

HELIOStudio: Designing the Energy Commons

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Renewable energy technologies are transforming our landscapes with distributed installations that have the potential to reshape the commons. HELIOStudio at Carnegie Mellon University speculated how solar technologies and the (re) emergence of distributed energy infrastructure will reshape the relationship between landscape, urban form, spatial practices, and organizational structures. What new rituals and practices might arise if the means of production and consumption were contained within a site, a neighborhood, or a city? HELIOStudio examined the urban structure of energy landscapes and the community structure of an energy commons to advance social, environmental, and economic justice. Grounded in urban theory and technical strictures, the studio engaged the nonprofit Land Art Generator Initiative (LAGI) and several other technical and community experts. The studio resulted in a replicable method for organizing energy landscapes, spatial proposals for an energy-informed commons, and implementation protocols that enable new organizational structures and shift the balance of power to communities and individuals.

The paper will share three streams of HELIOStudio investigation: PERSONAL ENERGY, LOCAL ENERGY, and URBAN ENERGY. The human dimension of energy was analyzed in PERSONAL ENERGY, where lived experience and the invisible flows of energy technologies and policies were visualized. LOCAL ENERGY investigated how distributed solar technologies might inspire new urban practices and engagement with urban drosscapes, ranging from performative inventions to ritualized solar installations. Lastly, URBAN ENERGY's design proposals and community engagement informed possibilities for industrial-scale production within the confines of the city and examined the technostucture of production and consumption. Together, the findings have informed designers, policymakers, and planners on the potential of new energy landscapes.

ENERGY TRANSITION AND THE COMMONS

After two centuries of dependence on fossil fuels and “buried sunlight,” there is broad convergence that we are on the cusp of an energy transition to carbon-free fuels. Energy transition and the adoption of new technologies will require new spatial patterns and practices, all of which are design opportunities. A carbon-free transition needs to occur globally to shift the trajectory of climate change. It will start at the scale of the site and the city where technical challenges and cultural practices will create alternative landscapes of energy generation¹.

It makes sense that rich nations such as the United States that have contributed the most to historical emissions and reaped the greatest wealth from fossil fuels should take the lead on decarbonization, reaching a 50% reduction by 2035 and zero emissions by 2050². This urgent transformation in the modes of energy production will have a significant impact on our visual landscapes and our built environment. This transformation of our urban fabric will be more drastic than that which came with the proliferation of the automobile and the construction of interstate highways in the middle of the 20th century. It is therefore important that these changes to our built environment be designed with intention so that the spatial injustices of the past are not repeated.

The complexity of permitting new remote greenfield energy developments and the transmission infrastructure required to connect them to population centers threatens to slow the pace of decarbonization. This is especially true in the wake of the 2022 Inflation Reduction Act, which incentivizes the electrification of home heating, transportation, and industrial processes, adding demand to already stressed electrical grids. Increasing the amount of distributed solar power and energy storage capacity installed in cities can help to reduce the need for centralized exurban power infrastructure and transmission, while providing design opportunities to bring social co-benefits to urban neighborhoods³.

When designed in collaboration with communities, solar installations can improve the quality of life and the beauty of public spaces. Photovoltaic modules can provide aesthetic shade, creating new microclimates that expand the comfort zone in

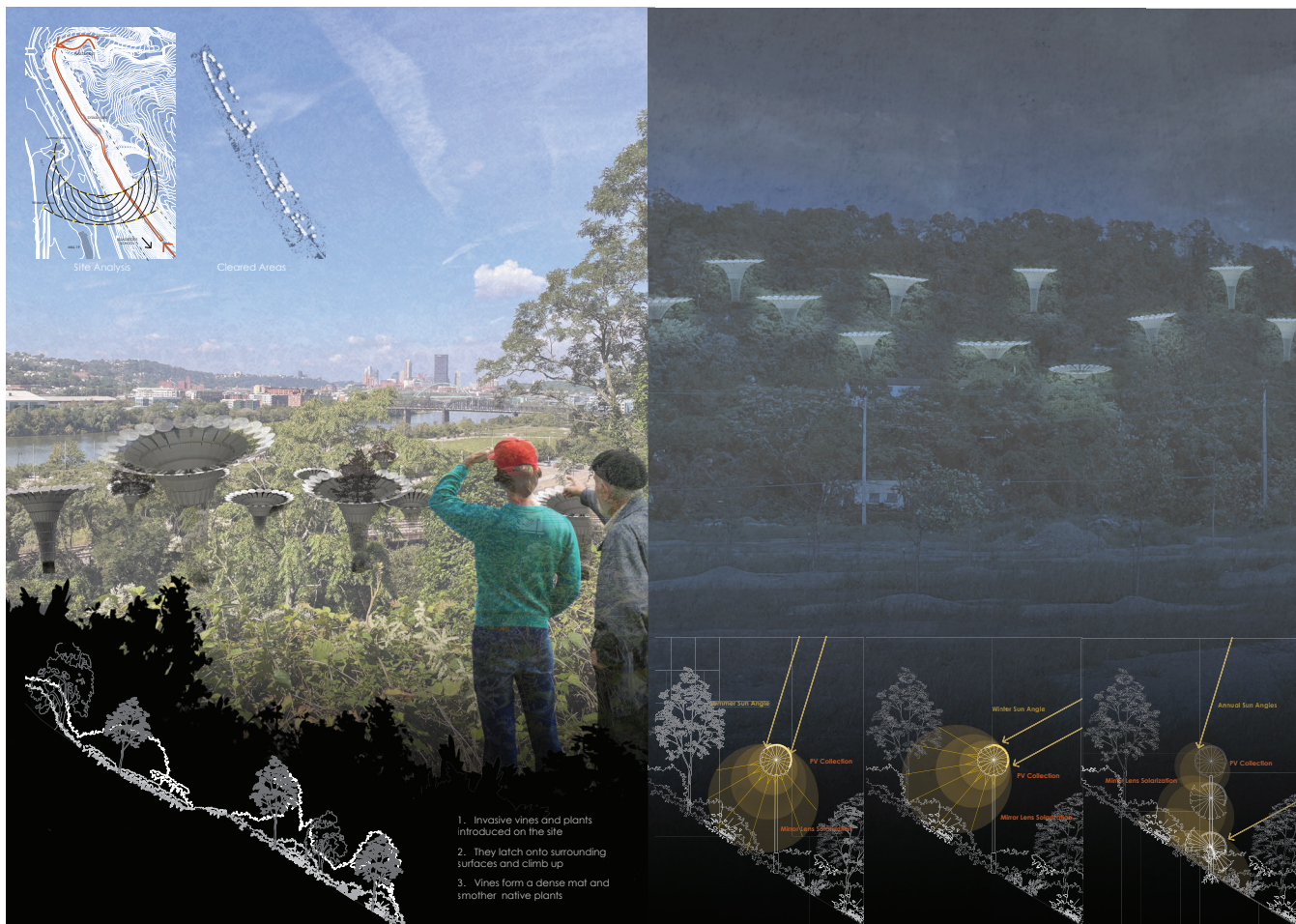


Figure 1. LOCAL ENERGY. Solarization Thistles concentrate solar energy as a nontoxic alternative to herbicides to eliminate invasive species in urban greenways. The Thistle regimen includes solarization and reseedling with preferred species. [Ammar Hassonjee and Elena Marzina].

hotter regions during the summer months for human activities in outdoor public spaces and reduce heat island effects. Solar photovoltaic energy production on reservoirs reduces losses from evaporation. The body of water also acts as a heat sink, keeping the solar modules cool and therefore operating more efficiently. Similarly, solar energy generation can make urban gardens more productive, help harvest stormwater, and reduce the need for artificial irrigation by reducing plant transpiration. Biodiverse and productive landscapes cultivated below solar modules also help improve their performance by keeping the photovoltaic panels cooler.

Community solar projects can provide opportunities for individual investors to benefit from low-risk rates of return and help tackle issues of energy poverty and the abuses of monopoly utilities when designed with an eye towards social return on investment. Community solar with storage can offer additional revenue streams through energy services like demand management that keep the grid stable through periods of peak demand or remote outages.

In short, there is a need for designers to examine PERFORMANCE to accelerate the energy transition, PROCESSES that will integrate utility-scale urban solar into city-making, PEOPLE and the equitable management of decentralized systems, and the PUBLIC REALM in the remaking of the commons.

HELIOSTUDIO AND LANDSCAPES OF ENERGY

HELIOStudio examined how energy technologies will reshape our use of space and the reciprocal relationship between landscape, urban form, and distributed energy infrastructure. HELIOStudio investigated the micro patterns of personal energy use as well as the macro urban patterns as found in the neighborhoods of Pittsburgh, Pennsylvania. The inquiry looked through the lens of solar power generation to find new spatial qualities, ways of using space, and ways we can use energy technologies to experience familiar spaces in new ways. The studio explored the experiential and cultural connections to energy technologies to uncover the meanings behind what we make and how it shapes our understanding of the world.

Western Pennsylvania is a place of energy firsts. Some of the nation's earliest coal mines were found in Pittsburgh's hillsides and the black rock heated homes, powered steamships, and anchored early industries, enabling the city to grow. Western Pennsylvania is also home to the first commercial oil wells, the nation's first nuclear power plant, and is now the epicenter of the Marcellus Shale gas fields. All local energy stories are global and the gas fields have brought about the nation's newest ethane cracker plant that will process regional extractions into plastic products proliferated worldwide.

Energy commons are energy landscapes that are managed for sustainability. Each fuel has extraction and distribution networks and end uses that create a land use signature and settlement patterns; thus each fuel creates an observable landscape that can be characterized by its physical structure, its resources and flows, and its cultural practices. As Pasqualetti and Stremke write³, "Energy landscapes are co-constructions of space and society that come into existence through a series of material and social relations (Pasqualetti and Stremke 2018)." De Roo and Noorman paint a compelling picture of three generations of energy landscapes⁴ (Noorman and de Roo 2011). The first generation energy landscapes were interdependent physical and socio-economic landscapes where socio-economic activities and spatial practices develop in concert with production. Production and consumption were local and energy was not considered a public good to be organized by authorities--if energy was managed, it was proximity-based. The second generation energy landscapes of the industrial era are characterized by more intensive use of energy and fuel sources with higher power density. Consumption was spatially detached from production as extraction of fossil fuels from remote areas meant that there is little awareness of the impact on the commons. Distribution networks like railroads moved fuel and organized the landscape for efficiency and not for any spatial qualities. Today, the third generation of energy landscapes is arising from the clean energy movement. New forms of production and renewables such as solar, wind, biomass, and geothermal promise decentralized production that is dependent on the structure and capacity of the land, reconnecting us to the landscape through localized spatial practices.

Each successive energy technology has reshaped our culture and sense of place and has resonated with design opportunities. In addition, De Roo and Norman's decentralized third generation of energy landscapes point to the need for and likelihood of community activation, not merely as consumers of energy, but as producers who engage each other differently to fulfill their energy diet. As agents of change concerned with both the physical environment and socio-ecological systems, designers have a unique role in shaping future energy landscapes.

HELIOSTUDIO METHODS

HELIOStudio speculated how Pittsburgh might advance its history of energy innovation with the design of a third-generation

energy landscape and acquire the mantle of the first equitably integrated solar city. HELIOStudio used design to explore the energy transition through two reciprocal scales—a site scale design problem to build knowledge about carbon-free technologies within an urban context and a city-wide examination of the potential for energy generation and exploration of public realm design. Architecture and infrastructure were hybridized through critical engagement of technology, culture, and urban systems, with a goal of identifying 30 megawatts of generation capacity. This goal was set with the intention of meeting the economies of scale for photovoltaic module purchasing that centralized greenfield solar installations typically obtain. By aggregating a dozen 1–3 megawatt community solar installations across the city in ways that enhance the quality of life for people, the studio aimed to demonstrate the potential of cities to function as renewable energy landscapes at scale while enhancing public support for the energy transition.

HELIOStudio collaborated with Robert Ferry and Elizabeth Monoian, the founders of the nonprofit Land Art Generator Initiative (LAGI). Through a series of international competitions, LAGI has proposed "land art generators" that showcase renewable technologies; the studio tapped their technical knowledge of energy transition and drew inspiration to query how art might inspire collective action on issues of climate change. Both the workflow and products of the semester exercises in turn are informing future LAGI competitions focused on implementation in cities and neighborhoods. The studio work was intended to be both proof-of-concept and a road map for similar public processes in the future, using Pittsburgh as a test case.

The studio was structured as a semester-long query that resulted in summary documents that described site specific design recommendations, illustrated energy typologies for the public realm, demonstrated community engagement methods, and pointed to policy recommendations. The students explored through individual efforts and group projects and were expected to produce architectural and spatial designs, write and create narrative arcs, and illustrate key concepts and data.

HELIOStudio brought in visiting experts to share information on concepts such as:

- urban computational analysis (Nico Azel)
- community dynamics and engagement (Anna Rosenblum)
- energy systems and technologies (Steven Baumgartner)
- infrastructure and history of the city (Joel Tarr)
- competitions and design as change agents (Ray Gastil)
- public policy and implementation (Paul Martinchich)

STUDIO STRUCTURE

The semester consisted of a series of exercises that composed a multi-scalar energy landscape investigation, ranging

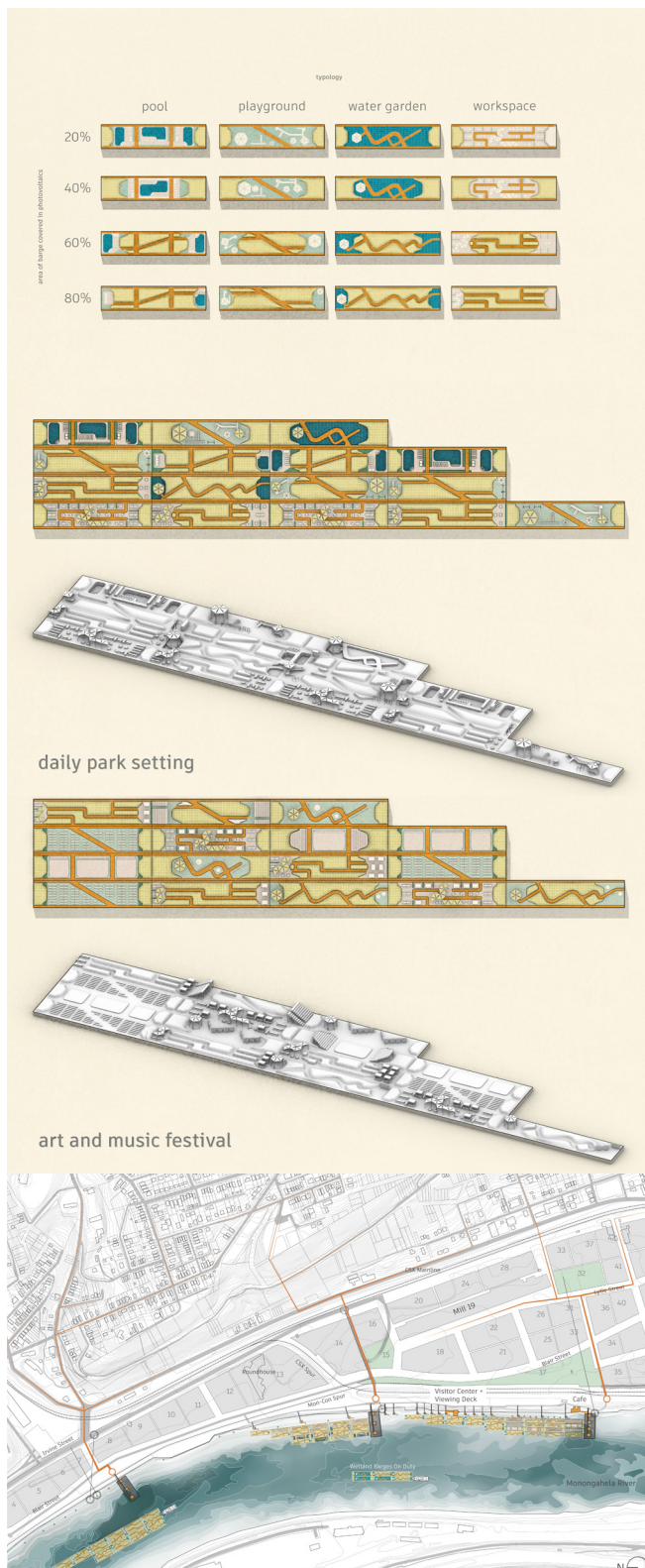


Figure 2. LOCAL ENERGY. Energy Barges are flexible and mobile configurations of energy generation, park space, and water ecology restoration. [Jasmine Lee and Yingying Yan]

from the individual scale, to the neighborhood scale, to the city-wide scale.

The work was produced primarily in teams of two, developed across four assignments. Assignments were constructed to allow students to bring their own interests to the query while seeking shared knowledge through team research. The assignments included:

ONE::PERSONAL ENERGY. Like most infrastructure, energy use is invisible to us until it is noticeably absent. PERSONAL ENERGY is an exercise to visualize the human dimension of energy. As an introduction to energy issues, the students became familiar with resources, frameworks, and vocabulary to build the case for their semester investigation. By starting with the individual scale, the exercise connected lived experience with invisible flows and difficult-to-visualize large quantities that often characterize energy technology and policy.

This project resulted in a series of well-produced, content-rich diagrams and a narrative presentation that can help a novice understand energy issues.

TWO::LOCAL ENERGY. In this exercise, the students designed an artful and performative installation in the public realm to explore the potential of generative landscapes. The students examined the structures inherent in solar technologies, the urban structure and its relationship to energy infrastructure, and community structure and the implications of cultural and spatial practices as related to energy. The project focused on five prototypical urban sites, a riverfront, a brownfield, a vacant lot, a greenway, and a cemetery in the Hazelwood neighborhood of Pittsburgh to ground concepts in the specifics of place.

This project resulted in “ideas competition” proposals for a solar installation, illustrating urban relationships, spatial and experiential qualities, performance potential, and community connections.

THREE::URBAN ENERGY. In this exercise, the students speculated on how the typologies and strategies of previous assignments might be replicated at an urban scale. The projects expanded upon the LOCAL ENERGY “proof-of-concept” exercise to test viability at a city-wide scale. The results of this exercise were intended to inform policymakers, planners, and architects about the potential of these strategies to accelerate the deployment of renewable energy, improve the public image of the post-carbon future, and increase the resilience and livability of cities.

This project produced a technology guide with urban solar typologies, an urban analysis and implementation guide, and protocols for community engagement that can be replicated in other places.



Figure 3. URBAN ENERGY. The Community Role Playing Game enables informed decisionmaking by communicating energy fundamentals while gathering community preferences. [Ammar Hassonjee, Elena Marzina, Susie Kim]

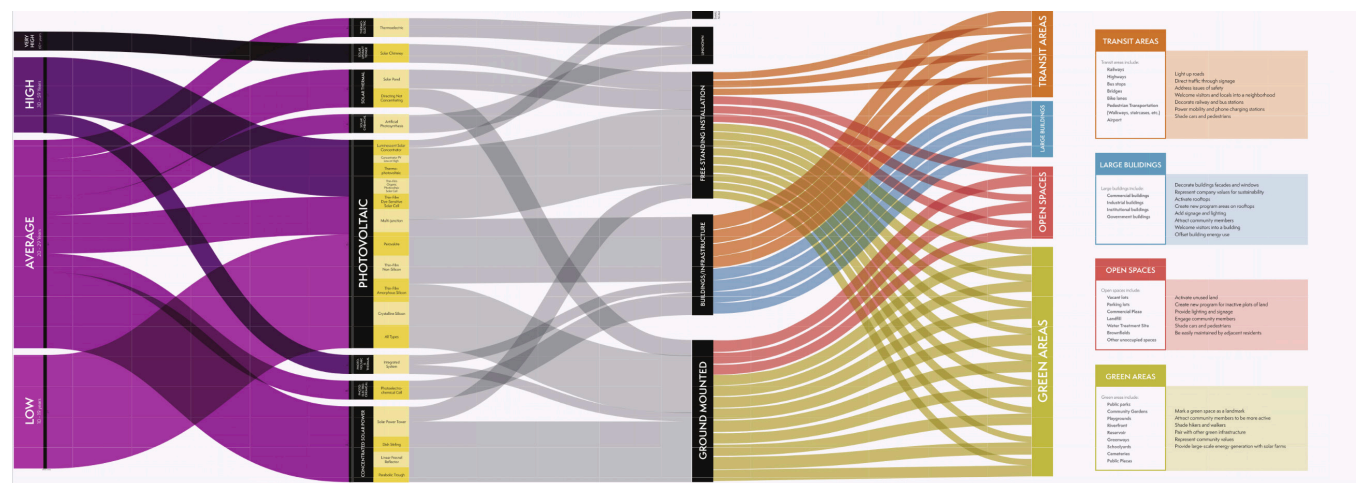


Figure 4. INITIATIVE. Benefit analyses compared technology lifespan, installation types, and community co-benefits. [Shanice Lam]

FOUR::INITIATIVE. This exercise was a self-defined effort to infuse student interests into the structure and assignments of the studio. This was loosely defined to encourage students to pursue their own query parallel to the group assignments.

The assignment resulted in a written narrative or drawing series, completed by each individual, on a topic of their choice.

EXERCISES AND OUTCOMES

Each exercise is explained in more detail, including findings from the student work.

ONE::PERSONAL ENERGY

Life requires energy and we live within an abundance of harvests--what is our energy metabolism?

Our lifestyles require a certain amount of energy to sustain and our individual metabolism creates a draw on the commons. The two scales are often disconnected and our perception of energy use is without perceptible magnitude. Understanding personal energy requires raising our awareness of direct energy use (e.g. for heating or cooking) as well as indirect energy use such as that embodied in materials.

The students explored energy in relation to energy use, sources, the concept of net-zero and net-positive, and the opportunity for design within energy systems. The students produced a series of graphically compelling and content-rich data visualizations as part of a narrative to assist a novice (and presumably future community members) in understanding energy issues.

Students estimated their personal energy use through a number of different calculators or other methods. They compared their energy use in relation to the global average, and analyzed how the usage was reflected in spatial practices. By exploring multiple measuring methods and software, they could evaluate what each measured and what each omitted, as well as the time frames and units of measurement.

In addition, the students investigated the representation of energy flows through graphical analysis, and trends of use over time. Energy flow charts, or Sankey diagrams, visualize the transformation of resource flows through different lenses, and the students benchmarked historical and current source-and-use relationships for Pennsylvania using data from the Lawrence Livermore National Labs Energy Flows project⁵ (Lawrence Livermore Labs n.d.). The LLNL data has aggregated thousands of lines of data to visualize energy flows by state for a number of years, and from these diagrams the students were able to visually compare sources and uses over time and in different geographies.

TWO::LOCAL ENERGY

What does it take to make solar infrastructure that serves as a romantic backdrop for a kiss?

In this exercise, the students designed an artful and performative installation in the public realm to explore the potential of generative landscapes. The students examined the structures inherent in solar technologies⁴, the urban structure and its relationship to energy infrastructure, and community structure and the implications of cultural and spatial practices as related to energy. The project focused on five prototypical urban sites, a riverfront, a brownfield, a vacant lot, a greenway, and a cemetery in the Hazelwood neighborhood of Pittsburgh to ground our ideas in the specifics of place. The project resulted in "ideas competition" proposals for a solar installation, illustrating urban relationships, spatial and experiential qualities, performance potential, and community connections.

For this exercise the students addressed technostucture⁵, using photovoltaic or solar thermal technology to meet an existing demand and establish a balance between the functional use of the site and the production of energy. The students also learned about urban structure to understand the history, geography, and details of the design site, and the broader context of Pittsburgh. Lastly, the students investigated community structure to consider the social, environmental, and economic justice aspects of their energy installation, positioning the proposal relative to issues such as racial injustice, energy poverty, sustainable mobility, affordable housing, etc.

THREE::URBAN ENERGY

How do we take experiential energy systems to scale?

Through PERSONALenergy and LOCALenergy the students explored corporeal and cultural connections to energy and probed the experiential potential of localized energy systems. During the second half of the semester we shifted scales to understand the possibilities of the city as generator, and speculated on how infrastructure might integrate into cultural practices, redefining the public realm.

URBANenergy defined a replicable and generative methodology that could be applied in cities around the world by identifying 30 megawatts of energy across the City of Pittsburgh as a proof of concept. The students sought design opportunities, performance potential, and community concerns across four neighborhoods and extended the findings to the city.

The students were organized into three teams to explore:

Typologies [generalized urban integrated typologies]
What technologies can be used in urban settings and what principles can be used to shape the public realm?

Urban Performance [urban solar capacity analyses]
What is the generative potential for a city and what rituals, behaviors, and social structures will arise with a city-wide approach?

Community [tools for engagement and empowerment]
Given the emerging infrastructure, how do we ensure equitable outcomes with protocols that create agency and empowerment?

The students created a Solar Public Realm Guide of spatial typologies and administrative models that operate with urban integrated solar technologies, and illustrated examples in four communities. The students defined an Urban Solar Capacity Assessment Method, including neighborhood-specific evaluation methods, and prototyped the methods in four communities. Lastly, the students organized a Community + Energy Protocol consisting of methods and tools for community power and engagement. The Protocol was informed by the students' experience orchestrating a community engagement process called "Breaking Bread," a series of three community meetings where the students presented their material to introduce the concepts, gather feedback, and ground the theories of the first half of the semester. The community cohort included four neighborhoods and municipalities in and around the city of Pittsburgh. Resident experts from each community were paid to share their knowledge of their communities and their perspectives on energy infrastructure.

FOUR::INITIATIVE

Where can your personal interests add knowledge to the field?

This self-defined effort allowed the students to infuse their interests into the group studio investigation. For this project, each student proposed a topic to pursue in greater detail, ranging from the continuation of a previous project, a researched essay or narrative, or a drawing investigation into some aspect of energy or urban space. The student topics included: Reimagining Energy Ecologies: Post Extraction Futuring at Pittsburgh's Abandoned Schools, The Role of Competitions in Energy Transition, and Biointelligent Algae in Urban Environments, among others.

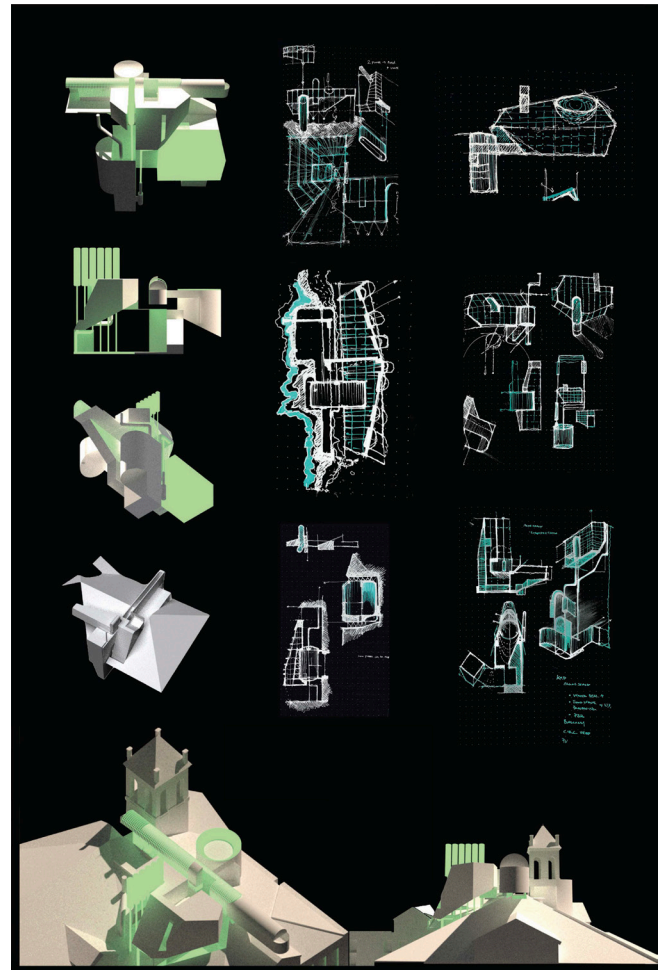


Figure 5. INITIATIVE The Algae Biofuel Kit of Operations integrated algae technologies in vacant schools. [Shariq Shah]

HELIOSTUDIO SUMMARY

HELIOStudio succeeded on three levels: it generated new knowledge about how utility scale urban solar can be integrated into an urban environment, it provided direct benefit to the participating community stakeholders, and it provided a rich tapestry of collaborative experiences preparing the students for practice.

Students discovered an expanded role for designers in infrastructure that is typically dominated by engineers. They discovered that challenges to implementation can become design opportunities and that designers need to be facile with technical structures, social structures, and governance and economic structures. The students created new urban forms and methods, such as a typology of distributed solar

infrastructure, a “possible-probable-preferred” method for project implementation, and practice protocols to ensure that quality of place is not sacrificed in the race for performance.

Embedding the project in the community had anticipated and unexpected benefits. As part of their investigation, the students were able to participate in the planning process for an city-led 2 megawatt solar park, a first for the city’s redevelopment agency. Representatives from the agency participated in the studio process and the student work on public realm design standards and community engagement protocol were essential to inform the work. The community representatives were similarly enthusiastic about the multi-meeting process and were able to implement what they learned in advocacy efforts in their neighborhoods. The community representatives asked for copies of the game and educational materials for use in their neighborhoods.

Lastly, the studio models the transdisciplinary collaboration that is needed for wicked problems like distributed infrastructure. The pedagogical approach was carefully planned for group

and individual work to feed into the collective results, and the students greatly benefitted from a multidisciplinary team of advisors and experts that contributed content. The studio methods could be repeated in other cities or in other academic contexts to give students a macro-meso-micro understanding of distributed infrastructure and to provide valuable research for a locality striving for energy transition.

ENDNOTES

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6. **TECHNOSTRUCTURE: Energy Technologies (with [redacted] and [redacted])**
To inform our design, the students learned about the sociotechnical aspects of energy technologies through two workshops that provided a background on the history of energy infrastructures, energy technologies, their design, and their relationship to human culture. Within the context of pathways to net-zero emissions by 2050, the sessions probed at how the energy transition might manifest within built environments and rural landscapes, and how it might be possible to maximize generation capacity within population centers by co-designing energy landscapes with communities.

The students were presented with various renewable energy technologies to consider their feasibility and adaptability as media for design and creative expression and were able to explore the technologies through two in-class workshops to consider function, morphology, and ecology.

URBAN STRUCTURE: Physical Context (with [redacted])
The students explored how urban structure influenced the design and deployment of technologies and explored both site relations and environmental conditions, through pre-established grasshopper tools including sunlight access, land use composition, mobility access, and photovoltaic energy potential.

Students applied these tools in workshops prototyping installations on individual sites, and generated layouts summarizing each tool’s results for comparative discussion. Along with tutorials on each analysis script, students were provided a Rhino file with geospatial data for manipulation and testing within the workshop.

COMMUNITY STRUCTURE: Social Context (with [redacted])
The students explored how community capacity and culture influence the design and deployment of technologies and speculated on how to integrate equitable engagement and design into future processes.

Students were introduced to the theory and practice of community engagement and the role of the designer through an in-class workshop and were encouraged to consider possible project outcomes such as an equity framework for energy landscapes, recommendations for future processes, and/or a statement on community energy transition.