Drawing Energy Abu Dhabi: Critical Reflections

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Figure 1. Drawing Energy Abu Dhabi site strategy by Niall Patterson. The Drawing Energy Studio critiqued the conventional ways in which energy is treated in technical and design teaching and was a provocation, asking students to engage with the spatial dimensions of energetic exchanges through drawing the ephemeral, fleeting and in flux.

INTRODUCTION

> There is little in common between "e" when a physicist writes it and "energy" when the word is used by an economist, politician, or windmill fan. "E" is an algorithm. "energy" is a loaded word. "E" is meaningful only within a formula. "energy" is charged with hidden implications: it refers to the subtle something that has the ability to make nature do work.
> -Ivan Illich, "The Social Construction of Energy" [1]

In architecture, conversations about energy tend to focus on technical "E". The conversation goes something like this: energy is something that buildings consume a lot of both in construction and for operation. More specifically, energy is contained in embodied form in materials used for construction and can be measured for the full life cycle of the building, and energy is utilized operationally to heat, cool, light, and service it. There are better and worse ways of siting, sourcing materials, detailing and servicing buildings and these strategies can be tested, measured, and compared. Material embodied energy, building operational energy, carbon footprints and thermal resistance can be calculated and collated to give a sense of holistic building performance. Essentially, energy use in all its guises should be minimized, there are ways of tracking and recording energy consumption, and these metrics are analytic tools used to evaluate building performance.

This technical understanding of energy is urgent information to impart to students given current environmental challenges of diminishing resources and ecological devastation caused by global warming. But this narrative, complex yet tidy in a way that only calculations can be, lacks dimension because it only reflects half of the quantitative / qualitative binary. A softer understanding of how energy behaves or is registered in buildings and landscapes, its scales of operation, and how it is perceived are less explored. To fully engage with the broader implication of the role and impact of energy on the built environment, how might we engage with the generative potential of understanding energy as "the subtle something that has the ability to make nature do work"?[2]

In refocusing conversations from the technical to the experiential, other topics gain ascendancy, specifically, thermal comfort and microclimate modification. These topics are more conducive to qualitative reading because they are foundationally experiential in a way that embodied or operational energies as an abstraction are not. Positioning design conversations around topics such as energetic registration of and on materials, how solar, wind or tidal forces visibly register on landscapes, or the occupation of the shifting ground/water conditions of an intertidal zone, for example, makes energetic exchanges and site forces accessible and therefore generative. These topics encourage respect for and ability to design in sympathy with the larger context. Further, they give "organizational responsibilities" to topics that are often considered either the domain of electrical and mechanical engineers or simply "auras" or "effects".[3]

The Drawing Energy Abu Dhabi Studio

The Drawing Energy Abu Dhabi Studio, taught Autumn 2010 to third year University of Edinburgh architecture students, critiqued the typical ways in which energy is treated in technical and design teaching and was a provocation, asking students to engage topically through drawing the ephemeral, fleeting and in flux.

The studio was structured in three stages. The first exercise asked students to conduct an *energy experiment* and to visually record that experiment or transformation. The subject of those experiments varied from tracking naturally occurring phenomena such as shifting tidal patterns to creating mechanisms that induced kinetic exchanges. Students translated the recorded energy transformation into a composite drawing. The drawing compressed temporal and spatial conditions into a single field. It also established a visual vocabulary for drawing ephemeral conditions and established a dialogue between the fixed or inert and the shifting or in flux. The relationship between static and the shifting established cues for energy/matter conversations later in the term. (Fig. 2 top)

Armed with a visual and verbal vocabulary, students then translated the energy drawing to a site drawing that recorded energetic phenomena. Wind data, tide tables and solar trajectories were merged into a single site drawing that shared dna with the energy experiment drawing. This drawing facilitated exploration of the meteorological conditions of the site over time and allowed students to test how the site's physical obstructions such as topography impacted ephemeral conditions of wind, water, and sun. (Fig 2 middle)

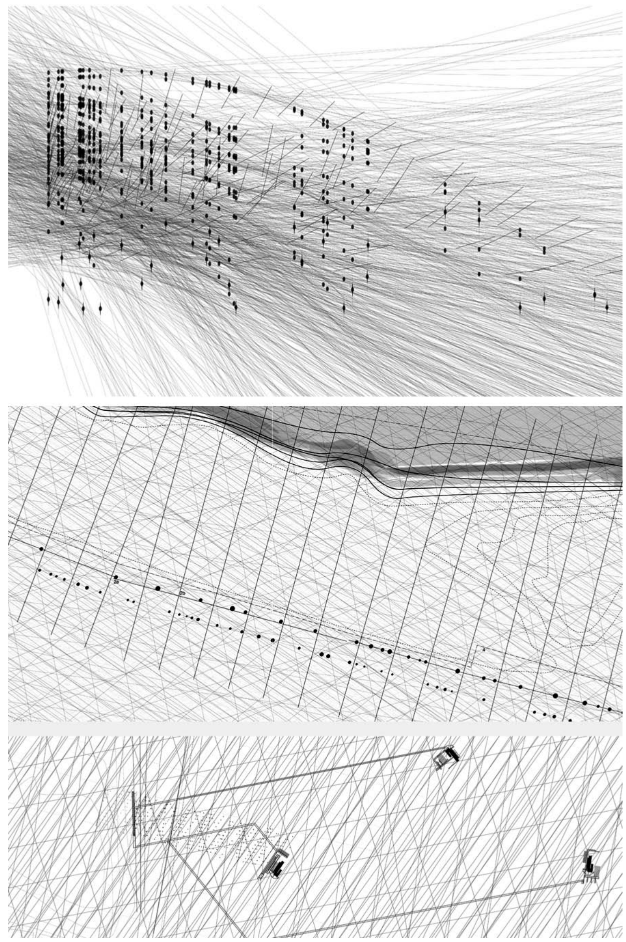

Figure 2. Drawing Energy Experiment (top) by Sayan Skandarajah and Jamie Henry. Sayan and Jamie built a catapult with tensile adjustments. The composite energy drawing overlays projectile trajectories, tangents and points of impact. In the Site Analysis (middle) Sayan applied the drawing vocabulary to wind, tide and vehicular trajectories. A single tangent slice was isolated for further development of three buoyant observatories, which responded to and drew energy from wind and tides. (bottom).

With an awareness of the microclimatic conditions on the site, students then transitioned to the final stage of the project. They designed a renewable energy landscape and an energy lab or public observatory in this landscape. An understanding of the site's shifting weather patterns facilitated designing an *active* landscape of energy production and a *passive* building that minimized energy consumption. (Fig 3 bottom)

The initial energy experiments and energy drawings yielded compelling results. The act of reading the energy drawing for spatial cues, understanding the codes embedded in their production, and gaining a credible vocabulary for applying the conditions explored in the experiment, however, presented clear obstacles. The intent of this paper is to make explicit three latent challenges of working with energy as a spatial topic that became clear through teaching the Drawing Energy studio. The challenges that students in the Drawing Energy studio faced reveal larger gaps in our collective understanding in architecture of energy as a qualitative or spatial entity.

First, energy is conceptually and therefore spatially opaque. Energetic behaviors, scales and extents of operation are ambiguous, and the relationship between energy and materiality varies depending on scale of observation. We do not have a shared disciplinary vocabulary for describing these conditions, nor do we easily navigate thermodynamic thinking without teetering between the pseudo-scientific and poetic metaphor. Second, the taxonomies we use to describe energy in architecture deny a larger spatial reading of the topic. There are taxonomies other than operational/embodied or renewable/nonrenewable that facilitate clearer spatial readings of energy in architecture, but they are not disciplinary conventions. Finally, there is a gap in our representational strategies for exploring common energetic conditions. The way that we draw conditions such as thermal transfer and microclimate modification ranges from the overly schematic environmental section to the overly prescriptive computational fluid dynamic rendering. There is little precedent in between and neither technique is generative. This paper explores these three challenges using images of relevant student work to visually illustrate these conditions.

ENERGETIC TENDENCIES

Pedagogically, we are more familiar with energetic spatial topics than we are with energetic spatial tendencies. Energetic topics include passive heating and cooling, microclimate modification, and thermal comfort, all extensively explored within sustainable and ecological design. In the Drawing Energy studio, projects engaged with topics such as microclimate variability, calibrated exterior to interior transitions, spatial sequences that shift based on seasonal variation, and registration of temporal phenomena such as wind and tides on buildings and landscapes. Students gained an awareness of the dialogue between landscapes as active registrars and of buildings as mediators of their environmental surroundings. They saw processes as manifestations of energetic transformations, and came to work strategically with abundant naturally occurring energy. The behaviors of what was being registered or mediated, the exact nature of the collusions between energy with the inert materials of construction and how to represent these conditions were latent pedagogical questions.

Thermodynamic Thinking

It became clear in teaching the studio that we lacked a clear, consistent, and precise vocabulary for discussing energy spatially. We looked to the science that governs energy transfer, thermodynamics, for cues.[4] The first law of thermodynamics states that energy can neither be created nor destroyed, but can change form; all forms of energy are ultimately reducible to the same unit of measure[5], and this hints at an ultimate equivalence of all forms of energy. The second law of thermodynamics, the 'Law of Entropy', offers an understanding of efficiency and directionality to all processes, which seek equilibrium. Entropy is understood less as randomness, and more as the tendency for a system to move towards dispersion or equilibrium.[6] Fundamentally, energy, which is charged, fluctuating, dynamic and temporally thick, is understood in contrast to matter, which is generally static or inert.

Matter vs Energy

Understanding the dialogue between matter and energy became a primary issue at stake in conversations about energy as a spatial entity in design. Thinking of energy spatially introduces expanded notions of what constitutes a physical boundary to include thermal boundaries, which may or may not coincide with material boundaries or enclosure. As Addington notes,

> Thermodynamic boundaries are not legible and tangible things, but instead are zones of activity, mostly non-visible. In this zone of activity - the boundary – the truly interesting phenomena take place. This is where energy transfers and exchanges form, and where work acts upon the environment… boundary operates as fundamental transition zone for mediating the exchanges between two or more static variables.[7]

In expanded energetic thinking, boundary and enclosure, then, do not always coincide.[8] Thermal boundaries decouple surface and energy; surface and energy are conceptually re-coupled when materials take on the role of registrar of energetic conditions. Materials absorb, reflect, and emit; they have the capacity to visibly, tactilely and acoustically register energetic exchanges. While construction materials weather, patina or erode over time, relatively speaking, they are static and longevity is measured in decades rather than seconds. It is because of this temporal disjunction that materials can provide a static, relatively speaking, backdrop to the kinetic exchanges that occur upon them.

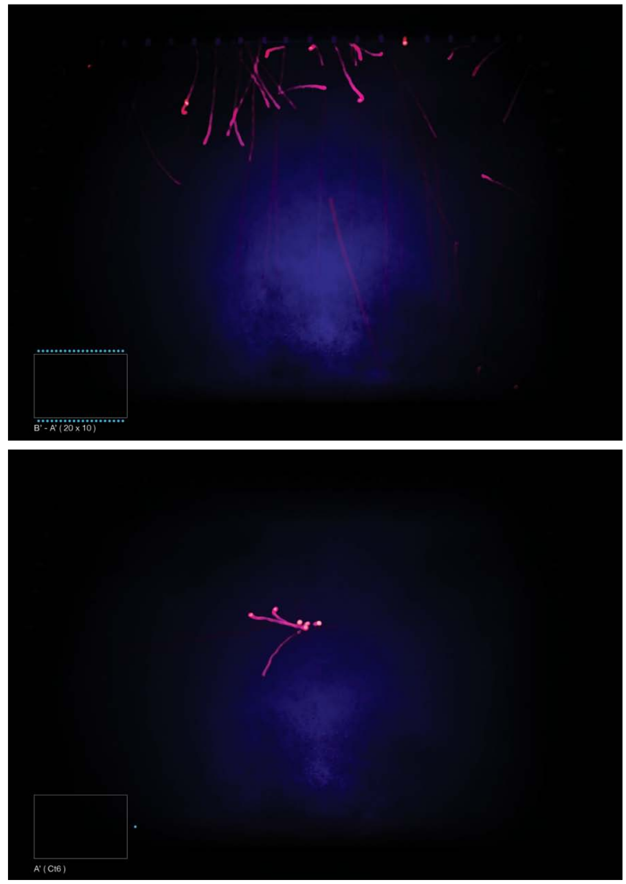

Figure 3. Drawing Energy Experiment by Niall Patterson and Yexi Tran. Niall and Yexi created a board upon which permutations of paint-coated steel balls were shot like pinballs, creating complex collision patterns. Long-term exposure photographs captured these patterns. Particularly conducive to readings at extremely fine scales, these photographs raise the issue of what scales of observation best facilitate reading energetic exchanges in the built environment.

Energetic Scales and Extents

Clear understanding of the relationship between matter and energy required clarifying the scales and extents of observation most conducive to exploring these exchanges. Students generally had difficulty navigating scales of relevance, and in particular struggled with the multi-scalar possibilities of drawing energy. This was best highlighted when students were asked to translate energy drawings, which were most often understood conceptually as operations occurring at very fine scales to the broader territorial scales of the site. (Figure 3)

While construction materials are generally sized in relation to the dimensions of the human body or to the dimensions of modes of transport, the scales of operation of luminosities, thermal exchanges, meteorological forces, or acoustic resonances vary substantially. It is tempting to expand scales of observation far beyond that of the traditional dimensions of construction. Philippe Rahm suggests a scalar shift "from metric composition to thermal composition, from structural thinking to climatic thinking, from narrative thinking to meteorological thinking. Space becomes electromagnetic, chemical, sensorial and atmospheric with thermal, olfactory and coetaneous dimensions." [9]

This expanded scalar reading is exciting as it opens broader spatial possibilities and conceptual readings. It acknowledges that the behaviors and tendencies of energy operate spatially at very different scales than do traditional building materials. This expanded scalar reading is, however, also problematic. At a certain scale, energy / matter binaries unravel. Certainly at the subatomic level, distinctions between matter and energy disintegrate, as Einstein's mass-energy equivalence theory captures, and the distinction between "static" materials and "shifting" energetic exchanges no longer holds. Furthermore, working skillfully with energy at scales beyond those familiar to architects requires an informed understanding of sophisticated technical disciplines such as particle physics or human anatomy. While architects are skilled at mining lateral disciplines, this mining tends to be more productive in softer disciplines where creative interpretation and metaphorical readings are reasonably transferable.

Galiano offers a counter view to Rahm. In the first passage of *Fire and Memory: On Architecture and Energy,* Galiano argues for a protection of the traditional architectural scales when observing energy/matter exchanges:

> Architecture does not exist as an object of knowledge outside of what physicists call *intermediate* dimensions. At the scale of the very big and the very small, one may speak of the architecture of the cosmos or the intimate architecture of matter, but this involves a metaphorical use of the term. The architecture we refer to here has the scale of the building or the city. Of course the distinction would not easily hold in situations belonging to another dimensional field: in high-energy physics, for example…What is important here is that in our immediate environment… the distinction between matter and energy is epistemologically and phenomenologically valid.[10]

While Rahm and Addington advocate for an expansion of the spatial scales of observation in architecture, from the microscopic to the territorial, this seems to deny the importance of the local implications of these exchanges on the built environment.

Rather than reconfiguring scales of spatial observation, in the Drawing Energy studio, it became more productive to reconfigure the scales of temporal observation to highlight process and exchange within timeframes, seasonal or otherwise, that are relevant to those exchanges. Further, it became productive to expand the extents of observation beyond building footprints to include any broader context that impacts the meteorological and microclimatic effects on buildings. Broadening the extents of investigation to capture a wider context not only acknowledged that exterior conditions directly impacted those in the interior, it introduced a broader spectrum from full enclosure to full exposure from which to test the implications of energy spatially. Energetic thinking required thinking equivalently of interior/exterior conditions. (Figure 4)

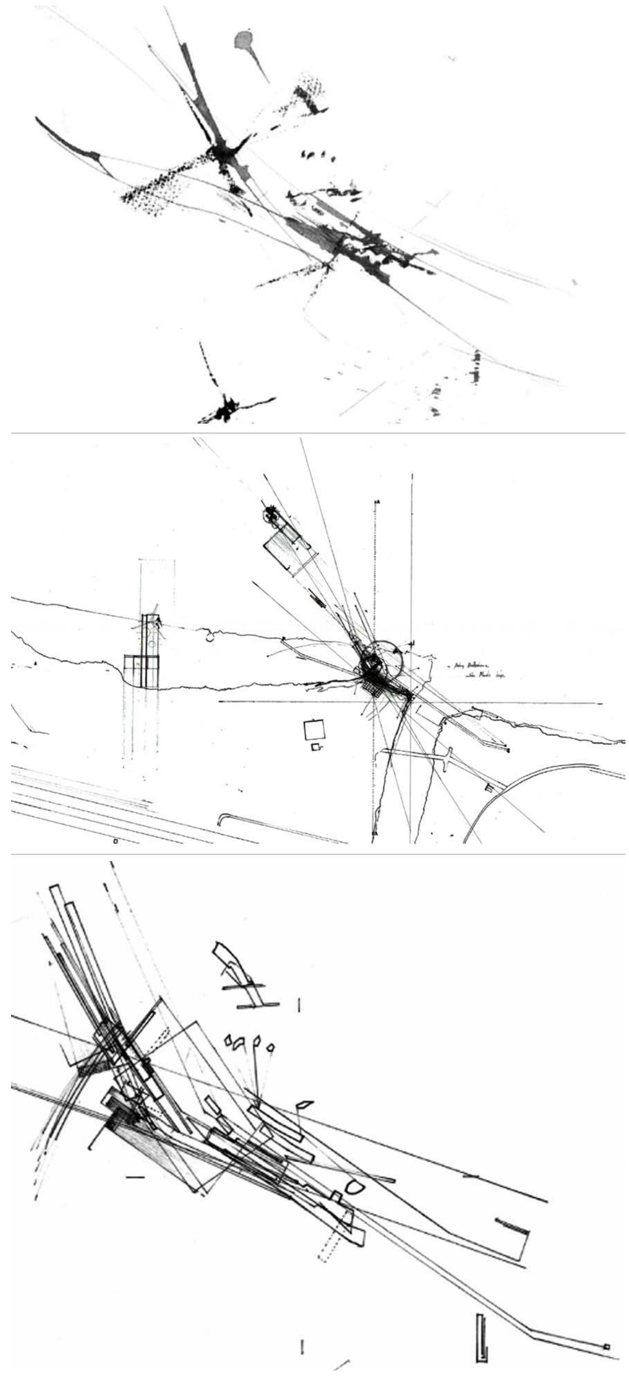

Figure 4. Niall Patterson developed a drawing strategy that overlaid fixed with variable building and site conditions. Revising extents of observation to include larger territorial exchanges encouraged thinking about interior/exterior conditions with more equivalence. Partnership.

ENERGY TAXONOMIES

Students were asked to design a renewable energy landscape that capitalized on the abundance of naturally occurring solar, wind and tidal energy available on their coastal site. The renewable/non-renewable binary, while useful for discussing issues related to temporal registration of kinetic energy on mechanical implements, offered less in terms of establishing a coherent vocabulary for discussing energy spatially.[11] The way we taxonomize energetic conditions reflects further limitations in our vocabulary for discussing energy spatially.

Operational / embodied energy focuses on units of stuff depleted. Renewable / non-renewable classifications focus on the source of the stuff that will be depleted. Neither taxonomy illuminates behavior; neither is conducive to experiential or physiological readings. While not clear during the teaching of the studio, upon reflection, two possible alternatives for categorizing energy have emerged: Galiano offers a taxonomy tied specifically to the human body and I offer a taxonomy tied to the second law of thermodynamics, understanding energy transformation in relation to work and to heat. Both alternate taxonomies lend themselves to spatial and experiential reading.

Galiano ties his taxonomy of energy to the human body through the concepts of endosomatic and exosomatic energy. Endosomatic energy is energy that is internally consumed and has fixed consumption limits. It is the internal energy required for metabolic processes and can be likened to a closed-loop system in which there are biological limits on input based on the limits of caloric intake.[12] Exosomatic energy is that which occurs outside of the body. It has no input limits. It is an open loop system in which limits on consumption are tied to larger economic variables and are reflected in contemporary social inequities tied to globalization. Galiano's taxonomy makes clear distinctions between energy consumed inside vs outside of the human body. While schematic and requiring further development of hierarchy classifications, this distinction points to potentially fruitful understanding of energy as something that exists in either open-loop or closed-loop systems and is registered both within and outside of the human body; it has spatial dimension.

Focusing on energetic transformation, a closer reading of the first and second law of thermodynamics yields another potential taxonomy, one that orders energy by work and heat. The second law of thermodynamics states that molecular activity in a closed system contains both uniform molecular motion, which yields work, and random molecular motion, which yields heat. I see this distinction between work and heat as being particularly fruitful when discussing energetic impacts in the built environment.

Work is understood as movement visually registered. This could be the movement of people, tied to notions of the energy of production or cultivation; mechanical movement such as that of wind turbine blades which visually register wind's kinetic energy; or the movement of the stuff of the natural world such as waves, wheat fields, leaves in trees.

Heat is understood in terms of modes of thermal transfer, convection, conduction and radiation and is generally physiologically registered. Here, issues related to passive heating and cooling and microclimate modification resonate. These distinctions require refinement and have similar limitations in terms of developing clearer organizational hierarchies and are perhaps better understood as dialectics than as taxonomies. However, this reading provides a more direct platform for discussing energy transformation in space, encouraging design engagement.

DRAWING ENERGY

Conventions

In order to engage more fully with energy as a spatial topic, our modes of drawing and testing energetic conditions need fine-tuning. The best work of the *Drawing Energy* studio took place in the first exercise when students were asked to conduct and then draw an energy transformation. The range of topics explored and the richness of drawings enacted opened fertile territories for investigation. When students were asked to draw the energetic exchanges that colluded with their designed buildings/landscapes, however, drawing these conditions proved difficult. The paralysis induced was tied partially to confusion about energy behavior and scales of operation as previously explored, but it is also tied to limitations of familiar drawing precedents.

The conventions we use for drawing energy range from the highly diagrammatic to the highly prescriptive; neither offer generative cues. In conventional technical teaching about microclimate modification and passive heating and cooling strategies, drawing is used as an analytic, not a generative tool. Techniques range from simple site or building plans overlaid with vectors indicating either wind movement/ventilation or sun angles/shading patterns to computational fluid dynamic models that illustrate more complex thermal exchanges over time.

There are a few obvious limitations to the ubiquitous environmental diagram. First, drawing the diagram requires first having a developed section upon which to overlay the diagrammatic content. This denies the stuff of the diagram, the thermal conditions, from playing a more active role in generating the section itself. Second, the diagram tends to be isolated to a single building section, which may represent an "optimal" condition, but suppresses all other spatial data not included in that section. Finally, the static nature of vectors, combined with the limited number of base drawings neglects the essence of these conditions, which are, by nature, shifting, ephemeral, varied and in flux. The diagram depicts a dynamic condition as one that is flat and static.

At the opposite end of the spectrum lies computational fluid dynamics, which offers an alternative way of visualizing thermal transfer and airflow. While cfd certainly addresses some of the deficiencies of the environmental diagram given its dynamic nature, it has limitations due to its complexity for younger students; it is perhaps also more beneficial as an analytic tool.[13]

I see two sources of limitation in both of these techniques that prevent them from being generative: their singularity of use and their rigidity of output. I will conclude with two suggestions for how we might develop these techniques further; one suggestion looks back to the work of Victor Olgyay and one involves looking sideways to a lateral discipline, landscape architecture. Olgyay's *Design With Climate* provides a broad overview of techniques for analyzing climatic conditions and attuning building form and orientation to these conditions. While some of the techniques developed are perhaps too quantitatively elaborate, Olgyay's strength in *Design With Climate* lies in the diversity of techniques devised to test a range of conditions at a range of scales. It is perhaps not that the environmental diagram or the cfd model are deficient in and of themselves, it is their singularity of use that is more problematic. If each representational mode offers opportunities and limitations, diversifying techniques provides a fuller collective reading of conditions.

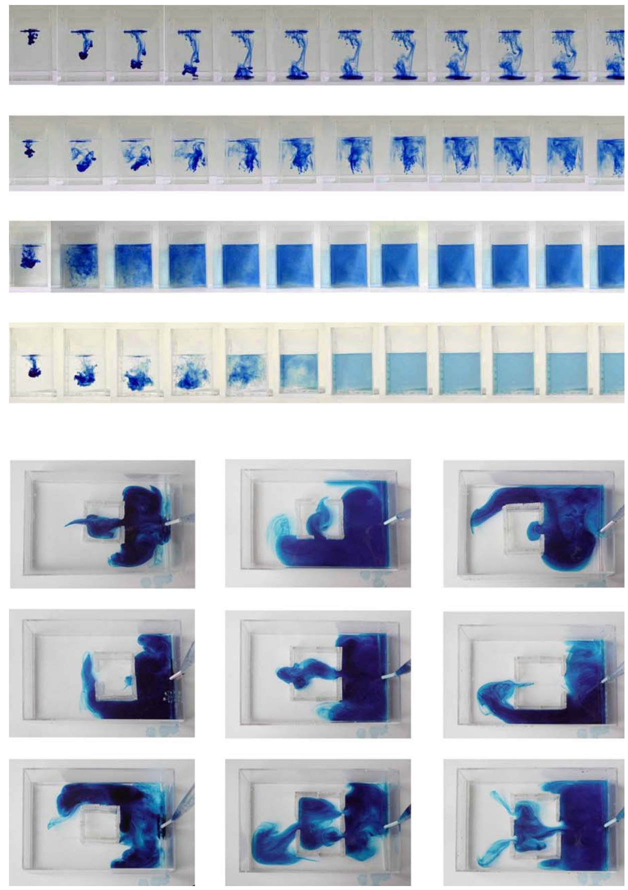

Figure 5. Emilie Tennant and Carin Nakanishi tested the impact of physical obstruction on flow. These tests share a lineage with both Victor Olgyay's wind/smoke studies as well as physical models chronicled in On the Water: Palisade Bay (see endnote 15). The physical model allows for simple empirical tests for understanding fluid behaviors.

With increasing advances in computational fluid dynamics, it is tempting to rely solely on the digital realm for visualization methods, but engaging directly through empirical observation often more directly facilitates understanding of fluid tendencies. (Figure 5) It is the reciprocity between multiple representational modes that yields fuller spatial understandings.[14]

As a discipline, we may be suffering myopia induced by the increasing precision afforded by digital modes used for form generation and energy visualization. When exploring energetic conditions, which involves exploring conditions that are shifting and in flux, perhaps our drawing and modeling strategies need to loosen up rather than gain precision. In this way, we may benefit by looking laterally less towards engineering and more towards other creative disciplines. Landscape architecture, in particular, is a discipline more fluent and comfortable working with ephemeral conditions of dimensional ambiguity. Work and writing by people like James Corner and, in particular, Anuradha Mathur and Dilip Da Cunha,[15] yields fertile territory for exploring how we might draw and design for conditions that ebb, flow, fill and track.

CONCLUSION

I recently completed teaching *Drawing Energy 2: Isle of Kerrera*, sited on the Inner Hebrides of the western Scottish coast. The conception of the studio was informed by a critique of the successes and limitations of *Drawing Energy 1: Abu Dhabi* that have been outlined in this paper. What is at stake pedagogically is how we teach an expanded reading of energy that qualifies as much as quantifies. By giving energy spatial, material and organizational consequence, it can take on more responsibility in the design process.

The successes and difficulties faced by the *Drawing Energy* students highlight a number of conceptual difficulties that mirror those within the discipline. This paper has offered a schematic overview of these three topical areas with hopes that by providing a clearer conceptual foundation, we might work with more precision on the details within that schema.

First, a clearer understanding of energetic behaviors and tendencies specifically in relation to materials requires an expanded reading of energy/material exchanges. The scales of observation that we use to analyze these exchanges impacts our understanding of them and there are differing opinions on the relevant scales of observation that are most conducive to a sound and accurate reading of energy in the built environment. I suggest that it is not necessarily the spatial scales of observation that should be extended, but the temporal scales and the spatial extents of observation that yield more fruitful spatial insights. The taxonomies we use to categorize energy are not robust enough to accommodate spatial readings, and I have offered two tentative alternatives, endo and exosomatic energy and heat and work, that require further exploration, but expand possibilities. Finally, the representational strategies we typically use to describe environmental/energetic exchanges vary from the highly schematic to the overly prescriptive. I have suggested that a turn towards the empirical and a broader range of strategies may be necessary to fully comprehend energetic tendencies and that perhaps we should loosen rather than tighten our tolerances and look towards landscape architecture for relevant precedents. Understanding energy as "the subtle something that has the ability to make nature do work"[16] requires a disciplinary expansion in thinking, but it is an expansion worth doing as it provides a fuller reading of a topic of significant environmental and ecological consequence.

ENDNOTES

1 Illich, Ivan. "The Social Construction of Energy." *New Geographies 2*. Harvard University Press, 2010, 11-19. Text is a previously unpublished opening talk, "The Basic Option Within Any Future Low-Energy Society," El Colegio de Mexico, July 1983.

2 Ibid.

3 Lally, Sean. "Twelve Easy Pieces for the Piano." *Architectural Design: New Material Boundaries*: 79. John Wiley & Sons (2009): 7-11.

4 For a very basic overview of thermodynamic principles, see Atkins, Peter. *The Laws of Thermodynamics: A Very Short Introduction*. OUP Oxford, 2010.

5 The value of converting all units of energy to the same base unit for cross-comparison is illustrated in MacKay, David J.C. *Sustainable Energy - Without the Hot Air*. UIT, 2008.

6 Addington, D. Michelle, and Daniel L. Schodek. *Smart Materials and New Technologies for the Architecture and Design Professions*. Architectural Press, 2005.

7 Ibid., 51.

8 While beyond the scope of this paper, a schematic thermodynamic history of architecture that visually traced the relationship between thermal boundary and physical enclosure from vernacular architecture to modernism to contemporary "smart" building envelopes would yield a vast range of thermal/enclosure variations that mirror shifting attitudes about active vs passive modes of heating and cooling and the politics of conditioned air.

9 Rahm, Philippe. "Meteorological Architecture." *Architectural Design: New Material Boundaries*: 79. John Wiley & Sons (2009): 32.

10 Fernandez-galiano, Luis. *Fire and Memory: On Architecture and Energy*. Illustrated edition. MIT Press, 2001: 2.

11 A related point: the temporal disjunction between renewable energy and non-renewable energy production points to radically different scales of temporality. Renewable energy often visibly harvests or converts energy in "real" time, whereas there is a substantial temporal and spatial gap between subterranean

carbon-based energy, transport and consumption. This is explored in Ghosn, R. New Geographies 2. Harvard University Press, 2010.

12 This reading expands our understanding of energy to include the human energy required for material cultivation and production. This reading has interesting implications on embodied energy, which typically doesn't account for the politics of the human energy utilized for material production.

13 Lally suggests that cfd has generative potential in Lally, Sean, and Jessica Young. *Softspace: From a Representation of Form to a Simulation of Space*. New Ed. Routledge, 2006: 4-5

14 The work of Guy Nordenson, Catherine Seavitt, Adam Yarinsky and Princeton University's School of Architecture is a particularly relevant contemporary precedent of the use of multiplc analog and digital methods used to visualize complex fluid exchanges. Digital fluid dynamic modelling was used in addition to empirical physical models to test the impacts of land formations in the complex intertidal zone of New York's harbor region. See Nordenson, Guy. *On the Water: Palisade Bay*. Hatje Cantz, 2010.

15 See, in particular, Anuradha Mathur and Dilip da Cunha. *Deccan Traverses: The Making of Bangalore's Terrain*. Rupa & Co, 2006.

16 Illich, "The Social Construction of Energy."