Urban Futures: Adaptable Resourcing Infrastructures, Buildings, and Envelopes

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Understanding the totality of urban life remains an unsolved puzzle. As cities are transformed, so are our visions and positions toward them. Whether we identify cities as seamless or disjunctive urban membranes, the complex structures of nature and artifice intersected by human life render cities into an evolving conundrum. And yet society fundamentally agrees on the fact that urban quality of life is primarily based on a dynamic equilibrium of material and informational resources where inhabitants have access to robust physical, socioeconomic, and intellectual infrastructures. But if dynamic equilibrium of urban resources is the aim, what strategies can guarantee its necessary resilience? During the late-twentieth century, this discussion revolved around developing strategies of mitigation. Yet, the rate and densities of new constructions, particularly in emerging metropolises, required a reassessment of preexisting approaches *(1)*. In response, a new vision based on principles of urban adaptability and resilience is shifting how we position ourselves toward resources. Adaptable cities are considered as contexts capable of responding and adjusting dynamically to both physical and nonmaterial urban parameters. Originating from this approach, a new frontier of urban strategies is emerging in which adaptability and resourcing intersect. ***Adaptable resourcing*** is founded on resilience and adaptability as a means to synergistically capitalize on the versatile and complex processes present in urban resources. Whether pressing urban challenges derive from resource scarcity, excess, unpredictability, or various combinations, the equation of how we supply energy, water, and food and process waste must shift.

Adaptable resourcing is twofold. Its derived technologies must both provide integrated multifunctionality and be designed interdependently from the small to the large scales. Multiscale interdependencies is a fundamental performance criteria to the design of built environments. As with multifunctional matter *(2)*, these new building systems are established to provide benefits far beyond the mere addition of high-performance components. Energy and matter are seamlessly integrated to synergistically regulate methods to capture, concentrate, transform, redirect, and process resources that dynamically adapt. Such buildings and urban infrastructures are actually designed to work with and capitalize on environmental and climatic flows. But radically new sustainable architectural and engineering urban practices cannot be met through traditional methods of research and collaboration. Consequently, architecture, engineering, and science are converging to establish new sustainable technologies from the inception of the research process. In 2010, the National Science Foundation (NSF) established the 2010 EFRI-SEED awards *(3)*, recognizing the need for transformative research frontiers of sustainable buildings and infrastructures. With this aim, the NSF requested, for the first time in its history, the incorporation of architects into the proposal teams, cementing a new frontier of interdisciplinary collaborations. This event cemented the grounds for funded research collaborations among engineering, architecture, and science. The NSF Emerging Frontiers in Research and Innovation-Science in Energy and Environmental Design (EFRI-SEED) funded 10 projects deemed as transformative research in this field. At the center of these proposals is the aim to augment adaptability, resilience, and resource efficiency of built environments from simulation capabilities to new building systems. New **adaptable resourcing methods** based on multifunctional and selective capabilities (energy and matter integration) are presented through a set of studies concentrated at the infrastructural, building system, and building envelope scales.

The first category addresses adaptable resourcing strategies developed for new **urban infrastructures**, integrating **energy and water**. This discussion is framed through *Local Code* (UC Berkeley: de Moncheaux), a research study that intersects hydrology, landscape architecture, civil engineering, city planning, real estate, and policy. The *Local Code* pilot study finalist at the WPA 2.0 International Competition *(4)* was designed for San Francisco. Yet, it could be applied to major U.S. cities with city-owned abandoned lots, including New York, Los Angeles, Chicago, and Washington, DC. Through geospatial analysis, the study identified thousands of publicly owned abandoned sites that could be used to optimize thermal and hydrological performance. The identified vacant lots could be used as means to relieve, in an integrated fashion, the burden on existing urban infrastructure (water and energy) by contributing to substantially diminishing water runoff and heat island effects. Interdisciplinary variables spanning from hydrology to policy were intersected into a unique parametric design that landscaped each vacant lot to local resource requirements, enhancing urban performance, and relieving burdens on its existing infrastructure. *Local Code*'s quantifiable, integrated benefits on energy conservation and storm water remediation eliminate the need for sewer and electrical upgrades. Overall, urban quality of life and resource performance can be obtained by a robust network of locally tailored systems of adaptable resourcing at the urban level.

The **second category** presents research focused on advancing **energy** and **matter** concentrated on the **building envelope**. This topic is discussed through the NSF EFRI 2010 funded research *Energy Minimization via Multi-Scalar Architectures: From Cell Contractility to Sensing Materials to Adaptive Building Skins* (NSF-EFRI-SEED Award #1038215). This research is established by a unique interdisciplinary collaboration that includes engineers, design architects, and cell biologists (e.g., Yang, Sabin, Lucia, Engheta, Jones, and Van der Spiegel) from the University of Pennsylvania. The team is investigating the flexibility and sensitivity of human cells as the models for next-generation building skins that adapt to changes in the environment. The "eSkin" *(5)* consists of a responsive biomimetic membrane that combines the engineering of passive materials and sensors that integrate devices at the nano- and micro scales for accomplishing climatic adaptability to augment energy and material efficiency.

The **third category** discusses research that interpolates the scales of the first two categories. It is presented through a building system focused on **water**, **energy**, and **waste** activated at the **building envelope** and distributed internally across the **full-building** scale. *SOAP for GRIT* (NSF-EFRI-SEED Award #1038279) research establishes an integrated greywater and thermal building control system activated by solar energy, designed for regions of acute water scarcity with heating requirements that span a wide geographic range *(6)*. *Solar Optics-Based Active Panels (SOAP) for Greywater Reuse and Integrated Thermal (GRIT) Building Control* intersects architecture, civil engineering, and bioengineering (UC Berkeley: Gutierrez, Hermanowicz, Lee). Sunlight is used to capture and store energy as a means to disinfect greywater, providing an integrated method to balance water demands and day and night thermal shifts in high-density buildings particularly located in hot-arid and temperate and dry winter-tropical savannah regions. The research of solar water disinfection, heating and its potential use for thermal management was initiated many decades ago *(7) (8)*. Nevertheless, *SOAP for GRIT* is opening a new research frontier in this field by establishing **microoptics and microfluidics** technologies on a thin-lightweight panel system with the potential to perform in variable geometries and orientations. Its nano and microengineering basis has the potential to supplant ongoing research designed through mechanical infrastructures and/or large optic or tube systems. A comprehensive greywater disinfection method is structured through an integrated microarray optical detection system (microlenses) *(9)* placed on a polymeric substrate combined to photocatalytic suspended nanoparticles. The investigation also evaluates potential failure mechanisms (e.g., optical, optofluidic interface, thermal, structural, and biological) dependant on variable urban densities. *SOAP for GRIT* aims to *adaptable resourcing* by integrating interdependencies between water, energy, and waste addressed from nanoengineering to architecture and from the building envelope to the urban scale.

The emergence of a transformative interdisciplinary culture between engineering, architecture, and science is bound to revolutionize sustainable urban and building technologies. Adaptable resourcing strategies can transform the future of cities and the cities of the future.

References:

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(2) Y. Bar-Cohen, *Biomimetics: Biologically Inspired Technologies* (Boca Raton, FL: CRC Press, 2006), 309–13.
(3) NSF EFRI-SEED awards, available at: http://www.nsf.gov/news/news_images.jsp?cntn_id=117731&org=EFRI
(4) WPA 2.0 International Competition, available at: http://wpa2.aud.ucla.edu/info/index.php?/theprojects/local-code/
(5) ESkin press release: NSF EFRI-SEED award, available at: http://www.design.upenn.edu/news/sabin-jones-and-lucia-penndesign-and-school-medicine-awarded-2000000-nsf-efri-seed-grant
(6) SOAP for GRIT, available at: http://newscenter.berkeley.edu/2010/08/26/grey_water/
(7) The first study of the sunlight effects on microorganisms was published in 1877. See: J. Blanco-Galvez, et al., "Solar Photocatalytic Detoxification and Disinfection of Water: Recent Overview," *Journal of Solar Energy Engineering, Transactions of the ASME* 129, no.1 (2007): 4–15.
(8) MIT's *Solar I*, a prototype built in 1939, constituted the first house in America conditioned by solar energy (hot water). Available at: http://mit.edu/solardecathlon/solar1.html
(9) L. Lee, J. Kim, and K. Jeong, "Artificial ommatidia by self-aligned microlenses and waveguides," *Optics Letters* 30, no. 5 (2005).