Visioning Energy: Environmental Simulation, Visualization and the Instrumental Nature of Energy

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> "The obvious world that we know on the gorse levels of sight, sound, taste and touch can be connected with the subtle world revealed by our scientific instruments and devices. Seen together, aerial maps of river estuaries and road systems, feathers, fern leaves, branching blood vessels, nerve ganglia, electron micrographs of crystals, and the tree like patterns of electrical discharge-figures are connected, although they are vastly different in place origin and scale. Their similarity of form is by no means accidental. As patterns of energy-gathering and energy-distribution, they are similar graphs by similar processes" (Gyorgy Kepes, *The New Landscape in Art and Science*)

A glance at the recent history of the evolving conceptual relationship between energy and building related disciplines, reveals the coextensive emergence of tools and crisis. Whether economic, environmental, technological or cultural, these conditions are shadowed by an analogous — and exponential — leap in the power of computing along with a reciprocal decline in its cost (Figure 1). Moreover, it is not a coincidence that the progressive growth of computation based tools used in the evaluation of interior atmospheres is paralleled by similar historic benchmarks in twentieth-century environmentalism. First adopted in 1965, the ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy), for example, established a metric for indoor thermal comfort, and arrived during an era which saw the first energy crisis and also began to consider the impact of buildings within ecologies[1].

Embedded within this history are multiple polyvalent and intertwined paradigms in design thinking. Any attempt to comprehensively articulate this lengthy narrative of the relationship between architecture and energy would exceed the scope of this essay, instead we propose to identify a causal link(s) between the abstract instruments used to measure and observe energy, and the cultures of design that they engender. More precisely, this session explores how advances in computation are producing a growing range of virtual tools used in the modeling, simulation and visualization of thermal and environmental flows and how these emerging technologies have given rise to new methods of evaluating building performance, altered the economics of lifecycle and resource management, and problematized the traditional metrics of thermal comfort.

Changes to the performative capacity of traditional representational modalities, such as plan, section and perspective are host to the outward-most expression of the specter of virtually simulating and visualizing complex thermodynamic flows. Underlying this, however, are more universal and far reaching themes. When articulating architectures reciprocity to energy, we necessarily examine how architecture frames its relationship to the natural world through representation, or, how architecture represents and anticipates, uncertainty and indeterminacy. How does it define its real and subjective boundaries?

As the environmental, economic and social impact of building performance has changed, architecture has been thrust into rethinking its now nascent relationship to the natural world through an ecological frame of reference; these new modes of visioning energy have also changed the role of testing and research in the design process. Buildings are now understood as a complex ecosystem of "energy-gathering and energy-distribution" - a soft-boundary mediating the intersection of climate, material, space and structure[2].

While every method of energetic visioning, invariably produces its own subjectivities, expressed as spatial, political or economic biases, this discussion explores how we "see" these energetic subjectivities as intrinsic to Architecture. As well as how the instrumental representation of energy transforms the institutions of architectural and engineering practice. Supported by the collaborative intersection of academic and practice based research, this next generation of thinking in the design of mediated environmental control systems expands on what the architectural historian and critic, Reyner Banham, termed the "well-tempered environment"[3]. Static and steady-state building conditions, which Chris Reed of STOSS described as "classical ecological orders," favored stability, certainty and order, and are endemic of a

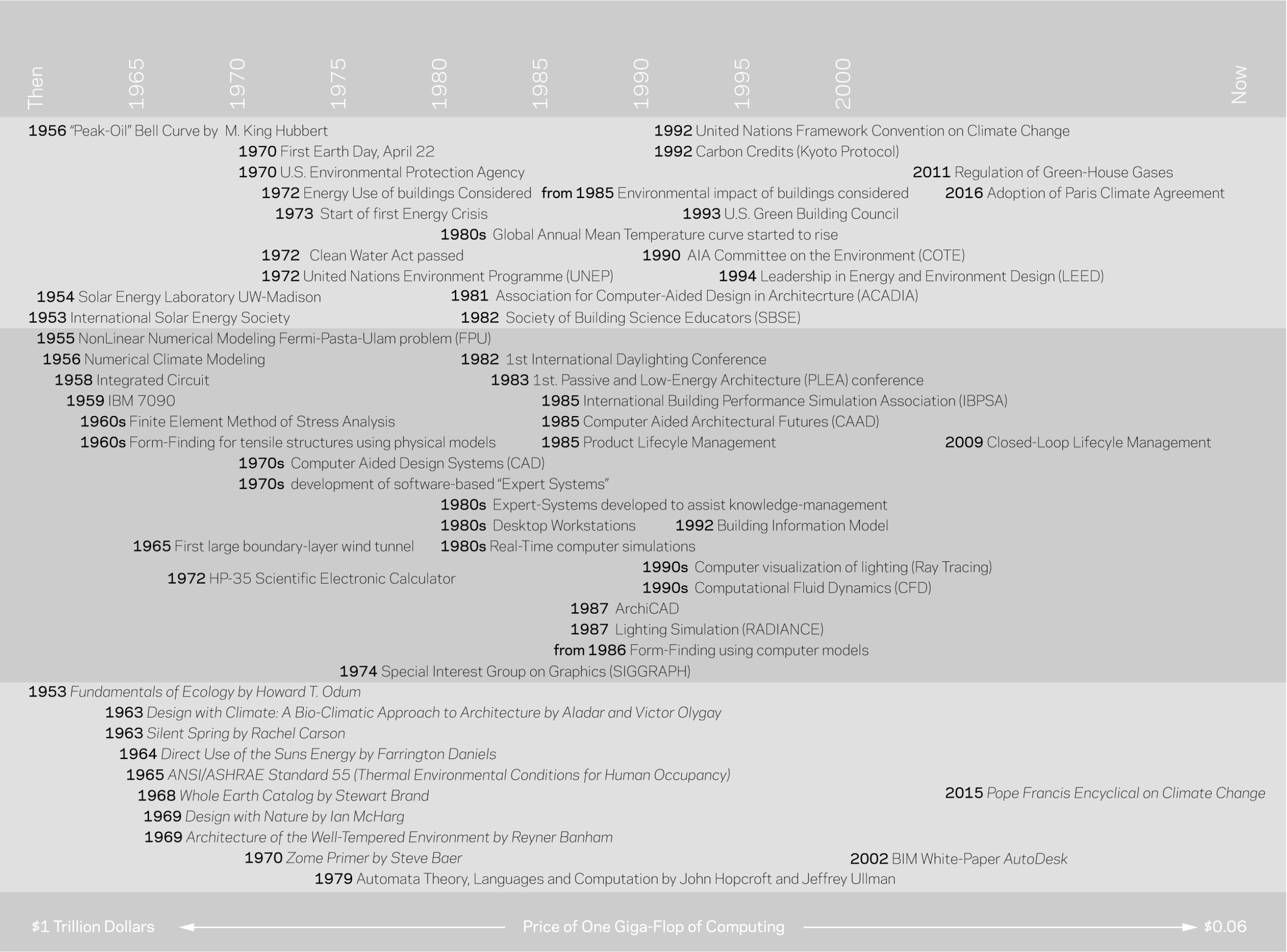


Figure 1. Recent history of the the relationship between energy and building related disciplies.

post-war approach to the design of environments — not to mention at odds with the statistical and probabilistic nature of thermodynamics.[4] Instead, it is dynamic change, adaptability and resilience, that now frame our aspirations.

Ecology, is a perpetual source of reference within this discourse. This is in part an outcome of the comprehensive world-view that it embodies, and by the metrics and quanta that ecology has invented, or adopted since the immediate post-war era - many of which accurately capture and describe the inherent material and thermal conditions of buildings and occupants. Metabolism, mass, power, area and entropy, are expressions of thermodynamic forces in biological systems that are either the same or have analogs in architectural terms.[5]

The fluid mutability of ecologies core concepts is evidenced by their widespread, though diffused, application by disciplines as varied as ecology, economics, geography, landscape architecture, urbanism, architecture, thermodynamics, and others. A majority of which use the concept of energy to denote the material and informational exchange inherent to all mechanical and biological processes. In this regard, energy, as the index of thermodynamic forces, has been and continues to be the general epistemological framework of the 20th and 21st century, structuring a way of knowing the world that is contingent on describing the connections and pathways of things[6].

A map of the pathways that pass between energy and architecture is manifested in a widely divergent and sometimes conflicting ensemble of tools. Models, play a particularly important role as the primary tool in managing the discussion between disciplines because they provide a conceptual scaffold for the deliberation between the metaphors of indexical diagrams, the "sankey", for example, and more complex mathematical models outside of the architects anticipated scope of expertise[7].

While the "Sankey" diagram notates the connections and pathways of energy, it does not image them or retain an indexed record of their exchange. As the biophysicist, Harold Morowitz had outlined in his book, Energy Flow in Biology, "The flow of energy through a system acts to organize that system"[8]. Meaning that the patterns, forms and structures that we observe, whether geological, political, economic or architectural, are shaped in direct reciprocity to the exchange of energy. Any alternate representational model for mapping the reciprocity between architecture and energy would necessarily leverage the "experimentation in contact with the real."[9]

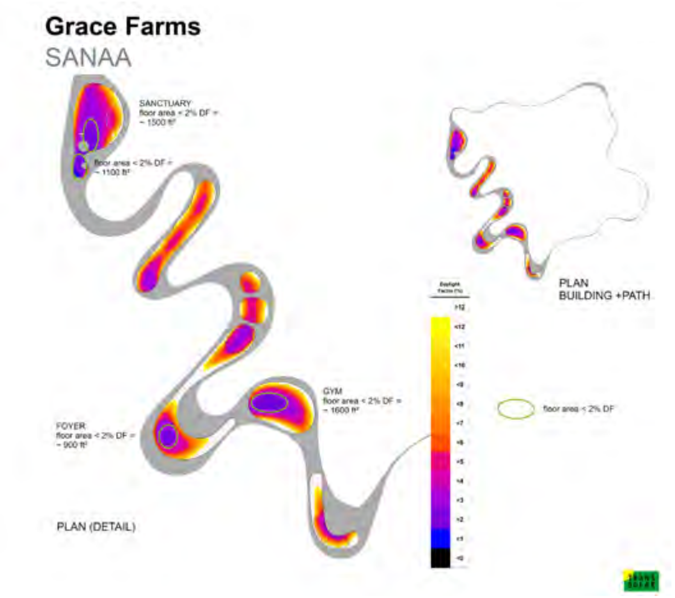


Figure 2. Thermal analysis of roof overhangs for Grace Farms.

Heavily influenced by this paradigm of ecologies, the architectural "systems" diagram, could be construed as a reductive device, capturing just enough of the easily recognizable features of the thermodynamic quotient of space one that domesticates environmental flows and perpetuates the dominance of "steady-state" architectural iconography in the transmission of a powerful image. Rather than obsess over this "temporary" trend of artistic license verging on the pseudoscientific, we propose to examine the productive correlations between the tools and methods currently used by designers and engineers to simulate thermodynamic effects.

Among these new instruments, Infra-Red Thermographic Imaging (IRT) and Computational Fluid Dynamic Simulation/Visualization (CFD), TRNYSYS, and Radiance modelers such as DIVA, are examples of contemporary tools deployed within the profession and related industries. These represent a shift in the conceptual modeling of Energy manifested within the thermodynamic flows present within buildings. Many of these new approaches instrumentalize the role of energy in relationship to structure, form, program and building systems and as a result are implicated at the earliest phases of the design process, providing for the expansion of disciplinary expertise into new material concepts and territories of design agency.

The subject of Tools and methods for the instrumentalized nature of Energy is premised on identifying a new set of collaborative approaches that leverage the unique disciplinary expertise embodied within distinct but often sublimated instruments of representation. Increasingly Architects and Engineers are engaging in a collaborative and creative dialog enabled by the access to these emerging visual tools. This model moves away from architectural (20th century mechanical) engineering as a professional service towards an integrative model. ARUP and Transsolar exemplify this new breed of design consultancies reframing questions of architecture and environment as one of design. This is a question of the dynamic implications of tools and the disciplinary boundaries they represent.

QUESTION AND ANSWER WITH ERIK OLSON / TRANSSOLAR, AND MAHADEV RAMAN / ARUP AND ARUP UNIVERSITY

Lonn Combs and Filip Tejchman: The models that engineers use are primarily mathematical constructs. Perhaps as a function of their intrinsically abstract nature, these models provide a framework that is alternately predictive and immaterial. Describe the relationship between models and nature as it pertains to the methods found in your practice.

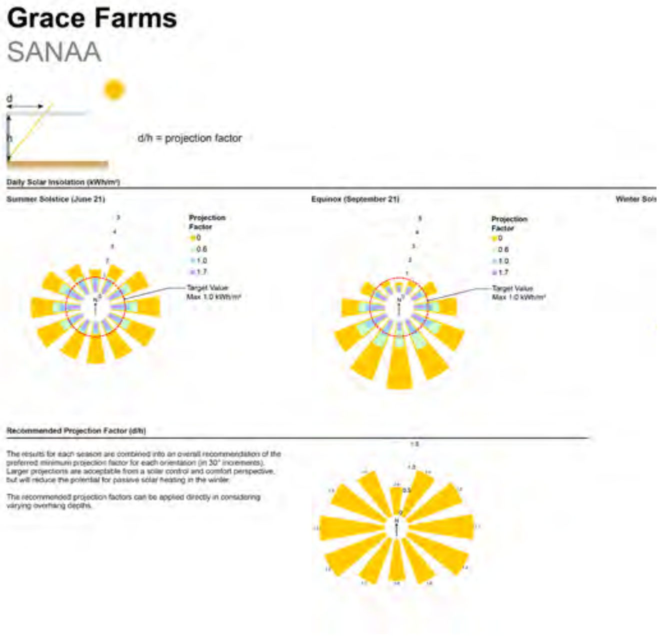
Erik Olson: Engineering models are simplified representations of the real physics governing a specific problem or situation. They are not meant to be wholly representative of reality, but only representative enough to capture effects that have a meaningful influence on the parameters being studied. Identifying which parameters are relevant, and which are superfluous, is a key skill in developing models for engineering analysis.

Mahadev Raman: A third factor in the relationship between models and nature is the modeler. Being able to perform a proper 'reality check' on model results based on the modeler's knowledge and experience is vital as there's always the danger of 'garbage in - garbage out'.

LC and FT: Can simulations introduce a new digital materiality into the design process that alters the conversation between architect, engineer and client? How are these tools changing or influencing practice?

EO: Engineering analysis has long had an influence on the design conversation but architect, engineer, and client. Today's performance simulations extend this conversation, allowing a conversation which was often limited to the truly material field of structural design to extend to diverse and more immaterial fields such as climate-responsive thermal design, daylighting design, and acoustic design.

Zaryadye Park is an extreme example, allowing the creation of semi-outdoor space whose environmental performance was unimaginable a generation ago, and with basic governing rules for form generation determined through



The results for each season are combined into an overall recommendation of the preferred minimum projection factor for each orientation (in 30° increments). Larger projections are acceptable from a solar control and comfort perspective, but will reduce the potential for passive solar heating in the winter.

The recommended projection factors can be applied directly in considering varying overhang depths.

Figure 3. Translation of thermal analysis of Grace Farms into "solar rose."

simulation (Figure 2). Similarly, the sinuous curves of the roof overhangs at Grace Farms are informed by thermal analysis determining the required overhang depths, which were translated into a 'solar rose' which could be used for immediate feedback in the design process(Figure 3).

MR: An important current role for simulations is to provide near real-time feedback on energy performance during the design process to inform the design of net-zero buildings that are essential to meeting future carbon reduction targets.

LC and FT: Can the visualization of simulation data alter the understanding of the underlying model or, reveal inherent liabilities?

EO: Carefully designed visualizations can reveal patterns which might otherwise be invisible. They can also identify unexpected results, and when results are unexpected, the first step is generally to question the model: Have all of the relevant physics been properly understood and represented? If so, does further critical analysis of the physics and the results provide new insight into previously unexpected behavior?

MR: More often than not, the visualizations help to clearly identify areas where the design can be improved or optimized, something that is less easily achievable by scrutinizing pages of numbers.

LC and FT: How do the diagrams used by engineers differ from this used by architects?

MR: During the design process, some of the most useful engineering diagrams and visualizations are those that significantly improve the communication of engineering concepts and phenomena to architects.

EO: Many – if not most – useful engineering diagrams do not include geometric information. A good engineering diagram will still have visual clarity, but doesn't necessarily represent geometry. This is because the topic being studied – particularly in the field of climate-responsive design – often does not have strong sensitivity to architectural geometry. As an example, consider the validation of the natural ventilation design for the new School of Business at Portland State University. The steps necessary to eliminate mechanical cooling are considered in sequence without any need to represent geometry (Figure 4).

LC and FT: Have digital tools and more precisely, advanced modeling and simulation software, changed our expectations of building performance?

MR: There is certainly a growing expectation of predictability in the performance of any given design. There are fewer excuses for results falling short of expectations!

EO: Advanced modeling has changed our expectations of the relationship between performance and design. Increasingly these two topics, traditionally seen as in opposition, are understood as converging. Simulation provides information that allows performance to be studied in relationship to design, meaning both design intent and performance goals be met.

Building performance goals – particularly for energy – have also been becoming more aggressive. However, this is likely a result of increased attention by society to the topic, and not because the simulation tools themselves encourage clients to adopt more aggressive goals.

Lastly, advanced modeling can sometimes allow a new understanding of the definition of performance. For example, thermal comfort

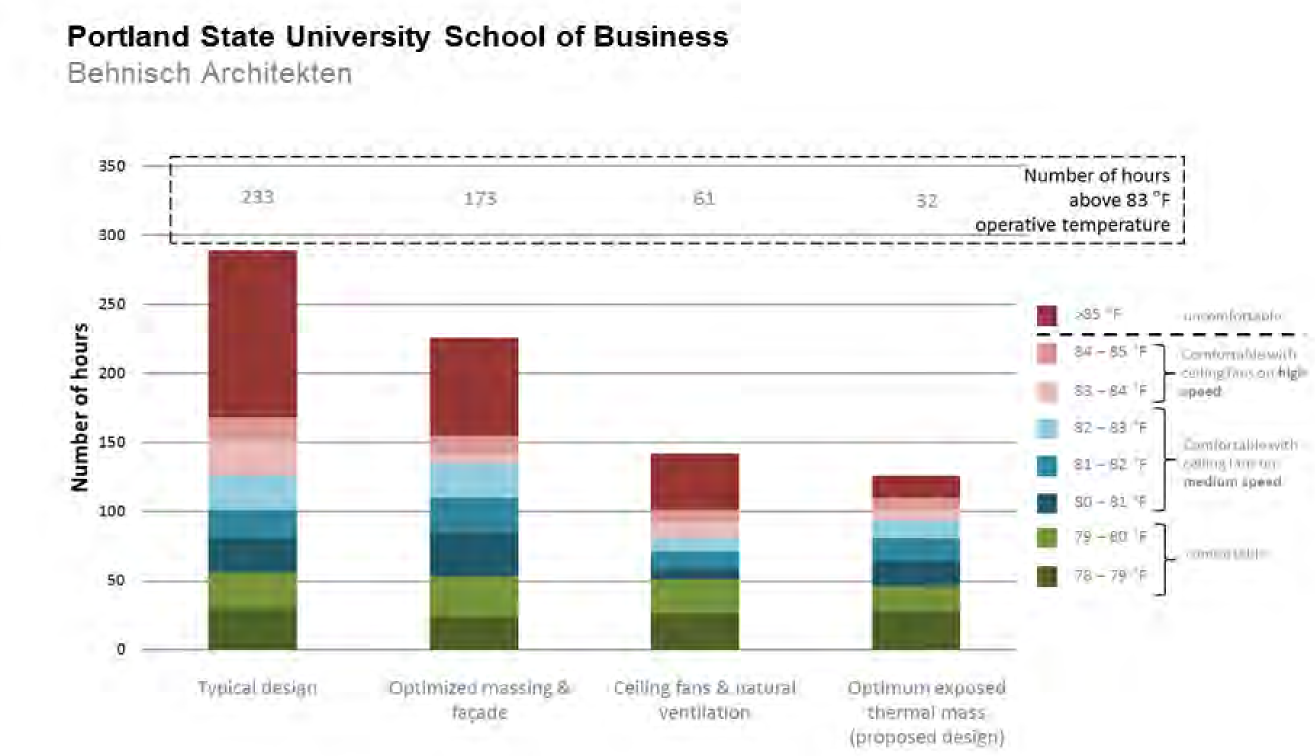


Figure 4. Validation of the natural ventilation design for the new School of Business at Portland State University.

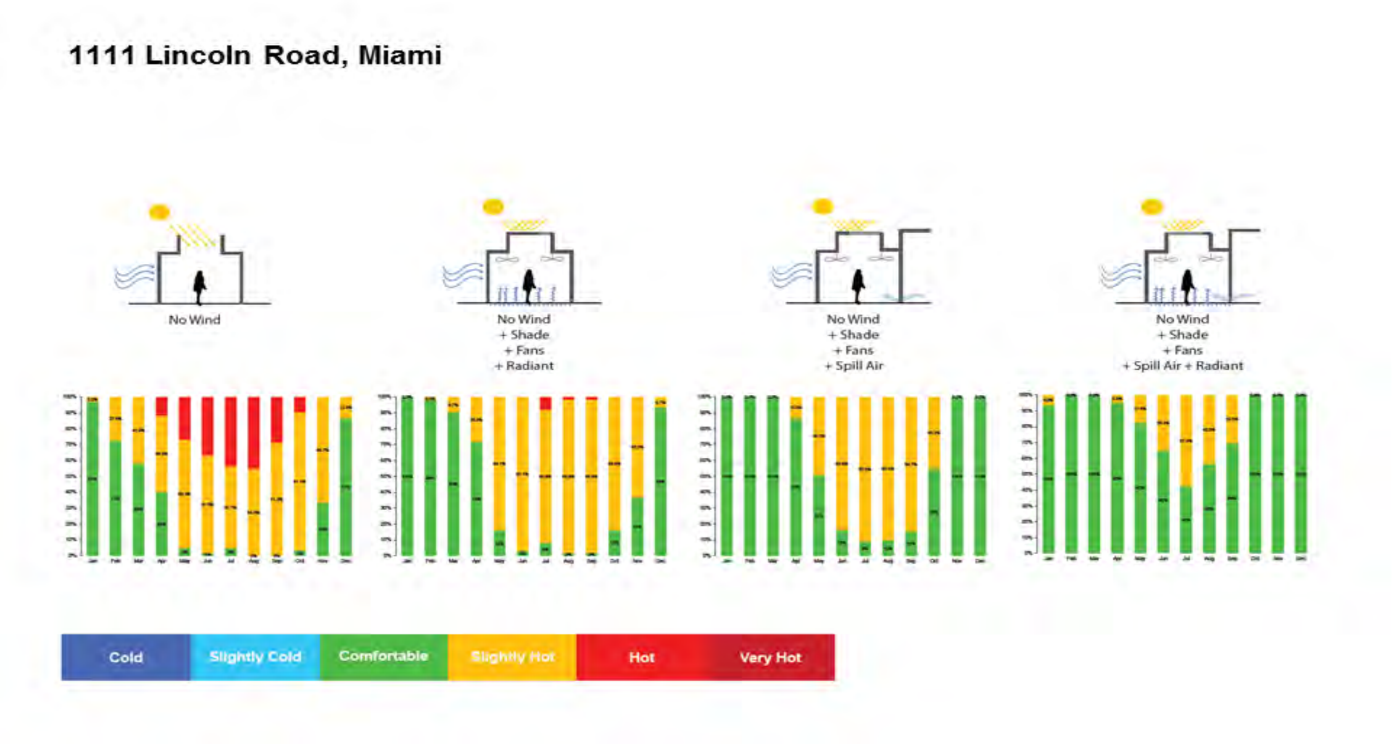


Figure 5. Comfort assessment for 1111 Lincoln Road.

has traditionally been evaluated with air temperature, an incomplete representation of comfort. New tools allow ever-easier calculation of more comprehensive metrics considering all factors affecting comfort – in our practice with increasingly use the Universal Thermal Climate Index (UTCI) for outdoor comfort assessment, such as Lincoln Road in Miami, and Standard Effective Temperature (SET) for indoor comfort assessments (Figure 5).

ENDNOTES

1. Bill Addis, *Building: 3000 Years of Design, Engineering and Construction* (London, UK: Phaeton Press Limited, 2007)

2. Gyorgy Kepes, *The New Landscape in Art an Science* (Chicago, IL: Paul Theobald, 1956)

3. Reyner Banham, *The Architecture of the Well-Tempered Environment*, 2nd. Ed. (Chicago, IL: The University of Chicago Press, 1984)

4. Chris Reed and Nina Marie-Lister, “Parallel Genealogies” in *Projective Ecologies*, (New York, NY: ACTAR Publishers and the Harvard University Graduate School of Design, 2014)

5. Filip Tejchman, from “Beyond the Invisible Rainbow” presented at the 68th Annual Conference of the Society of Architectural Historians, April 13-15, Chicago, IL

6. ibid.

7. Annabel Wharton, “Scaffold, Model, Metaphor” in *ARPA Journal* Issue 04, Instruments of Service ed. by Janette Kim and Jennifer Leong (New York, NY: ARPAJournal.Net, 2016)

8. Harold J. Morowitz, *Energy Flow in Biology* (London, UK: Ox Bow Press, 1979)

9. James Corner, “The Agency of Mapping: Speculation, Critique and Invention” in *Mappings* ed. by Dennis Cosgrove (London, UK: Reaction Books, 1999)