 2006. "Ornament, Structure, Space [A conversation with Jacques Herzog]". Herzog & de Meuron 2002–2006, El Croquis, no. 129 / 130, p. 33.
Churchman, C. West. 1967. Guest Editorial: Wicked Problems. JSTOR.
Costello, Lisa A. 2013. "Performative Memory: Form and Content in the Jewish Museum Berlin." *Liminalities: A Journal of Performance Studies* 9 (4): 9–4.
De Dear, Richard, and Gail Schiller Brager. 1998. "Developing an Adaptive Model of Thermal Comfort and Preference."
De Looze, Michiel P., Lottie F. M. Kuijt-Evers, and Jaap Van Dieen. 2003. "Sitting Comfort and Discomfort and the Relationships with Objective Measures." *Ergonomics* 46 (10): 985–997.
Dewey, John. 1938. "Logic: The Theory of Inquiry." Holt, Rinehart and Winston, New York.
Dewey, John. 1925–1953. "The Later Works". Ed. J. A. Boydston, 17 vol., Carbondale and Edwardsville, Southern Illinois University Press, 1981–1990.
Dewey, John. 2005. "Art as Experience." Penguin.
Dewey, John. 2007 (first edition 1921). "Human Nature and Conduct: An Introduction to Social Psychology." *Cosimo Classics Philosophy*. Kindle edition.
DIS, ISO. 2009. "9241-210: 2010. Ergonomics of Human System Interaction-Part 210: Human-Centred Design for Interactive Systems." International Standardization Organization (ISO). Switzerland.
Dodds, George. 2005. "Building Desire: On the Barcelona Pavilion." Routledge.
Doucet, Isabelle, and Kenny Cupers. 2009. "Agency in Architecture: Reframing Criticality in Theory and Practice." *Footprint,* 1–6.
Epron, Jean-Pierre. 1981. "L'architecture et la règle: essai d'une théorie des doctrines architecturales." Vol. 15. Editions Mardaga.
Frankfurt, Harry G. 1988. "The Importance of What We Care about: Philosophical Essays." Cambridge University Press.
Gibson, Grant Wellington. 2016. "Experience, Education and Subjectivity: A Comparison of John Dewey's and Maurice Merleau-Ponty's Conceptions of Experience and Their Implications for Education." PhD Thesis.
Giedion, Sigfried. 2008. "Space, Time and Architecture: The Growth of a New Tradition." Harvard University Press.
Godber, Ben. 1998. "The Knowing and Subverting Reader." *Occupying Architecture. London: Routledge.*
Hanrot, Stéphane. 2009. "La qualité architecturale. Acteurs et enjeux." Edited by Véronique Biau and François Lautier. Paris, Éditions de La Villette.
Heylighen, Ann. 2000. "In Case of Architectural Design. Critique and Praise of Case-Based Design in Architecture."
Hill, Jonathan. 2005. "Occupying Architecture: Between the Architect and the User." Routledge.
Jacobson, Howard. 2007. "Great Modern Buildings: Howard Jacobson on the Jewish Museum, Berlin." *The Guardian,* October 11, 2007, sec. Art and design. https://www.theguardian.com/artanddesign/2007/oct/11/architecture.berlin.
Johnson, Mark. 2005. "Dewey's Zen: The 'Oh' of Wonder" n.d. Accessed December 6, 2018. http://www.philosophy.uncc.edu/mleldrid/SAAP/USC/DP17.html.
Johnson, Mark. 2008. "The Meaning of the Body: Aesthetics of Human Understanding." Paperback edition. Chicago London: The University of Chicago Press.
Johnson, Paul-Alan. 1994. "The Theory of Architecture: Concepts Themes & Practices." John Wiley & Sons.
Lawson, Bryan, and Kees Dorst. 2009. "Design Expertise" *(Vol. 31).* Architectural Press, Oxford, UK.
Lawson, Bryan. 1980. "How Designers Think." *Westfield, NJ: Eastview Editions.* Inc.
Leddy, Tom. 2006. "Dewey's Aesthetics." September. https://plato.stanford.edu/archives/win2016/entries/dewey-aesthetics/.
Lucan, Jacques, Bruno Marchand, and Martin Steinmann. 2003. "Matière 6: Actualité de la critique architecturale." Presses polytechniques et universitaires romandes. https://infoscience.epfl.ch/record/85685.
McKim, Robert H. 1972. "Experiences in Visual Thinking." Monterey, Calif: Brooks/Cole Pub. Co.
Malfroy, Sylvain. 2010. "Atmosphère." Faces n° 67.
Merleau-Ponty, Maurice. 1962. *"Phenomenology of Perception" [Phénoménologie de la perception].* Routledge & Kegan Paul.
Nobel, B. 2010. "Alliance Contracts in Australia." *Mainroads Western Australia* 4.
Ortiz, Marco A., Stanley R. Kurvers, and Philomena M. Bluyssen. 2017. "A Review of Comfort, Health, and Energy Use: Understanding Daily Energy Use and Wellbeing for the Development of a New Approach to Study Comfort." *Energy and Buildings* 152: 323–335.
Pallasmaa, Juhani. 2014. "Space, Place and Atmosphere. Emotion and Peripherical Perception in Architectural Experience." *Lebenswelt. Aesthetics and Philosophy of Experience.*, no. 4.
Perry, Dewayne E., and Alexander L. Wolf. 1992. "Foundations for the Study of Software Architecture." *ACM SIGSOFT Software Engineering Notes* 17 (4): 40–52.
Plattner, Hasso, Christoph Meinel, and Larry Leifer, eds. 2011. "Design Thinking: Under-

stand – Improve – Apply." *Understanding Innovation.* Berlin: Springer.
Quetglas, Jose. 1988. "Fear of Glass: The Barcelona Pavilion" in: *Architecture Production, Colomina, B. and Ockman, J.* New York, NY, Princeton Architectural Press.
Rittel. 1984. "Second Generation Design Methods | Design Methods | Cost–Benefit Analysis." n.d. Scribd. Accessed December 7, 2018. https://www.scribd.com/document/223709722/Rittel-1984-Second-Generation-Design-Methods.
Rowe, Peter G. 1994. "Design Thinking." 5th print. Cambridge, Mass. London: MIT Press.
Schon, Donald A., and Vincent DeSanctis. 1986. "The Reflective Practitioner: How Professionals Think in Action." Taylor & Francis.
Schumacher, Patrik. 2012. "On Parametricism: A Dialogue between Neil Leach and Patrik Schumacher." *Time+ Architecture* 5.
Simon, Herbert A. 1969. "The Sciences of the Artificial MIT Press." Cambridge, MA.
Thibaud, Jean-Paul. 2004. "De la qualité diffuse aux ambiances situées." *Raisons Pratiques*, no. 14: pp–227.
Tombesi, Paolo. 2012. "What Do We Mean by Building Design?" *Digital Workflows in Architecture: Designing Design – Designing Assembly – Designing Industry.* Edited by Scott Marble. Vol. Basel: Birkhäuser.
Tucker, Don M. 2007. "Mind from Body: Experience from Neural Structure." Oxford University Press.
Unwin, Simon. 2016. "The Ten Most Influential Buildings in History: Architecture's Archetypes." Routledge.
Vischer, Jacqueline C. 2003. "Designing the Work Environment for Worker Health and Productivity." In *Proceedings of the 3rd International Conference on Design and Health,* 85–93.
Voordt, Dorotheus Johannes Maria van der, Theo J. M. van der Voordt, and Herman B. R. Wegen. 2005. "Architecture in Use: An Introduction to the Programming, Design and Evaluation of Buildings." Routledge.
Wilson, George, and Samuel Shpall. 2016. "Action." In *The Stanford Encyclopedia of Philosophy,* edited by Edward N. Zalta, Winter 2016. Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/win2016/entries/action/.
Zumthor, Peter. 1996. "Thermal Bath at Vals." Architectural Association.
Zumthor, Peter, Maureen Oberli-Turner, Catherine Schelbert, and Hélène Binet. 2006. "Thinking Architecture." Vol. 113. Boston: Birkhäuser.
Zumthor, Peter. 2006. "Atmospheres: Architectural Environments – Surrounding Objects." Basel: Birkhäuser.

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Fig. 2.1 Poncety, Amélie, Arianna Brambilla, Endrit Hoxha, Didier Vuarnoz, Stefano Cozza, Vanda Costa Grisel, Cédric Liardet, and Thomas Jusselme. 2016. "Graphical Representation of the Smart Living Building Research Program." Gruyères, Switzerland.
Fig. 2.2 Jusselme, Thomas, Arianna Brambilla, Endrit Hoxha, Yingying Jiang, Didier Vuarnoz, and Stefano Cozza. 2015. "Building 2050 – State-of-the-Arts and Preliminary Guidelines." EPFL, Fribourg.
Fig. 2.3–2.4 Poncety, Amélie, Arianna Brambilla, Endrit Hoxha, Didier Vuarnoz, Stefano Cozza, Vanda Costa Grisel, Cédric Liardet, and Thomas Jusselme. 2016. "Graphical Representation of the Smart Living Building Research Program." Gruyères, Switzerland.
Fig. 2.5 Jusselme, Thomas, Arianna Brambilla, Endrit Hoxha, Yingying Jiang, Didier Vuarnoz, and Stefano Cozza. 2015. "Building 2050 – State-of-the-Arts and Preliminary Guidelines." EPFL, Fribourg.
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Fig. 4.1 Poncety, Amélie, Arianna Brambilla, Endrit Hoxha, Didier Vuarnoz, Stefano Cozza, Vanda Costa Grisel, Cédric Liardet, and Thomas Jusselme. 2016. "Graphical Representation of the Smart Living Building Research Program." Gruyères, Switzerland.
Fig. 4.2 Cédric Liardet, Building2050, EPFL.
Fig. 4.3 Corinne Cuendet, Lutz Architectes.
Fig. 4.4 Dominic Villeneuve, LASUR, EPFL.
Fig. 4.5 Cédric Liardet, Building2050, EPFL.
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Fig. 4.14 Endrit Hoxha, Building2050, EPFL.
Fig. 4.15–4.16 Derek Christie, LASUR, EPFL.
Fig. 4.17 Dominic Villeneuve, LASUR, EPFL.
Fig. 4.18–4.19 Hoxha, Endrit, Cédric Liardet, and Thomas Jusselme. 2018. "Measuring the Effect of Office Densification on the Energy and Carbon Lifecycle Performance."

Fig. 5.1 Jusselme, Thomas, Arianna Brambilla, Endrit Hoxha, Yingying Jiang, Didier Vuarnoz, and Stefano Cozza. 2015. "Building 2050 – State-of-the-Arts and Preliminary Guidelines." EPFL, Fribourg.
Fig. 5.2 SCBI, U. 2006. "Sustainable Building and Construction Initiative: Information Note." Paris, France *DTIE*.
Fig. 5.3 Barbara Haemmig de Preux / TERRABLOC.
Fig. 5.4 Arianna Brambilla, Building2050, EPFL.
Fig. 5.5 Amélie Poncéty, Building2050, EPFL.
Fig. 5.6–5.8 (left) Arianna Brambilla, Building2050, EPFL.
Fig. 5.8 (right) Brambilla, Arianna, and Thomas Jusselme. 2017. "Preventing Overheating in Offices through Thermal Inertial Properties of Compressed Earth Bricks: A Study on a Real Scale Prototype." *Energy and Buildings* 156 (December): 281–92. https://doi.org/10.1016/j.enbuild. 2017.09.070.
Fig. 5.9 Brambilla, Arianna, Jérôme Bonvin, Flourentzos Flourentzou, and Thomas Jusselme. 2018a. "Life Cycle Efficiency Ratio: A New Performance Indicator for a Life Cycle Driven Approach to Evaluate the Potential of Ventilative Cooling and Thermal Inertia." *Energy and Buildings* 163 (March): 22–33. https://doi.org/10.1016/j.enbuild.2017.12.010.
Fig. 5.10 Brambilla, Arianna, Jérôme Bonvin, Flourentzos Flourentzou, and Thomas Jusselme. 2018a. "Life Cycle Efficiency Ratio: A New Performance Indicator for a Life Cycle Driven Approach to Evaluate the Potential of Ventilative Cooling and Thermal Inertia." *Energy and Buildings* 163 (March): 22–33. https://doi.org/10.1016/j.enbuild.2017.12.010.
Fig. 5.11 Brambilla, Arianna, Jérôme Bonvin, Flourentzos Flourentzou, Thomas Jusselme. 2018b. "On the influence of thermal mass and natural ventilation on the overheating risk in offices." *Buildings* 8(4); 47.
Fig. 5.12–5.16 Brambilla, Arianna, and Thomas Jusselme. 2017. "Preventing Overheating in Offices through Thermal Inertial Properties of Compressed Earth Bricks: A Study on a Real Scale Prototype." *Energy and Buildings* 156 (December): 281–92. https://doi.org/10.1016/j.enbuild.2017.09.070.5.13.
Fig. 5.17–5.19 Brambilla, Arianna, Jérôme Bonvin, Flourentzos Flourentzou, and Thomas Jusselme. 2018a. "Life Cycle Efficiency Ratio: A New Performance Indicator for a Life Cycle Driven Approach to Evaluate the Potential of Ventilative Cooling and Thermal Inertia." *Energy and Buildings* 163 (March): 22–33. https://doi.org/10.1016/j.enbuild.2017.12.010.
Fig. 5.20 Arianna Brambilla, Building2050, EPFL.
Fig. 5.21–5.22 Brambilla, Arianna, Jérôme Bonvin, Flourentzos Flourentzou, and Thomas Jusselme. 2018a. "Life Cycle Efficiency Ratio: A New Performance Indicator for a Life Cycle Driven Approach to Evaluate the Potential of Ventilative Cooling and Thermal Inertia." *Energy and Buildings* 163 (March): 22–33. https://doi.org/10.1016/j.enbuild.2017.12.010.

Fig. 6.1–6.2 Didier Vuarnoz, Building2050, EPFL.
Fig. 6.3 Thibaut Schafer,

Institut Energy, HEIA-FR.
Fig. 6.4–6.7 Didier Vuarnoz, Building2050, EPFL.
Fig. 6.8 Agnès Lisowska-Masson, Human-IST, UNIFR
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Fig. 6.16 Philippe Couty, Institut Energy, HEIA-FR.
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Pages 171–174 Benoît Jeannet, from the projects "A Geological Index Of The Landscape" (2011–2015) and "Untitled" (2018).

Fig. 7.1 Pieter Brueghel the Elder, bAGKOdJfvfAhYQ at Google Cultural Institute zoom level scaled down from second-highest, Public Domain, https://commons.wikimedia.org/w/index.php?curid=22178101.
Fig. 7.2–7.5 Florinel Radu, Institut Transform, HEIA-FR.
Fig. 7.6 Samuel Ludwig, www.samuelludwig.com.
Fig. 7.7 Mr. Nutt (Own work) [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons.
Fig. 7.8 Florinel Radu, Institut Transform, HEIA-FR.
Fig. 7.9 Arch Photo, Inc., 112 Macdonough Street #4, Brooklyn, NY 11216.
Fig. 7.10 Florinel Radu, Institut Transform, HEIA-FR.

Fig. 8.1–8.2 Jusselme, Thomas, Emmanuel Rey, and Marilyne Andersen. 2018a. "Findings from a Survey on the Current Use of Life-Cycle Assessment in Building Design." *Proceedings of the PLEA 2018 conference: Smart and Healthy within the 2-degree Limit.*
Fig. 8.3 Kellenberger et al. 2012.
Fig. 8.4 Amélie Poncéty, Building2050, EPFL.
Fig. 8.5 Jusselme, Thomas, Emmanuel Rey, and Marilyne Andersen. 2018b. "An Integrative Approach for Embodied Energy: Towards an LCA-Based Data-Driven Design Method." *Renewable and Sustainable Energy Reviews* 88 (May): 123–32. https://doi.org/10.1016/j.rser.2018.02.036.
Fig. 8.6 Thomas Jusselme and Pedro Antunes, Building2050, EPFL.
Fig. 8.7 Raphaël Tuor, Human-IST, UNIFR.

Fig. 8.8 Andreas Koller, EPFL ECAL-LAB.
Fig. 8.9–8.12 Renato Zülli, EPFL ECAL-LAB.
Fig. 8.13 Amélie Poncéty, Building2050, EPFL.
Fig. 8.14 Thomas Jusselme, Building2050, EPFL.
Fig. 8.15 Stefano Cozza, Building2050, EPFL.
Fig. 8.16–8.17 Thomas Jusselme, Building2050, EPFL.

Fig. 9.1 Didier Vuarnoz, Building2050, EPFL.

Pages 253–256 Benoît Jeannet, from the project "A Geological Index Of The Landscape" (2011–2015).

Pages 273–280 Jeremy Ayer, "BlueFactory", (September 2018).

Authors

Marilyne Andersen holds an MSc in Physics and a PhD in Building Physics from the École polytechnique fédérale de Lausanne (EPFL), where she is a professor of sustainable construction technologies and Head of the Laboratory of Integrated Performance in Design (LIPID). Her research at LIPID focuses on the integration of building performance in design, with an emphasis on daylighting and themes such as health, perception, comfort and energy. She was Dean of the School of Architecture, Civil and Environmental Engineering (ENAC) at EPFL from 2013 to 2018 and is the Academic Director of the *smart living lab*. Before joining EPFL as faculty member, she was a Visiting Scholar at the Lawrence Berkeley National Laboratory, and Assistant then Associate Professor at MIT (USA), where she founded the MIT Daylighting Lab in 2004. She is the author of over 100 refereed scientific papers, several of which have earned distinctions, and was the first laureate of The Award for Daylight Research in 2016. She was also the leader of and faculty advisor to the Swiss Team, which won the 2017 US Solar Decathlon competition. She is co-founder of the start-up OCULIGHT dynamics, is a member of the Board of the LafargeHolcim Foundation for Sustainable Construction, an expert for Inno-Suisse and a Foundation Culture du Bâti (CUB) board member.

Emmanuel Rey earned a degree in architecture at École polytechnique fédérale de Lausanne (EPFL), followed by a European postgraduate diploma in architecture and sustainable development (1999) and a PhD from the Université catholique de Louvain (2006). His doctoral thesis was awarded the European Gustave Magnel Prize in 2009. Since 2000, he has worked at Bauart, an architectural and urban design firm based in Bern, Neuchâtel and Zurich, and has been a partner there since 2004. Through his work, he is involved in a wide variety of projects, competitions and achievements that have been published, exhibited and/or awarded on several occasions. He has also been professor of architecture and sustainable construction technologies at EPFL, where he founded the Laboratory of Architecture and Sustainable Technologies (LAST), since 2010. His contributions focus on the transcription of sustainability principles into architectural design, from the neighbourhood scale to construction components. He has been involved in the conceptual development of the *smart living lab* from its inception, and was Chair of the "Smart Living Building" Scientific Committee from 2014 to 2016. In 2015, he received an award from the Swiss Academies of Arts and Sciences and the swiss-academies award for transdisciplinary research (td-award).

Hamed Alavi is a senior researcher and lecturer at the Human-IST Institute (University of Fribourg) and a visiting research fellow in University College London. With a background in computer science, his research looks into Human-Computer Interaction as a design research field in the ever-evolving area of buildings and urban spaces, which is increasingly incorporating artificial intelligence. His current research on the notion of Human-Building Interaction questions the complexity of our interactive experiences with smart built environments.

Arianna Brambilla graduated from the Politecnico di Milano in 2011 with a degree in building engineering and architecture and a focus on sustainability and technological innovation. She got her PhD in 2014 (in collaboration with Aalborg University) for her work on the interconnections between energy efficiency and occupants' use of building equipment. In 2016, she completed a postdoc on thermal comfort and occupants' perception with the Building2050 research group at EPFL. She now works as lecturer in architectural technology at the University of Sydney, Australia.

Derek Christie is a public health biologist whose main research interest is the sustainable development of urban areas through a combination of health, transportation and environmental approaches. In 2018, he received his PhD from the Architecture and Sciences of the City doctoral programme at the EPFL with a project entitled „Frequent Walkers." He has been a board member of Geneva's Association for Transport and Environment for 20 years and has worked as a researcher and science writer at the University of Geneva and the World Health Organization, as well as in the private sector.

Anne-Claude Cosandey is the operational director of EPFL Fribourg and has been responsible for coordinating the *smart living lab* since 2014. She graduated with a degree in environmental engineering from EPFL in 1998 and earned a PhD from EPFL in 2002. She worked in a consulting engineering / biology company active in natural ecosystem protection for six years. In 2008, she became head of Ecoparc, a non-governmental organization that promotes sustainability in the built environment. In 2013, she coordinated the "demonstration projects for sustainable urban development" initiative from the Swiss federal office for spatial development. Throughout these experiences, she initiated and facilitated new projects involving a multitude of stakeholders including public, private and academic bodies.

Vanda Costa graduated in architecture from EPFL in 1998. She worked for several architecture firms in Lausanne before transitioning to a career in communications in 2003, honing her skills in graphic design, writing, event management and webmaster functions. A member of the association "Ville en Tête" since 2015, she leads children's activities to raise awareness about the built environment while helping to develop these programmes and their support material. She has been working as a scientific collaborator for EPFL at the *smart living lab* since 2016.

Philippe Couty began his PhD at EPFL in the field of turbine cavitation in 1997 after doing a Master's in physics and fluids mechanics. In 2004, he co-founded Karmic, Inc., which developed nanotechnology applications. In 2007, he decided to join the photovoltaic industry with Flexcell VHF-technologies, with a focus on increasing the cell efficiency of flexible solar panels. Since 2013, he has pursued a career in R&D and industrial development in the area of energy and industrial technologies. He has been the engineering leader for the Swiss Living Challenge for the past three years. In 2017, his team won the US DOE Solar Decathlon competition in Denver, Colorado. Today, he is self-employed as an energy and building consultant.

Stefano Cozza is a research engineer. He earned a B.Sc. MSc in Energy Engineering with a specialization in Renewable Resources from La Sapienza (University of Rome) in 2015. His Master's project, in collaboration with EPFL, concerned technical and architectural energy strategies for a sustainable building. After graduating, he continued to work as part of the Building2050 research group (EPFL), which looks at Building Performance Simulation and energy systems. Since June 2017, he has been pursuing his research as a doctoral candidate and teaching assistant at the Institute for Environmental Sciences of the University of Geneva. His research focuses on energy efficiency in the built environment and the energy performance gap in buildings more specifically.

Hugo Gasnier is an architect. He earned his degree at DSA Earthen Architectures (post-Master's training) and has been a researcher at CRAterre Laboratory, labex AE&CC and the ENSAG. He is in charge of the Dessin Chantier department, which works on the design and feasibility of architectural projects in France using earthen material. He is involved in research projects combining technique, training and architectural conception. His work brings together research and education, notably at DSA Earthen Architectures at the ENSAG. He is currently working on a thesis, which he began in 2015, on excavated earth as a resource for building environmentally-friendly towns.

Nicolas Henchoz is the Director of EPFL+ECAL Lab, EPFL's Design Research Center. With a background in Material Science and Journalism, he transitioned into art direction. His book, "Design for Innovative Technologies: from Disruption to Acceptance", defines a new vision of how technology can be turned into meaningful user experiences. His projects have been presented at various institutions including Harvard University, the Musée des Arts Décoratifs in Paris, the American Institute of Architecture in NYC and the Royal College of Art in London. His research work has also led to several articles and conferences such as ISMAR, Include and Siggraph. He is a visiting professor at the Politecnico di Milano and member of the board of the Global Alliance for Media Innovation.

Endrit Hoxha is currently a lecturer at EPOKA University, Albania. He earned a degree in Structural Profile Civil Engineering from the Polytechnic University of Tirana in 2010. An intern at École Spéciale des Travaux Publics du Bâtiment et de l'Industrie (ESTP) and EIFFAGE construction (Paris), he earned a Master's of Science from the École Nationale des Ponts et Chaussées (ENPC, Paris) in Mechanics of Materials and Structures in 2011 and a PhD in Environmental Science and Technology from the Université Paris-Est. In 2017, he completed a post-doc as part of the Building2050 research group at EPFL and later joined the Structural Xploration Lab at that same institution.

Thomas Jusselme is an eco-design engineer and researcher. He completed his education in 2003 with a Master's in Industrial Design at UTC Compiègne after earning a degree in environmental engineering in Lyon. He pursued his interests by studying sustainable architecture practices, travelling to 25 countries and subsequently co-founded exNdo (an architectural firm) and Milieu studio (an eco-design engineering office) in Lyon, where he was CTO for eight years. In 2015, he co-created COMBO Solutions, a start-up for energy and digital transition in buildings. He is currently a research associate with the Building2050 research group for EPFL at the *smart living lab* in Fribourg. He is also working on his PhD as part of the EPFL's LIPID and LAST laboratories.

Vincent Kaufmann is an associate professor of urban sociology and mobility at EPFL. He has also served as scientific director of the Mobile Lives Forum in Paris since 2011. After earning a Master's in sociology from the University of Geneva, he completed a PhD on the logics underlying transport modal choices at EPFL. He has been a guest lecturer at Lancaster University (2000–2001), École Des Ponts Paris (2001–2002), Université Laval (2008), Nimegen University (2010), the Université de Toulouse Le Mirail (2011) and Tongji University (2018). His areas of research include motility, mobility, urban lifestyles, the links between social and spatial mobility and land-use planning and transportation policies.

Denis Lalanne is a professor in the Department of Informatics at the University of Fribourg and heads the Human-IST Institute, an institute dedicated to research on and training in Human-Computer Interaction combining expertise in computer science, psychology and sociology. Human-IST aims to develop and evaluate new interface technologies that are useful, sustainable and attractive to a broad spectrum of people. At the *smart living lab*, his group is currently working on Human-Building Interaction to develop interactive technologies for understanding and improving building occupants' comfort and behaviour. He is a recognized expert in multimodal interaction and information visualization and has published over a hundred peer-reviewed scientific articles.

Jean-Marie Le Tiec graduated in architecture from the ENSAG and also holds a DPEA Architecture de Terre. He has worked for NAMA architecture, his own company, and with CRAterre as head of "dessin-chantier" section since 2005. CRAterre assists in the design and development of contemporary projects made of rammed earth and also is working to draft national regulations for earthen constructions in France. Through these two activities, he is involved in projects that focus on eco-responsible housing and constructive cultures.

Cédric Liardet earned a degree in Architecture from EPFL in 2008 and received the BG Consulting Engineers Award for Construction and Sustainable Development that same year. He then worked for the Dreier Frenzel architectural firm in Lausanne until becoming self-employed in 2011, led by his passion for economy of means ("doing more with less"). From 2016 to 2017, Liardet was also a scientific collaborator for EPFL's Building2050 group, where he worked on user environmental strategies.

Thierry Maeder is a geographer and a graduate of the University of Lausanne. He is currently working on a doctoral thesis in urban planning and development at the University of Geneva, where he also teaches the urban project. His research focuses on changes in planning policies by analysing patterns of production of art in the public space and the link between the arts, the city and critique. He previously worked as an urban planner for planning agencies and the city of Geneva's public art fund.

Marc Antoine Messer is an urban planner certified by the Federation suisse des urbanistes (FSU). He holds a PhD in urban science from EPFL, where he is now a post-doctoral scientific collaborator and lecturer. He is also the managing director of Mobil'homme, a spin-off of EPFL's Urban Sociology Laboratory. He is an expert in urban planning and metropolitan governance, and has developed an analytical method for understanding the interactions between stakeholders in urban regeneration processes. He was a member of the city council of the Greater Fribourg Area for 10 years, where he helped set up of the Greater Fribourg public authority.

Arnaud Misse is an architect and specializes in earthen building. He graduated from the ENSAG and earned a post-graduate degree in DPEA Architectures de Terre. He has been working in the field of earth architecture with CRAterre since 1998. He is currently responsible for the material department of CRAterre and also teaches a specialized course on earthen building systems at ENSAG. In 2006, he founded "NAMA architecture" with Jean-Marie Le Tiec to develop architectural projects that promote the use of local materials, know-how and building cultures to produce contemporary eco-responsible buildings.

Julien Nembrini has a background in mathematics and robotics, experience as a building physics engineer, and has worked on the use of digital tools for building and architectural processes ranging from design to post-occupancy evaluation. Committed to research with a potential for industrial applications, he currently focuses on the use of readily-available building data to study the interactions between buildings and their occupants. Combining data-centric techniques and visualization with user-centred qualitative approaches, the aim is to compare a fully-automated approach to mixed-mode automation that involves active users within the building context.

Cécile Nyffeler is pursuing a Master's in Environmental Sciences and Engineering with a focus in the monitoring and modelling of the environment at EPFL. She got her Bachelor's in autumn 2017. During the summer of 2016, she participated in the experimental phase of the *smart living lab*'s Envelope Design research project in Fribourg. Her main tasks were recording and processing data.

Luca Pattaroni holds a PhD in Sociology from the École des Hautes Études en Sciences Sociales (Paris). He is a senior researcher and lecturer at the Urban Sociology Laboratory at EPFL, where he heads the City, Habitat and Collective Action research group. He was visiting professor at the Federal University of Rio de Janeiro and the University of Columbia in New York. He is a member of the board of the "Swiss Journal of Sociology and Articulo-Journal of Urban Research". He also is Chairman of the Ressources Urbaines art cooperative and a member of the Cultural Council in Geneva. His research, which focuses on the expression of differences and the creation of the commons in contemporary cities, ranges from issues on housing and the public space to cultural and urban movements.

Florinel Radu is an architect and urban planner (UAUIM Bucharest, 1987). He earned his PhD from UAUIM Bucharest in 2000. He began teaching as a professor of architecture in the joint Master's of Architecture programme (HEIA-FR, HES-SO) in 2005. He has taught at several European schools including UAUIM Bucharest, EPFL and School of Architecture in Alghero, Sardinia, and has headed the TRANSFORM research institute since 2013. In addition, he has headed several applied research projects on user-centred sustainable architecture and urban planning.

Thibaut Schafer has a Bachelor's in mechanical engineering with a specialization in energy. With a background in the applied sciences, he earned a Master's at the University of Applied Sciences of Western Switzerland (HES-SO). His thesis looked at the energy efficiency of machine tools. He is currently working as an R&D engineer for the *smart living lab* at the HEIA-FR's Energy Institute.

Raphaël Tuor is currently working on a PhD at the Human-IST Institute in the department of Informatics at the University of Fribourg. In 2016, he earned a Master's in Computer Science with a focus in Advanced Information Processing. His Master's thesis focused on enhancing the visualization of mixed multidimensional data in parallel coordinates. He is now conducting research on the challenges of building data visualization and human-building interaction under the supervision of Professor Denis Lalanne.

Himanshu Verma is a postdoctoral researcher at the University of Fribourg, Switzerland. With a background in Human-Computer Interaction, his work focuses on users' socio-technical interactions and experiences with artefacts and environments, as well as interactions mediated through artefacts. He has contributed methodologically to ways of acquiring knowledge about latent aspects of users' contexts and demonstrated ways of leveraging this knowledge in Context-Aware Applications. His current research as part of the *smart living lab* aims to create knowledge about occupants' living experiences and behaviours to help architects to make informed design decisions with a sustainable human-centric approach.

Dominic Villeneuve is a policy analyst and post-doctoral coordinator at the TUM's mobil.LAB Doctoral Research Group. He completed his PhD in Architecture and Sciences of the City under the supervision of Professor Vincent Kaufmann at the EPFL's Urban Sociology Laboratory in 2017. His thesis compared car dependence and social exclusion linked to mobility in the regions of Quebec City (Canada) and Strasbourg (France). He has a Master's in Public Administration from the University of Ottawa. He is also co-founder and chief technology officer of Urby-me, a startup project that is developing a smartphone app to measure the mobility, comfort and satisfaction of public transport users.

Didier Vuarnoz earned a degree in energy engineering from the University of Applied Sciences of Western Switzerland (HES-SO) in 1999 and a PhD from Kobe University in Japan (2013). His research looks at Phase Change Slurries (PCS), thermo-magnetism (magnetocalorics and hyperthermia) and energy strategies for carbon emission mitigation in buildings. His activities in both Switzerland (HES-SO and EPFL) and Japan (Kobe University) have been mainly academic. He was also a visiting scientist at Hokkaido University (Japan, 2002), Okayama University (Japan, 2003) and MIT (Cambridge, USA, 2008) for several months. He is currently working on the sustainable integration of renewables and energy storage in buildings at EPFL.

Renato Zülli is a UX/UI designer with a background in print-oriented editorial design. After doing Graphic Design studies at ECAL, he worked for various clients in culture and the sciences. In 2013, he started teaching and working as an Interaction Designer at the EPFL+ECAL Lab. His unique research in big data and data visualization synthesizes the history of interfaces and has enabled innovative experiments within massive information environments. For the COP21 in Paris, he developed a new way of understanding global issues in the context of interdependent controversies. In addition to working together with the EPFL's Social Media Lab and the *smart living lab*, he has also worked with Idiap and Sciences-Po, as well as private partners like Faveeo.

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Workshops

Design process workshop
Fribourg, March 7–8, 2017

Chair
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Scientific workshop
Gruyeres, October 5–6, 2016

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