HYPERFUNCTIONAL ENERGY LANDSCAPES

RETROFITTING PUBLIC SPACE WITH RENEWABLE ENERGY INFRASTRUCTURE

A FRAMEWORK FOR URBAN DESIGN | ALISON GROVER

PHOTO: An underutilized asphalt surface in Portland, Oregon. Our cities are filled with underutilized landscapes. We must retrofit these spaces to become hyperfunctional [credit: author]

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Retrofitting public space
with renewable energy infrastructure

Alison Grover

HYPERFUNCTIONAL ENERGY LANDSCAPES: RETROFITTING PUBLIC SPACE WITH RENEWABLE ENERGY INFRASTRUCTURE

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ABSTRACT

Between 60% and 80% of global energy is consumed in urban areas, and this will increase with urbanization and population growth. We must meet this new demand sustainably. By 2050, the Green New Deal calls for global net-zero emissions, and by 2040, Oregon will require fifty percent of its energy use to be fueled by renewable energy sources. Scholars have noted that the US contains enough developed land to retrofit to meet our renewable energy goals without using greenfields. Siting renewable energy infrastructure within the built environment of cities can help reduce energy sprawl and transmission losses while creating an opportunity for social engagement and education. Making urban space multifunctional is important because of limited land availability and competing land uses. With that in mind, this project poses the question:

How could renewable energy synergize with social space, green infrastructure, and sustainable transportation in urban public space to create hyperfunctional energy landscapes?

ABBREVIATIONS | ROW = Right-of-Way

This project addresses multiple under-researched aspects of renewable energy including small-scale energy production, energy production in the right-of-way (ROW), and the social functions of energy production. This project reviews literature on decentralized energy systems, landscape multifunctionality, environmental justice, sustainable transportation, and environmental functions of the ROW. As a reference, I used an inventory process to analyze the hyperfunctionality of winning submissions to Land Art Generator, an annual design competition with the motto "Renewable Energy Can Be Beautiful". The overall findings of the literature review, inventory analysis, and projective design phases include the development of 12 Building Blocks, 9 Typologies of Urban Public Space, and 1 Site Design in the Lents Neighborhood of Portland, Oregon. Using a 7-block segment as example, the Site Design envisions the Lents Green Ring, a circuit of streets and greenways in an underserved neighborhood as a hyperfunctional energy landscape.

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1 | INTRODUCTION

Background on renewable energy, the scope of this project, and the research process as a whole.

INTRODUCTION

Problem Statement

Climate change is affecting the Pacific Northwest in the form of decreased snowpack, warmer year-round temperatures, river flow changes, increasing extreme heat and wildfire events, and more (Portland Climate Action Plan 2015). This has implications for public health, ecosystem health, and the economy. These changes in climate are mainly due to greenhouse gas emissions from the energy and transportation sectors (US Environmental Protection Agency). At the same time, more people are living in cities than ever before. Currently, between 60% and 80% of global energy is consumed in urban areas, and this will increase with global rapid urbanization and projected population increase (Grubler et al 2012). As energy demands increase, we must meet this new demand sustainably, since air pollution causes over five million deaths per year (Ritchie & Roser 2017). The Green New Deal calls for global net-zero emissions by 2050 (US Green New Deal), and by 2040, Oregon will require fifty percent of its energy use to be fueled by renewable energy sources (Oregon Department of Energy). This means that an increase in renewable energy generation is inevitable to power our future, for the health of our cities and our planet (Pasqualetti & Stremke 2018). But where should this new energy infrastructure be placed?

Renewable energy infrastructure can range in size from utility-scale solar and wind farms to privately owned rooftop solar installations. However, as low-density energy sources, wind and solar require more area than fossil fuels to generate the same amount of energy. Many solar and wind installations are placed in remote, rural areas, where they may affect habitat and the scenic character of natural areas. However, scientists at The Nature Conservancy have noted that the US contains enough developed land to retrofit to meet our renewable energy goals without using greenfields (Keisecker 2017). Rather than filling our wilderness areas with energy infrastructure, we must transform our existing developed areas into hyperfunctional energy landscapes. Considering the Green New Deal's call for action on climate, justice, and jobs, this project will focus on easily-deployed design interventions at the site scale.

Ekelund (2020) compares large and small-scale energy installations through a discussion of "efficiency versus effect". We need both large and small scale technologies because they serve different purposes, he says. While it is clear that utility-scale renewable energy projects are the most efficient way to produce energy, they are relatively invisible since they are located outside of urban areas. In contrast, small-scale, local energy infrastructures located within city limits can have a far greater effect. Smaller, locally sited energy can stimulate economic and ecological robustness while creating a cultural experience through its visibility, he argues. This can increase awareness and acceptance of renewable energy. Ferry & Monoian (2020) echo this statement, arguing that when energy infrastructure is placed far away, separated from people by chain link fences, it becomes foreign and alien. It loses touch with human culture. Rather, we must locate energy infrastructure within a human context and relate it to life, letting it act as a learning opportunity and an educational resource rather than a raw resource.

Scholars have proposed siting new energy infrastructure within the built environment of cities, which would reduce energy sprawl and transmission losses from channeling energy over long distances (Dimond 2020; Hernandez et al. 2015; Sarralde 2014). This is important because transmitting energy across state borders will require a vast increase of transmission infrastructure (St. John 2020). In contrast, siting energy infrastructure in the built environment could also avoid a conflict of environmental agendas (Ko et al. 2011), concentrating development away from natural areas. To increase resilience, we must generate more energy closer to where people live, using smaller technologies that integrate more easily into the urban fabric (Rizzo 2020; Ferry & Monoian 2020).

Dimond (2020) proposes a pattern language for solar photovoltaics to be integrated into the built environment. He makes the argument that as solar photovoltaics are woven into our developed landscapes, they must incorporate, “synergistic embellishments for enhanced landscape depth and purpose” (Dimond 2020). In fact, solar panels and other energy infrastructure integrated into our cities and suburbs could be an asset rather than a detriment to many qualities of public space including aesthetics, sound, air quality, and thermal comfort. Energy infrastructure in cities can increase the functionality and efficiency of public space, especially in the ROW. Vikas Mehta (2013) argues that, “the street is the most ubiquitous form of open space across the urbanized world”. This is true of Portland, Oregon, where streets make up twenty percent of public space by area (Portland 2035 comprehensive Plan). I investigate what streets, our most massive agglomeration of urban public space could look like if they were outfitted to be hyperfunctional corridors of human movement and energy generation. I define the ROW as the public space from building front to building front. On residential streets, I define the ROW as the inclusive area from sidewalk to sidewalk.

Renewable energy in the built environment is commonly seen as an extra feature, an add-on, or as a retrofit (Ozgun 2020). However, energy has the potential to transform space in a much greater way and should therefore be conceived as central rather than ornamental to the plot in redesigns. Renewable energy in public space has the potential to positively affect many aspects of urban life. Social life, sustainable transportation modes, and environmental functions in the ROW could all benefit from the introduction of energy, and these aspects are underexplored.

RESEARCH GAP

This study operates within the following research gaps:

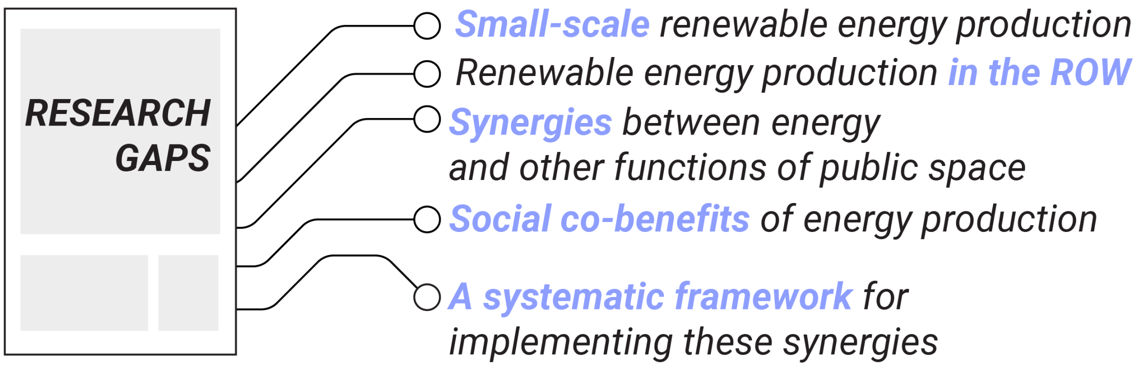


FIGURE 1: THE RESEARCH GAP

RESEARCH QUESTION
This study is guided by the following research question:

How could renewable energy synergize with social space, environmental functions, and sustainable transportation in urban public space to create hyperfunctional energy landscapes?

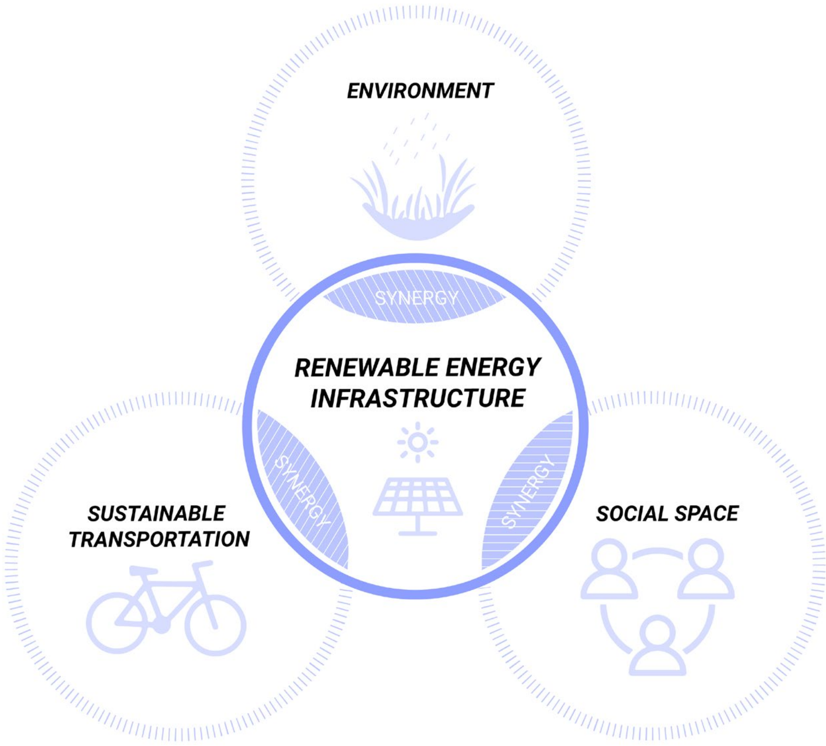


FIGURE 2: THE RESEARCH FOCUS

I define hyperfunctional landscapes as multifunctional, synergistic spaces that produce more than the sum of their parts (Lovell & Taylor 2013). I address these three topic areas of social space, sustainable transportation, and environmental functions because they are all vital components of a healthy, vibrant ROW. Hyperfunctional energy landscapes are culturally sustainable by being historically and justice-conscious, they are environmentally sustainable by being renewable and avoiding a conflict of greens, and they use space efficiently.

This study investigates how cities can integrate decentralized energy into public space, reducing reliance on a centralized grid. By situating energy with people, I investigate how renewable energy, especially solar, can be beautifully woven into the social urban fabric while providing a multitude of other benefits. Renewable energy technologies such as solar photovoltaics, biosolar roofs, and micro-wind, (Hernandez et al. 2015) can be installed on a variety of elements in public space. However, less research has been done on other parts of the built environment such as vacant land and the right-of-way. Vikas Mehta (2013) argues that, “the street is the most ubiquitous form of open space across the urbanized world”. This project investigates what streets, our most massive agglomeration of urban public space could look like if they were outfitted to be hyperfunctional corridors of human movement and energy generation.

I focus on the right-of-way and adjacent public spaces, which, as inherently social spaces, require our design interventions to be human-scale, aesthetically pleasing, and interactive. Focusing on Portland’s underserved outer-east neighborhood of Lents, this study seeks to increase energy resilience and equity on a neighborhood-scale, recognizing that environmental and social justice are deeply intertwined (US Green New Deal).

Urban energy systems in Oregon must increase their adaptive resilience in order to adapt to changing conditions. Currently, Oregon is investing in small-scale renewable energy infrastructure through the Oregon Community Solar Program (CSP). Initiated in 2016, the Oregon CSP incentivizes the construction of small, community-owned solar projects across the state. Although its emphasis on small-size and community ownership is progressive, the Oregon CSP does not address resilience issues related to reliance on a centralized energy grid. To take energy and community resilience a step further, we must make energy systems smaller scale, modular, redundant, and diverse.

Because of longstanding inequalities in city investments, it is important that energy infrastructure be deployed in communities that have low energy security and that have been excluded from wealth generation in the past. Scholars have made the case that structural change in our energy systems is necessary to address historical inequalities in wealth distribution and environmental justice. Baker (2019) argues that "if system resilience, rather than system transformation, becomes the focus of energy policy, we will miss an important opportunity to foster lasting justice". We must address a just energy transition by putting environmental justice at the forefront, or we risk replicating patterns of past oppression of the fossil-fueled energy system.

This project addresses these inequalities by using decentralized energy systems, which can represent radical shift towards equity, instead of simply substituting renewable energy for fossil fuels. The methods by which energy is distributed to people is as important as the types of energy sources used. This project uses a justice-oriented mindset to emphasize low-cost solutions, site choice for the projective design, and the types of synergies between energy and other functions of public space. Simply decarbonizing our current system does nothing for wealth inequality, disparities in investments, and corporations profiting off of working people (Baker 2019). This project seeks to make energy more accessible, more integrated into communities, and more adaptable to community needs, addressing issues in energy systems that will continue to oppress low-income communities of color unless we make changes to the system.

I address universal access to energy by selling energy back to the grid and generating funds for the community, through the provision of public power outlets, by using energy to power and increase the number of public amenities like street lights and crosswalk signals, and by using energy for animating underutilized space with color and light. Indirectly, we address equity in urban design through synergies between energy and other right-of-way improvements such as increased walkability, increased bikeability, the addition of green stormwater infrastructure, placemaking, and wayfinding.

LENTS NEIGHBORHOOD

In Portland, Oregon, the neighborhood of Lents is highly vulnerable to extreme heat and flooding. It lacks walkability, open space, and human-scale districts. It has largely been left out of the sustainable and climate-positive advancements that have swept central Portland in recent decades and earning Portland a reputation as a green, forward-thinking city. East Portland is less dense than the central city, which makes it more suitable solar installations. The area could benefit from synergistic, community-oriented, climate-focused urban design to improve equity, promote livability, and generate energy for public institutions.

SIGNIFICANCE

This project explores hyperfunctional energy landscapes in urban public space and the ROW. It focuses on synergies between compact renewable energy technologies that also enhance the urban environment. This research will be helpful to urban planners and designers in Portland, in addition to the designers of similar cities of similar densities across the world who are looking to catalyze widespread acceptance and implementation of renewable energy technologies. I make recommendations about how to maximize impact of renewable energy in urban public space.

It is important that renewable energy becomes widespread because of its low energy density. Since an integration of energy infrastructure into the built environment means higher visibility and proximity to people, social acceptance is key. This represents both a design challenge and an opportunity for synergizing energy production with multiple other uses of public space. Finally, it is important to retain the health of urban ecological environments for the myriad of ecosystem services that they provide to city dwellers including stormwater filtration, flood absorption, air purification, pollination, and cooling through transpiration.

METHODOLOGY

For this project, the methodology included a literature review, an inventory analysis of an annual design competition, and a projective design phase. Conclusions from each research phase informed the decisions made in the following phase.

PROJECTIVE DESIGN

Scholars note that “design…becomes research when it produces new generalizable knowledge about the world through its purposes, protocols, and outcomes” and that “the term projective design…focuses on the unique agency of design process for research outcomes” (Deming & Swaffield 2011). Therefore, in the Projective Design phase, I use insights gained from literature review and inventory to create generalizable visual examples of synergies between energy infrastructure and social space, sustainable transportation, and environmental functions.

LITERATURE REVIEW

This study reviews literature on decentralized energy systems, environmental literacy, sustainable transportation, social functions of the ROW, environmental functions of the ROW, landscape multifunctionality, and environmental justice. These topics help contextualize the project and help inform the multiple research gaps that this project addresses.

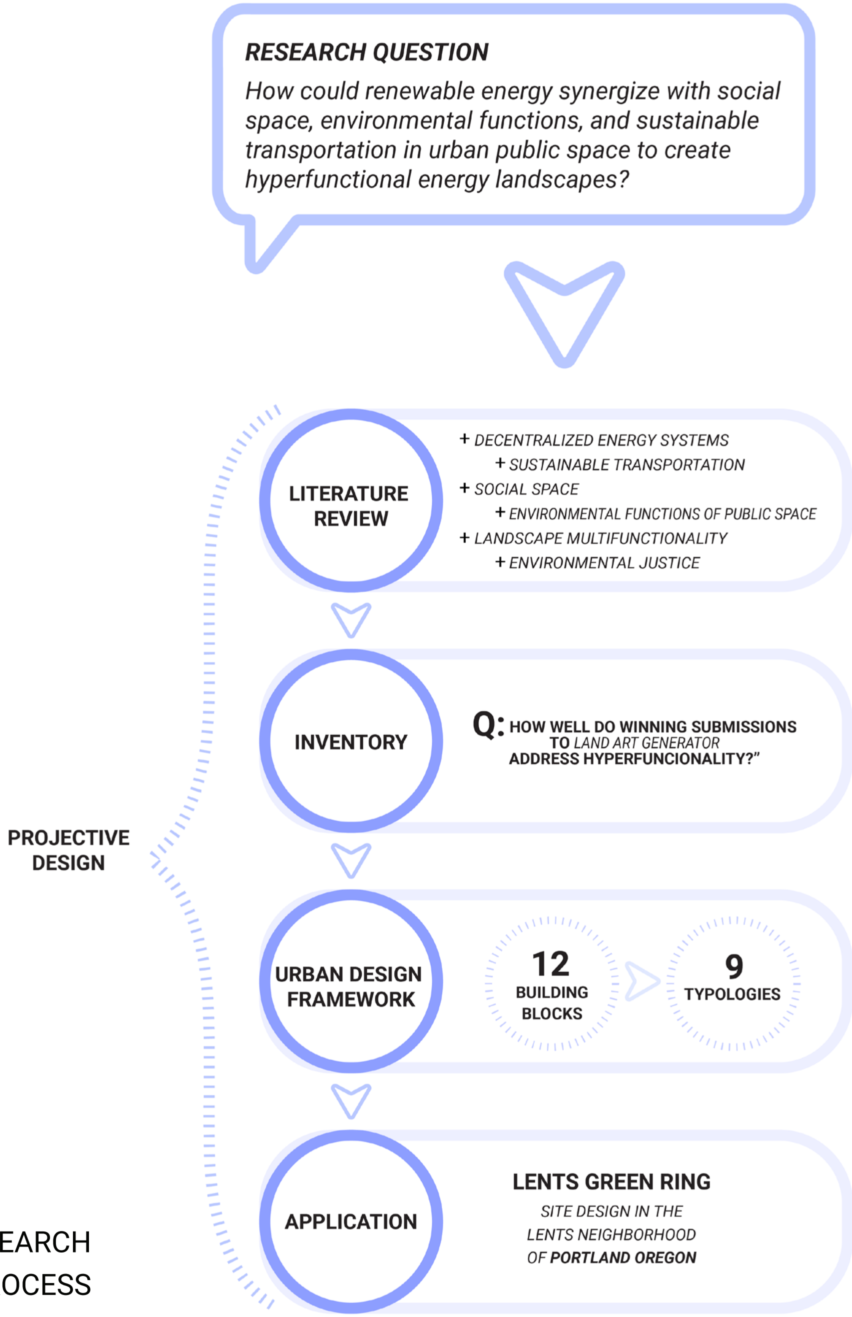


FIGURE 3: THE RESEARCH PROCESS

INVENTORY

I used an inventory process to analyze winning submissions to Land Art Generator, an annual design competition with the motto “Renewable Energy Can Be Beautiful”. Land Art Generator provides an online portfolio of previous design proposals at the nexus of land art and innovative energy integration. I analyzed the hyperfunctionality of 16 winning submissions from 2010 to 2019. These winners were selected each year from hundreds of creative, beautiful, and technologically innovative submissions. I conclude that these designs could incorporate more synergies in order to become more hyperfunctional. I use the conclusion of this inventory to inform the projective design phase.

URBAN DESIGN FRAMEWORK

The first step is Building Blocks, which lay the base for hyperfunctionality by demonstrating basic synergies between energy infrastructure and public space. The second step is Typologies, which illustrate how different types of public space could be retrofitted to become hyperfunctional. And the third step is Site Design, which adapts these typologies to a specific streetscape in the Lents neighborhood of Portland, Oregon, to demonstrate how energy infrastructure can contribute to place specificity.

For this study, projective design involved the development of building blocks and typologies of urban public space. Scholars argue that “multifunctionality is distinguished by… interactivity [that] is positive and synergistic” (Lovell & Taylor 2013). The typologies demonstrate innovative ways of synergizing energy infrastructures with social space, sustainable transportation, and environmental functions to create hyperfunctional energy landscapes.

APPLICATION

After developing design typologies that synergize renewable energy infrastructure, I apply these typologies to a specific site in the Lents neighborhood of Portland, Oregon to demonstrate how site-specificity can influence the design of hyperfunctional sustainable energy landscapes. This site design demonstrates how hyperfunctional energy landscapes can coexist with people by embodying education and engagement as public-facing installations of clean energy.

2 | LITERATURE REVIEW

An overview of scholarly research and design work on the topics of decentralized energy systems, social space, sustainable transportation, environmental functions of public space, landscape multifunctionality, and environmental justice.

LITERATURE REVIEW

DECENTRALIZED ENERGY SYSTEMS

Renewable energy integrated into our cities must be modern, resilient, and equitable in order to achieve intertwined climate and social equity goals (Sharifi & Yamagata 2016; Ko et al. 2019). Benefits can be felt strongly at the small-scale community level when energy infrastructure is owned by the community itself: “this sense of ownership is widely believed to contribute to resilience” (Ko et al. 2019). Therefore, the design of small-scale, resilient energy systems could take the form of community-level infrastructures that are highly autonomous, accessible, and community owned. Scholars have noted that “a focus on small, manageable systems may be the most productive approach” to increasing resilience and paving the way for larger developments and investments in a community (Lovell & Taylor 2013; Folke et al 2010).

We need disruptive changes to our current outdated energy grid (Crabtree et al. 2018). This project looks to decentralized energy systems because of their capacity to function during disturbances, the increased independence they afford communities, and the feelings of ownership and empowerment generated when communities own their own energy sources (Ko et al. 2019; Pevzner 2020). Urban energy system resilience has been shown to increase through decentralization, modularity, and redundancy. A diversity of energy sources and generation types leads to more adaptability as well (Sharifi & Yamagata 2016). Types of decentralized energy systems that are in use today include distributed generation, microgrids, and smart microgrids (Adil & Ko 2016). Energy storage must be coupled with renewable energy because the longer you can store energy, the higher percentage of renewables you are using overall (Sisternes 2016).

Parallel to energy systems, stormwater systems have a history of relying on centralized, large scale methods of management. In contrast, a new paradigm of green infrastructure stresses treating quality and quantity of stormwater onsite. This necessitates small, site-scale stormwater interventions located across the entire city rather than relying on a centralized systems of pipes and treatment plants. This is makes each site and therefore the city as a whole more resilient. Energy infrastructure must

+ *DECENTRALIZED ENERGY SYSTEMS*

like solar, wind, and kinetic energy

can coexist with other functions of public space, such as...

+ *SOCIAL SPACE*

+ *SUSTAINABLE TRANSPORTATION*

+ *ENVIRONMENTAL FUNCTIONS OF PUBLIC SPACE*

which, when combined through synergy, contribute to...

+ *LANDSCAPE MULTIFUNCTIONALITY*

which, when applied to an underserved community suffering from energy insecurity, contributes to...

+ *ENVIRONMENTAL JUSTICE*

FIGURE 4: AN OVERVIEW OF THE LITERATURE REVIEW

engage on the same path of decentralization and site-scale self-sufficiency in order to produce more resilient cities.

Moving away from energy centralization means moving towards energy democracy. The principles of energy democracy include universal access, social justice, renewable, sustainable, and local energy, public and social ownership of energy, fair pay, and the creation of green jobs (Energy-Democracy.net). Energy democracy is about putting people in charge of their own energy, its distribution, and the decision made around it so community members can assure their power is not being used to create more inequalities (Pevzner 2020).

Energy “prosumers” (Toffler 1980), an emerging market player with an increasing role in our future, are individuals or groups who produce, store, and consume their own energy, selling excess energy back to the grid (Milciuviene et al. 2019). They are important to our future because they increase the diversity of energy producers; they increase the capacity of renewables, meeting new increasing electricity demands; they will increase the overall use of renewables; and they decrease the market power of large energy companies; (Milciuviene et al. 2019). Prosumers using renewables like solar and wind power must remain connected to the grid to account for variability in weather conditions. To encourage energy prosumers connected to the grid, and thereby extending benefits to the whole energy system, it is important that the prosumers accrue economic benefits (Milciuviene et al. 2019), achieved through methods such as selling energy back to the grid (Ozgun 2015).

This project is an example of the energy infrastructure the Lents Community could use to become prosumers. It should be noted that to ensure intragenerational equity, governmental support is needed to cover upfront costs for low-income energy prosumers. Once initial installation costs are met, producing one’s own energy can significantly reduce energy bills (Milciuviene et al. 2019). Prosumers selling excess energy to the grid also increase energy affordability for all energy consumers. Regarding embodied energy, it has been noted that energy payback times, or the time it takes to generate as much energy as was needed to manufacture and install the infrastructure, are much faster than they were even eight years ago due to innovations in technology (Ozgun 2020). Energy technologies are advancing even faster than many predicted in the early 2000’s, which means that the future is brighter for renewables.

Renewable energy technologies have specific urban form requirements. Access to sunlight via a southern exposure are essential in the northern hemisphere. Building height, distance between buildings, and site coverage should be taken into consideration when siting solar photovoltaics (Sarralde et al. 2014). It is possible to achieve similar levels of solar irradiance with different combinations of urban form variables, such as building height, distance between buildings, and size undeveloped site areas (Sarralde 2014).

Although compact urban development has been theorized as an environmental solution to many issues such as excess vehicle emissions, other urban densities have their own benefits. The study site in Lents offers the opportunity to design in a lower density urban setting, which has been shown to promote efficiency of rooftop solar installations due to reduced building shadows and more roof area per capita (Ko et al. 2017). This benefit could be extrapolated to the ROW, assuming that lower density is correlated with lower building heights, less buildings, and therefore more access to sunlight.

Street orientation also affects energy use and can be optimized based on the climate (Ko 2013). In addition to building arrangements and street orientations, trees also reduce energy demand if planted strategically. They can moderate summer heat through shade and evapotranspiration, and deciduous trees would allow for winter solar access. Evapotranspiration is more effective at cooling than shade (Huang et al 1987), which means that trees cannot simply be replaced by shade structures and expected to produce the same amount of cooling. Maintaining a balance of energy infrastructure and natural elements can be beneficial in many ways, and this study seeks to incorporate trees among solar and other renewable technologies. Planting trees on the west side of buildings reduces energy use year round (Ko 2013). The albedo of a site and its materials is another important variable, and light colors should be used wherever possible (Ko 2013).

I use this information about decentralized energy systems to brainstorm synergies with social space, sustainable transportation, and environmental functions of public space. These topics are addressed in the following subsections. I start by summarizing the social potential of the ROW and applicable synergies with renewable energy infrastructure.

THE RIGHT-OF-WAY AS SOCIAL SPACE

MAIN PRINCIPLES

- Increase environmental literacy and the spread of ideas through social networks
- Repair, restore, and enhance without displacing people
- Aesthetic is essential for social acceptance of energy infrastructure
- Use art and wayfinding to tell histories, stories, and make cultural connections visible

TRANSLATION OF MAIN PRINCIPLES INTO ENERGY INFRASTRUCTURE

- Make energy infrastructure interactive, engaging, and playful
- Create opportunity for both active and passive engagement with energy
- Use energy infrastructure to educate and spread ideas about renewable energy
- Couple energy infrastructure with wayfinding in ways that demonstrate local character

The ROW is inherently a social space, so energy infrastructure in the ROW must function harmoniously with people. Public space is complex, dynamic and alive, changing based on different flows: "unlike embedding renewable energy into a building, designers need to complement the evolutionary and dynamic nature of a public space when embedding renewable energy" (Ozgun 2015). Although streets have more limitations in accessing sunlight than rooftops or building facades, they offer the unique opportunity to facilitate educational, experiential moments as people share hyperfunctional urban space with renewable energy infrastructure.

An example of interactive energy generation is the "Energy Carousel" in Dordrecht, Netherlands, designed by Ecosistema Urbano. The carousel generates energy as children circle the structure on foot and then stores the energy for night lighting. Hue and brightness of the lights vary with the amount of energy generated that day. The carousel stimulates physical activity, play, increases safety at night by acting as a meetup location and by illuminating the street, shades the street during the day, and educates people through visual feedback. It's important to combine these functions which harmonize with each other. Garcia (2020) notes that in order for successful climate literacy and engagement, energy cycles must be short and local, giving direct feedback through visual or auditory elements. People must be able to generate energy and use it in the same place to increase visibility. Putting energy upfront in public spaces, rather than hiding it increases our familiarity with energy.

Another key aspect of the social ROW is that, "public space can shift society into a sustainable energy lifestyle when used as an educational and information platform" (Ozgun 2020). Broadcasting the benefits of a renewable energy lifestyle in public space could have rippling effects across society, and therefore has the potential to multiply its carbon reductions. Scholars have noted the "positive impact of social networks on uptake of renewable energy technologies" (Adil & Ko 2016). Exposing people to renewable technologies and familiarizing them with their processes is essential to making renewable energy more ubiquitous in the built environment. Energy infrastructure in the right-of-way would function not only to generate energy, but also to spread awareness and familiarity about renewable energy capabilities while increasing climate literacy. Infrastructure in the street is the ultimate marketing tool and putting energy infrastructure where everyone can see it increases transparency, a central tenet of energy democracy.

Ozgun (2020) notes that the landscape SITES assessment addresses renewable energy's positive impacts on environmental categories such as carbon footprint and climate change mitigation, but it fails to account for the social potential provided by renewables. Social functions of public space, such as gathering space and social services are essential to livable streets. In fact, social infrastructure can be even more essential than physical infrastructure for weathering disturbances such as heat waves, flooding, or other climate-related hazards that lie in the near future of Portland (Klinenberg 2018). Social infrastructure can be defined as places where people congregate and build community such as parks, playgrounds, schools, libraries, or churches. Energy can be paired with social infrastructure to provide enhancements such as shade, night lighting, energy education, and environmental literacy opportunities.

In addition, it is more important than ever to boost social trust and cohesion by creating safe, diverse, and inclusive public spaces. Methods to increase trust, safety, and inclusion in public space include adequate night lighting and creating a walkable neighborhood. Energy infrastructure can contribute to creating walkable urban areas through pairing energy with traffic-calming measures such as chicanes, crosswalk bulb-outs, and street paint.

Ozgun (2020) makes the point that renewable energy infrastructure in conjunction with social space can engender both active and passive interactions in the form of education, information, and place making. Active engagement can include charging one's personal devices and vehicles, learning about energy through signage, and providing electricity for a street performance.

Passive engagement can take the form of energy acting as wayfinding or using the energy infrastructure as an aesthetic backdrop.

Gentrification is about the displacement of people who call a neighborhood home. Designers must avoid design practices that catalyze displacement. One strategy could be to identify and amplify the existing social nodes and flows rather than create new ones from scratch. In an effort to preserve the existing community, this amplification will focus on small-scale, everyday community assets rather than large, flashy attractions. This is particularly important because it differs from the extravagant, iconic and beautiful designs found in most Land Art Generator submissions. The everyday community assets function as social infrastructure for the long term residents and community members that are invested for the long term.

A barrier of entry for energy infrastructure in public space is its appearance. Some cities do not even allow solar panels because of their appearance. We must make energy infrastructure beautiful for it to even exist in the public realm. Meyer (2008) argues that beauty is a necessary component of sustainability and sustainable landscape interventions. Just like ecological functions of a landscape, beauty performs essential functions that are more than ornamental: "immersive, aesthetic experience can lead to recognition, empathy, love, respect and care for the environment". Meyer argues that "concern for beauty and aesthetics is necessary for sustainable design if it is to have a significant cultural impact". And in order for renewable energy to gain more traction nationwide, it requires a cultural impact. Luckily, scholars argue that the aesthetics of renewable energy can be manipulated to create beautiful works of art (Schuler 2017).

Historical energy infrastructure was in touch with human culture in a way that modern power plants and utility scale energy infrastructure are not. In order to create cherished pieces of public infrastructure, we must react and respond to local context, place specificity, and the human scale. Ideally, renewable energy infrastructure can be adapted and reused in the future just like these historical power plants.

A local Pacific Northwest example is Gas Works Park in Seattle. This is an energy landscape that people inhabit and consider a beautiful setting for a park space. As a former gasification plant, the rusting infrastructure was saved and now acts as an aspect of landscape memory referencing Seattle's industrial past. It adds character, texture, and a sense of place. Why must we wait until after energy landscapes have been decommissioned in order to enjoy the space that they create? Renewable energy infrastructure is

FIGURE 5: Tejo Power Station/Museu da Electrididade, Lisbon [lisboasecreta.co]

FIGURE 6: Gas Works Park, Seattle [Tony Cyphert]

much safer, leaves little to no impact on its site, and produces no emissions.

Environmental literacy, or the rate at which people are familiar with environmental and climate issues, is an important social function of public space. Since “knowledge has been shown to increase concern about climate change” (Harker-Schuch et al. 2020), bringing energy systems and environmental systems into the public view could increase concern for the environment. It is hard for new technologies to gain local acceptance, as solar panels and wind turbines commonly face resistance because they clash with local character and scenery (Pasqualetti, Gipe, & Righter 2002). However, scholars have noted that feedback loops are created when people are more familiar with their environments, are involved in their maintenance and care, and acquire the skills to become stewards (Lovell & Taylor 2013). Landscape architects can be essential for visioning and designing educational, place-based landscapes that draw on local character. Studies have shown that increasing one’s place attachment can influence climate-positive behavior down the line (Sheppard 2015).

Environmental literacy can be increased by signage, labelling, visualization of future conditions. People learn through visual, experiential, and contextual encounters. Sheppard (2015) recommends three broad principles to follow when designing for climate literacy: “Make it local, make it visual, and make it connected”. Incorporating elements of one’s local setting bring a concrete tangibility to climate change. “Making it local” also engages the emotional attachments we have for our neighborhoods, therefore increasing our care and concern for the health of the local landscape.

The ROW could distill information visually and experientially for passersby while generating energy in the process. The street could be an “in your face” canvas for local, visual, and connected learning about environmental processes leading to climate literacy. With an emphasis on energy generation, consumption, and distribution, energy infrastructures in the street could offer educational opportunities for local schools as well as residents, visitors, and anyone passing through. Content should focus on positive solutions rather than listing the disastrous and depressing statistics about climate change, since this has been shown to be a stronger behavioral influence than feelings of guilt (APA 2009). Examples of climate literacy in Land Art Generator Initiative (LAGI) submissions include “Solar Hourglass”, in which a large-scale sculpture both generates solar energy and reminds us how much time is left to save the planet from climate change. LAGI also hosts art and energy camps and is creating a boardgame to teach kids about energy.

In terms of energy technologies, Ferry & Monoian (2020) highlight solar murals as incredibly important for cities because of their engagement potential. Displaying artwork on solar panels makes them multifunctional, beautiful, and educational as visitors are reminded of the importance of pollinator health. I include a more comprehensive list of beautiful and compact renewable energy technologies in Chapter 3.

SUSTAINABLE TRANSPORTATION

MAIN PRINCIPLES

- Prioritize safety
- Design for all transportation modes equally: walking, biking, driving, and transit
- Make streets visually attractive for pedestrians
- Include elements of landscaping and stormwater management
- Clear wayfinding can strengthen placemaking

TRANSLATION OF MAIN PRINCIPLES INTO ENERGY INFRASTRUCTURE

- Use energy infrastructure to separate lanes of travel; as traffic calming
- Use energy to power street lighting
- Couple energy infrastructure with wayfinding in ways that demonstrate local character

The ROW can fit many more people on foot or on bikes than by cars. Sustainable transportation is about moving people efficiently rather than moving vehicles efficiently. It involves decentering of personal vehicles and the inclusion of various other modes into a transportation system such as walking, biking, and transit to build transportation equity and reduce carbon emissions. People who are left out of the ubiquitous car-centric model of transportation include children, families who cannot afford a car, people with disabilities, and elderly people (Tumlin 2012). By providing transportation options such as walking, biking, scootering, and riding transit, we give mobility and independence to entire groups of people who are otherwise marginalized by personal vehicle dependency. In addition to equity, sustainable transportation stimulates economic development through increases in access. Locations with access by multiple transportation modes have been shown to attract businesses and jobs (Tumlin 2012). Increasing carless transport options also functions to decrease stormwater pollution, noise pollution and air pollution. Getting more community members walking is a great way to increase public health, since our bodies require daily movement in order to function properly (Tumlin 2012).

The COVID-19 pandemic has changed the culture of our communities in many ways. Studies have shown that people spend more time doing outdoor activities than before (Outdoor Industry Association 2020). Small businesses, protesters, and the increasing number of houseless individuals have all spread themselves across streets in efforts to stay afloat. A street redesign in the pandemic and post-pandemic era must be hyperfunctional and prioritize community needs.

In the pandemic era, cities have been more receptive than ever to experimenting with the ROW. Experimental seating and dining areas have been planned, permitted, constructed, and weatherized on the streets in the City of Portland. Designers have made arguments for recreation in the ROW (Leonard & Egan 2014; Laybourn & Egan 2020). These types of design interventions disrupt the urban fabric, the status quo, and the pre-pandemic modus operandi of the street. In building resilience and adapting to disturbances in our urban ecosystem of Portland, we must build back better, more intentionally, and more equitably than before. Future innovations in the ROW should continue this trend of disruption and experimentation, and adding energy infrastructure is a viable solution.

Looking further into the future, autonomous vehicles (AV's) will be changing the form and function of our rights-of-way. Some potential opportunities for increase livability include less space needed for vehicle due to smaller vehicles and more controlled driving mechanisms, slower driving speeds due to automation, and less requirements for parking spaces due to a fleet-style operation of AV's (Riggs et al. 2020).

Play is an important social aspect of city life. To play safely means to increase standards for accessibility and safety of the ROW, which benefit more than just children. When we design for children, we design for everyone. Gehl (2010) addresses the concept of "the city as playground", where everyday city spaces are used multifunctionally as play space for all ages. Design professionals have also made the argument that play and recreation should be included in the design of streets, especially since the onset of the COVID-19 pandemic (Leonard & Egan 2014). In NACTO's "Designing Streets for Children" Guide, Janette Sadik-Khan notes that streets act as front yards for children, even though they were designed only with vehicles in mind. Children playing in the street is an integral aspect of a healthy and complete street.

Gehl urges planners to combine uses, take advantage of diversity, and plan for fixed, flexible, and fleeting uses all at once. Diversity of uses enlivens the urban space while increasing its efficiency. A diversity of uses also increases the number of "eyes on the street", thus improving street safety. Jacobs (1961) describes an "intricate sidewalk ballet" of children playing in the right-of-way in New York City in the 1960's. She argues that children are much safer playing on sidewalks, where they are within view by shopkeepers and neighbors, than they are at playgrounds, where there may be less eyes watching. In addition, children playing in lively places may gain exposure to people of varied ages and backgrounds when playing on sidewalks.

Energy can be coupled with play in the ROW by contributing to traffic calming measures such as street curves, which function dually to provide on-street space for green infrastructure while increasing the 'friction' of the street environment. Energy-generating play structures like swings and seesaws can also be used to encourage interaction with energy. Energy infrastructure could act as physical barrier, visual screen, and as markers of public space. Energy could help carve out space for urban play and increase overall street safety.

An important aspect of sustainable transportation is the inclusion of public seating. Seniors and parents with children especially need seating in public space, which can also help foster social connections among neighbors. Energy infrastructure can provide shade, night lighting, and charging outlets to seating refuges.

Wayfinding can act both as helpful directional signage and as placemaking representing the unique identity of a neighborhood. "Well designed signage supports a neighborhood or district's distinct identity…it reflects the culture and character of the surrounding neighborhood. Energy in public space can power lighted signs, blinking crosswalk signals, or showcase public art.

ENVIRONMENTAL FUNCTIONS OF PUBLIC SPACE

MAIN PRINCIPLES

- Specify native and novel plants that benefit at-risk species like birds and pollinators
- Integrate green stormwater infrastructure
- Include educational opportunities for learning about natural processes, cycles
- Synergies between energy infrastructure and artificial habitat can help attract at-risk species

TRANSLATION OF MAIN PRINCIPLES INTO ENERGY INFRASTRUCTURE

- Use energy to increase microclimate diversity through shading
- Use energy infrastructure to divert stormwater
- Provide habitat opportunities in energy infrastructure such as bird nesting

I define Environmental functions to Public space to include green infrastructure and urban ecology as they relate to the ROW and adjacent public space. This topic is about the structure and function of natural systems in urban areas. This involves relationships between plants, animals, humans, and abiotic elements like soil and water cycles. Our built environment must function to complement natural systems, which must be continuous through the city (Spirn 1984). Even habitat patches as small as residential backyards have been shown to increase biodiversity in cities (Werner 2011). Ecosystem services save cities countless dollars each year by performing functions like filtering stormwater, cooling the air through evapotranspiration, and absorbing pollutants. Because heterogeneous, biodiverse landscapes increase resilience, it is important to consider a broad array of ecosystem services in a multifunctional landscape (Lovell & Taylor 2013).

With a focus on the ROW, hyperfunctional energy landscapes in public space must engage with natural systems. They must complement natural features, mimic historic habitat, they must not encroach on existing patches of highly valuable habitat, and they have the potential to encourage increased interaction between people and their environment. Orff (2016) notes that, “Artificial habitat mimics lost habitat niches and fosters the return of wildlife to areas inalterably changed by urbanization”. In her 2016 book, Orff demonstrates how osprey nesting structures can be built into urban public space on a coastal ecology project in Brooklyn. Similar structures could be integrated into energy infrastructure.

Pollinators such as bees and insects are facing rapid habitat loss due to habitat loss and fragmentation. We must design urban landscapes to integrate pollinator habitat, which can integrate with renewable energy infrastructure using agrivoltaics as an example. The collocation of pollinator plants and solar infrastructure should be a vital part of hyperfunctional energy landscapes. We must focus on both natives and non-natives that are well-suited for the area in our implementation of green infrastructure and urban ecology in the streetscape.

The inclusion of trees and plantings on the street increases air quality and microclimates in a multitude of ways including cooling through shade and evapotranspiration, the absorption of air pollutants, the production of oxygen, and an enhanced visual pedestrian experience. In addition, trees cool the air to optimal temperatures for the operation of solar infrastructure. Energy infrastructure must coexist with trees and plants rather than replace them. This study proposes a mixture of environmental functions and energy infrastructure in public spaces, understanding that a symbiosis between the two can enrich our streets.

LANDSCAPE MULTIFUNCTIONALITY

Landscape multifunctionality is about cultural functions, ecological functions, and productive functions which interact and synergize (Lovell & Taylor 2013; Selman 2009). Designing for heterogeneity has been shown to improve resilience, richness, and efficiency (Lovell & Taylor 2013). In this study I focus on renewable energy, social space, sustainable transportation, and green infrastructure. It is important for this production of energy to be small-scale and accessible to locals since another important part of multifunctionality is the close relationship between the functions and landowners or stakeholders. To take multifunctionality a step further, hyperfunctionality is about synergizing these uses to create something bigger than the whole. Hyperfunctional spaces are land-efficient, cost-effective, and serve multiple uses simultaneously.

An example of a hyperfunctional energy landscape is Ecosistema Urbano's "Eco-boulevard" in Madrid. Built in 2005, this series of three artificial "trees" perform the functions of full-grown trees. They can direct air flow and spray mist at passersby, which improves the microclimate; they provide a space to play, incorporating swings at ground level; and they create social space through including an amphitheater and concert venue. These functions are all influenced by the identity of the place. The surrounding public space works in conjunction with the "trees" as flex space, allowing spilling of crowds and spreading of individuals during the pandemic.

ENVIRONMENTAL JUSTICE

Urban landscapes have been shaped and reshaped by the political, social, and economic agendas of those in power. However, to create hyperfunctional energy landscapes, the needs and desires of vulnerable communities must come first. Communities of color, indigenous peoples, and working-class neighborhoods have had a pattern of bearing disproportionate negative health effects at the hands of individuals, corporations and the government, which is a direct effect of system racism and classism.

The New Deal, which is recorded as an overwhelmingly successful era in American history actually perpetuated and reinforced patterns of environmental racism in the US through segregated work camps, discriminatory hiring, and the beginning of neighborhood redlining (Pevzner 2019). The Green New Deal and the widespread integration of renewable energy into our landscapes must diverge from the racist legacy of the New Deal.

In Portland, there has been disinvestment on the outer east side for decades. The reputation for Portland as a pioneer of sustainability and inclusivity seems incongruous because low-income Portlanders have been forced to relocate further and further east (Goodling et al 2015). Portland's cycles of capital accumulation and redistricting policies have contributed to disproportionate distributions of wealth and investment across Portland. It is not enough to save the environment or generate jobs at any cost (Baker 2019). We must do so mindfully and with the input of our most vulnerable communities so as not to erase the past or replace cultural histories with green infrastructure. Energy infrastructure must build on the existing histories to avoid suppression of community voices and the displacement of people (Lovell & Taylor 2013).

Ekelund (2020) argues that energy infrastructure must to respond and react to a landscape rather than plowing through unchanged. For example, he notes that powerlines can do more than monofunctionally transmitting energy. They can become public space makers. In reference to the design of energy infrastructure, he says that, "it's not the construction of a thing; it's the construction of place". He argues that energy infrastructure creates a social space when it's a captivating landmark to look at, to plan a meet up near, or to hold a concert at. On a related note, TriMet in Portland has integrated art at its MAX stops, an aspect of placemaking that makes each stop unique. As each stop begins to feel like a destination itself, people can more easily understand the context of the area.

Ekelund concludes that we should not just transform our public spaces for energy, but we should transform those spaces to be better through the introduction of energy. Further, how can the introduction of renewables help increase the amount of public space available to us? How can Lents public spaces be better and more numerous? How can the introduction of energy help achieve those goals? What traditional knowledge can help inform the design of a culturally-relevant energy intervention?

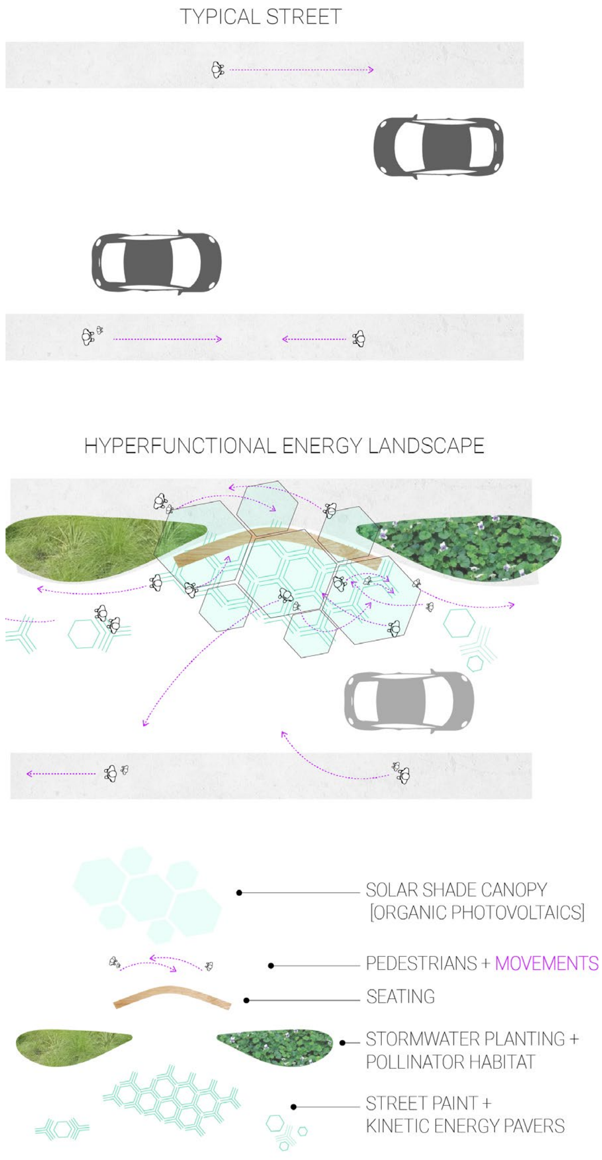


FIGURE 7: A TYPICAL STREET VS. A HYPERFUNCTIONAL STREET

3 | INVENTORY

An overview of my research topics including decentralized energy systems, social space, sustainable transportation, environmental functions, landscape multifunctionality, and envirionmental justice.

INVENTORY

For the purpose of gaining design inspiration and understanding hyperfunctionality of existing design proposals, I conducted an inventory of 16 winning design submissions to Land Art Generator Initiative (LAGI). LAGI is a biennial design competition with the motto, "Renewable energy can be beautiful", and submissions fuse public art and renewable energy in creative, innovative, and imaginative ways. Projects specify many of the numerous renewable energy technologies compiled in LAGI's publication A Field Guide to Renewable Energy Technologies (Ferry & Monoian 2016), which is over 100 pages. Technologies in their publication are categorized under Solar, Wind, Water, Bio, Other, and Storage chapters. I mention this to demonstrate the vast array of technologies available, which means there are almost endless combinations and options for creating beautiful designs. Many technologies are small, lightweight, and even transparent, which are all optimal qualities for use in human-scale energy installations. Becoming familiar with these technologies by reading LAGI's publication and reviewing winning submissions helped inform the projective design phase of this project as well.

THE GUIDING QUESTION
How well do winning submissions to LAND ART GENERATOR address hyperfunctionality?

MY HYPERFUNCTIONAL DEFINITION
At least 6 functions that synergize to create something greater than the sum of their parts

RESULTS
3 of the 16 winning submissions could be considered hyperfunctional, according to my definition

CONCLUSION
The reason most projects did not fit the definition was a lack of synergy among functions. There is room for improvement and energy landscapes could further push the boundaries of hyperfunctionality especially when it comes to synergizing adjacent functions.

Hyperfunctionality was determined based on the number of functions the design presented, and whether these functions synergized with each other. The results of the inventory indicate that there is opportunity for increased synergy among renewable energy infrastructure and other adjacent functions. Results are summarized in the following tables.

LAND ART GENERATOR INITIATIVE | *"RENEWABLE ENERGY CAN BE BEAUTIFUL"*

COMPETITION YEAR	***SITE***	***SITE TYPOLOGY***	***NUMBER OF WINNERS***
2010	DUBAI & ABU DHABI	URBAN GATEWAYS	3
2012	NYC FRESHKILLS PARK	LANDFILL	3
2014	COPENHAGEN	BROWNFIELD	3
2016	SANTA MONICA	COASTAL	3
2018	MELBOURNE	ENERGY OVERLAYS	2
2019	ABU DHABI	CITY PORTAL	2

FIGURE 8: AN OVERVIEW OF LAND ART GENERATOR WINNERS

ARE WINNING SUBMISSIONS TO LAND ART GENERATOR HYPERFUNCTIONAL?	2018 Light Up	2014 Quiver	2019 starlit stratus	2012 Fresh Hills	2018 Night + Day	2016 Paper Boats	2012 Scene Sensor	2016 Cetacea	2012 Pivot	2016 Regatta H20	2014 Solar Hourglass	2014 eMotions	2010 Lunar Cubit	2010 Windstalks	2019 sun Flower	2010 Solaris
HYPERFUNCTIONAL?	X		X					X								
# OF FUNCTIONS	9	9	8	8	7	7	7	7	6	5	5	5	5	5	4	4
ENVIRONMENTAL FUNCTIONS																
generates energy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
provides cooling via shade (and/or mist)	X		X										X		X	X
storage + collection of water		X	X							X				X		
provides drinking water			X					X		X						
increases resilience against floods/storms/erosion								X		X						
filters stormwater								X								
provide habitat		X				X		X								
air filtration				X												
improves air flow	X			X												
food growth				X												
powers the nearby neighborhood	X	X		X				X	X		X		X			
SOCIAL FUNCTIONS																
activates space at night via lighting			X			X	X							X	X	
generates capital by selling energy to grid					X	X										
acts as landmark/meeting point/spectacle	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
creates space for events/festival/concert		X	X						X							
provides space for art exhibition			X													
additional spectacle event (specify)	theatre, esplanade creation				evening water discharge											
energy education				X	X		X		X			X	X			
other education (specify)	wind pattern awareness	wind pattern awareness	Education on water collection			habitat awareness	wind pattern awareness				sustainability awareness	ecosystem education				
creates recreational or park space	X	X		X	X	X			X			X		X		
creates viewpoint/vantage point		X					X				X					
TRANSPORTATION FUNCTIONS																
improves pedestrian qualities	X				X		X									X

FIGURE 9: The functions I observed in each winning submission based on the team's submitted project posters and narrative.

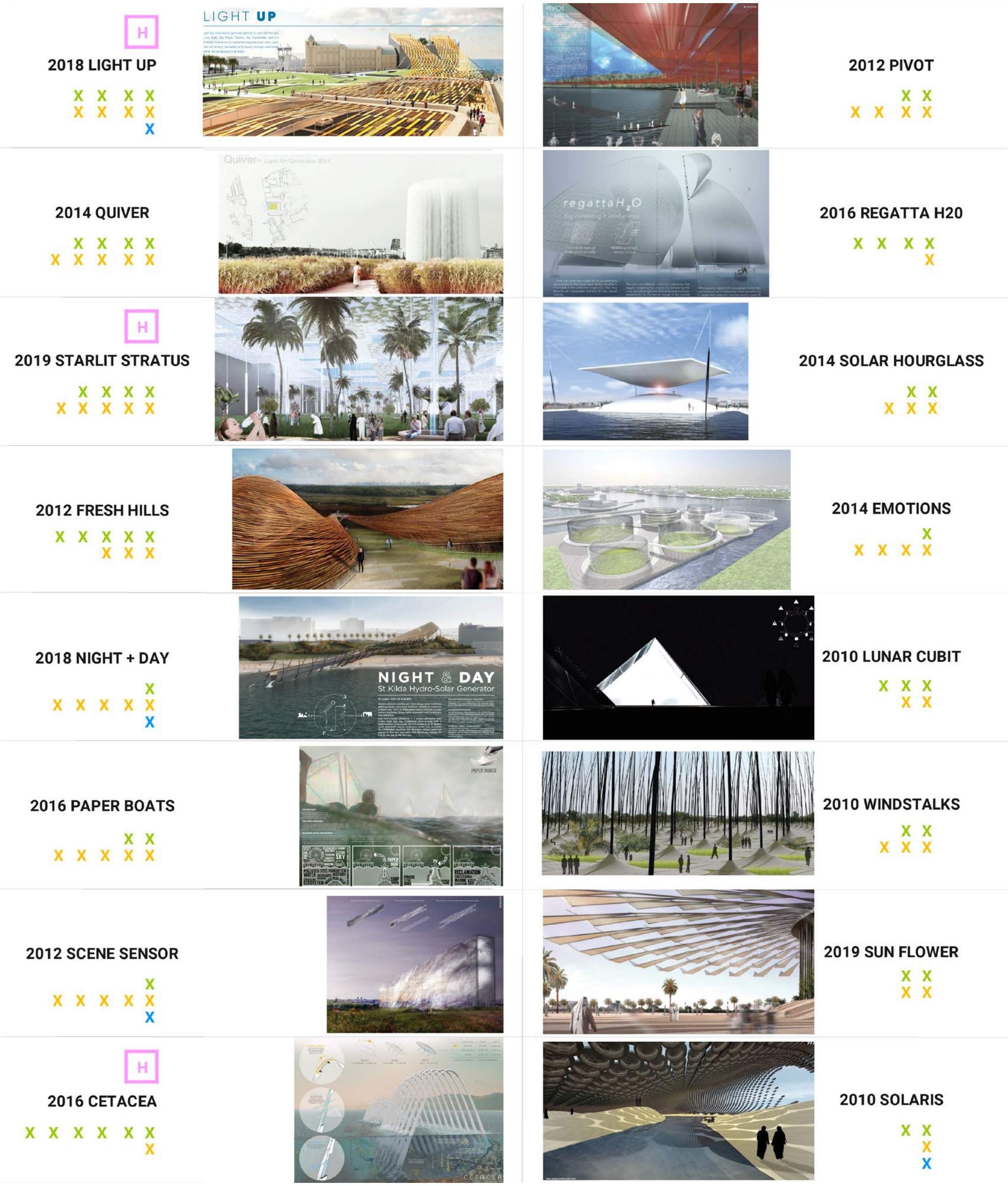


FIGURE 10: Photos of the winning submissions to Land Art Generator with functions visually mapped.

Many projects included interactive, social, and educational functions. For educational success, proximity to energy and legibility of the energy system is key. Only a few projects were ecologically oriented, and instead, most projects' environmental functions were related to generating energy and powering the neighborhood. I think that projects can take ecological functions a step further by creating co-benefits. It is not enough to simply state that a proposed project will do no harm to a local ecosystem because any alteration of a natural system will have unintended effects. It should also be noted that very few projects fulfilled transportation related functions. This is because sites chosen by the competition organizers included very few streets. However, even in urban plazas and parks there is potential to synergize energy with transit shelters and electric bike, scooter, and vehicle charging stations. In contrast, this study specifically investigates the street for its public nature and scalable opportunities.

I think it is important for designers to think boldly and creatively. Design needs to get people excited in order to gain public support, and this excitement should be stimulated by a combination of bold thinking and practical solutions.

To the right is a list of selected renewable energy technologies from Land Art Generator's publication A Field Guide to Renewable Energy Technologies (Ferry & Monoian 2016) which could be particularly well-suited for urban public spaces. I made these selections based on versatility, compactness, and aesthetic qualities.

In the left column, dye-sensitized solar cells are beautifully colorful and transparent, while performing better in low-light than common photovoltaics. Amorphous Silicon Photovoltaics present the opportunity to customize and to display art on a large scale. Piezoelectric energy comes in many forms, but piezoelectric poles made of ceramic discs can generate energy by swaying in the wind. On the bottom, one type of vertical axis wind turbine harnesses the wind from moving vehicles. Other types of vertical axis wind turbines harness environmental winds and are also compact in size.

On the right, biomass crops such as miscanthus or switchgrass can be harvested twice a year and can be burned to generate energy during sunless or windless periods, helping ease the inconsistencies in solar and wind energy generation. Widely available solar photovoltaics operate with an efficiency of about 17%. Organic photovoltaics are thin, flexible, and colorful; and kinetic energy pavers generate energy through footsteps.

FIGURE 11 [LEFT]: Renewable energy technologies well-suited for urban space.

Dye-sensitized Solar Cells

9-11% efficiency
Work well in low light
Cheeaper than traditional pv's

Biomass (Miscanthus / Switchgrass)

can grow 4m tall
2 harvests per year

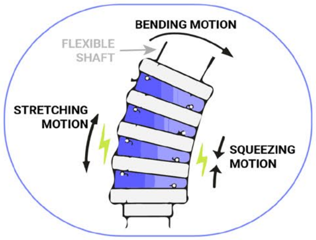
Amorphous Si Photovoltaic With Custom Lamination (Solar Mural)

12% efficiency
Can be outfitted with art

Solar Photovoltaic Cell

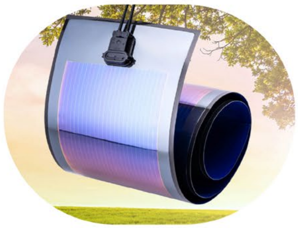
17% efficiency
Market competiton

Piezoelectric Poles



generates energy as it sways in wind

Organic Photovoltaics



13% efficiency
flexible, transparent

Vertical Axis Wind Turbines

vehicle movements generate wind
unique product

Kinetic Energy Pavers

3 Joules per footstep
Unique Market Product

IMAGES SOURCES

DSSC: Photo by Roland Herzog [sciencemag.org]
A-Si PV: 'La Monarca' from *A Field Guide to Renewable Energy Technologies* (Ferry & Monoian 2016)
PIEZOELECTRIC: Based on diagram at [thewindulum.com]
VERTICAL AXIS WIND TURBINE: Deveci Tech wind turbine "Enlil" [devecitech.com]

BIOMASS: Switchgrass Crop [https://willwestbiologist.weebly.com/switchgrass--microbes.html]
SOLAR PV: https://www.pxfuel.com/en/free-photo-xqrqv
OPV: HeliaSol by HeliaTek [https://www.heliatek.com/en/]
KINETIC PAVERS: [www.pavegen.com]

4 | URBAN DESIGN FRAMEWORK

A visual toolkit of replicable synergies applicable to any urban site. Part A lays a foundation with a set of 12 Building Blocks, and Part B illustrates how Building Blocks could be applied to 9 Typologies of urban space.

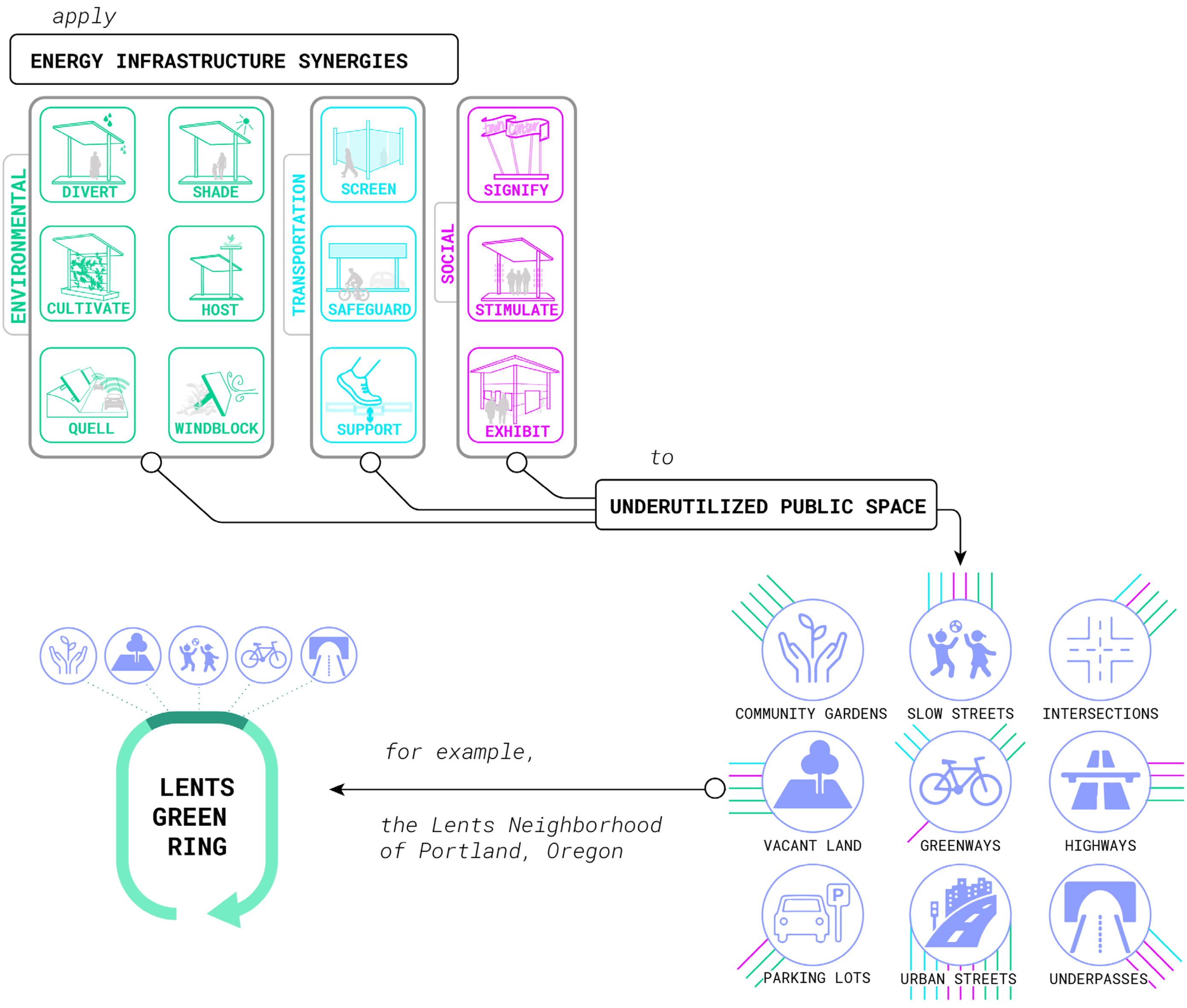
USE THE URBAN DESIGN FRAMEWORK as a guide to transform underutilized public spaces into hyperfunctional energy landscapes .

ENERGY INFRASTRUCTURE SYNERGIES are explained in the following section as “Building Blocks” for hyperfunctional energy landscapes. Mix and match these blocks to create vibrant, productive public space.

UNDERUTILIZED PUBLIC SPACES are illustrated in the second section of this chapter as “Typologies”. They function as inspiration for designers by presenting an array of ideas on applicable synergies for different types of public space. They may be mixed and matched to account for all types of public spaces, even ones not specifically mentioned in this chapter. Examples of such mixing and matching are given in Chapter 5: Application.

FIGURE 12: The Urban Design Framework

how to assemble a hyperfunctional energy landscape:



BUILDING BLOCKS

Through brainstorming, reviewing literature, and inventorying Land Art Generator Initiative (LAGI) projects, I have distilled synergies with energy infrastructure into the following 12 Building Blocks. These building blocks represent a myriad of ways in which energy infrastructure can synergize with other functions on a basic level. They can be combined and reimagined to create diverse combinations with each Building Block representing multiple ways to synergize. The synergies are divided into three categories: environmental, sustainable transportation, and social synergies.

DIVERT

Energy infrastructure, especially solar infrastructure will intercept precipitation before it hits the ground. This means that people situated under such a structure will remain dry, which could be incentive for someone to sit or stand underneath. This diversion of rainwater has implications for stormwater management as water can be collected via a rain gutter and distributed to a planter or swale, slowing the speed of runoff. Sheet runoff from a solar panel surface can also be designed to drip directly into a planter without the need for a gutter. Rainwater may be harvested through either method for irrigation, storage, or environmental literacy purposes.

SHADE

Energy infrastructure, especially solar infrastructure may be opaque or transparent, which means it can be harnessed both when shade is desired and when filtered sunlight is preferred. Shade is important as it can contribute to cooler temperatures, combatting the urban heat island effect. Trees are more ideal for cooling and should be integrated for ultimate cooling or aesthetic purposes where required. However, in areas which are either too compact or inhospitable to trees, energy infrastructure can both fill that niche to provide shade and generate power.

CULTIVATE

Energy infrastructure, especially solar infrastructure can act as a physical scaffolding for crop, habitat, or ornamental planting growth. This could contribute to urban agriculture as a form of agrivoltaics, to cooling the urban heat island as a source of evapotranspiration, or as a component of a habitat patch for pollinators. Synergies between ‘Divert’ and ‘Cultivate’ could contribute to planting irrigation.

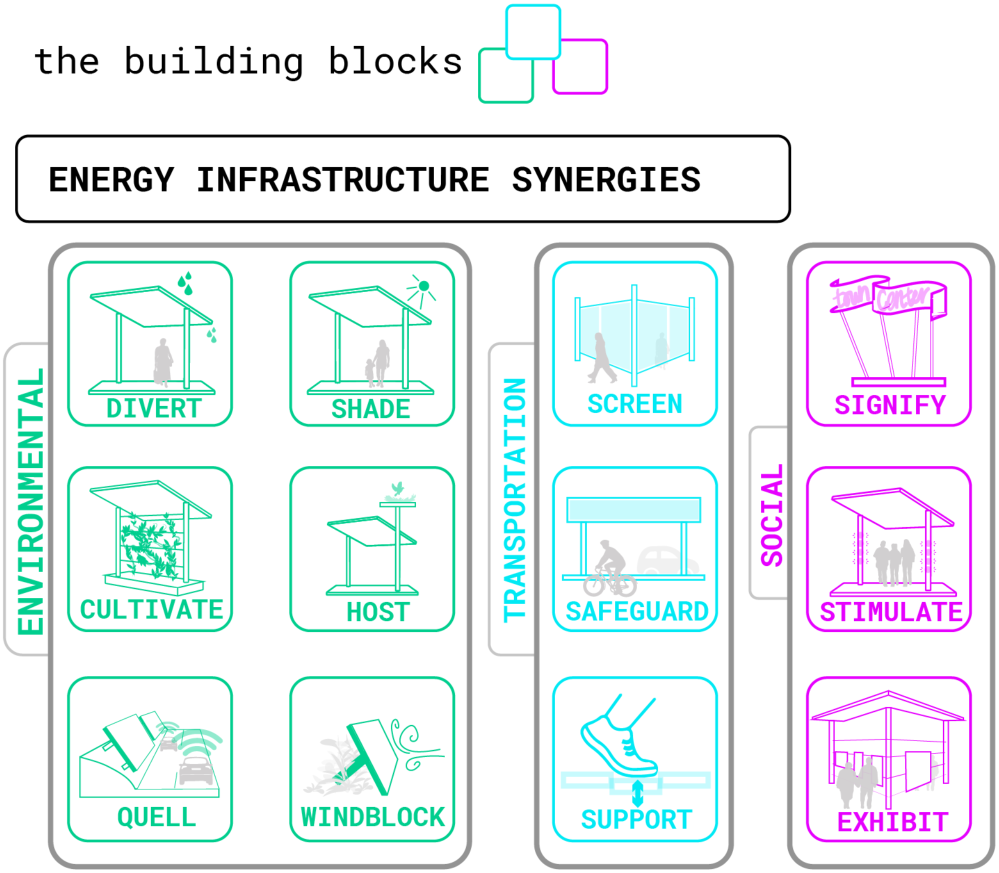


FIGURE 13: The Building Blocks: Energy Infrastructure Synergies

HOST

As mentioned in Chapter 2, energy infrastructure has potential to complement natural features, mimic historic habitat, they must not encroach on existing patches of highly valuable habitat, and they have the potential to encourage increased interaction between people and their environment. Orff (2016) notes that, "Artificial habitat mimics lost habitat niches and fosters the return of wildlife to areas inalterably changed by urbanization". In her 2016 book, Orff demonstrates how osprey nesting structures can be built into urban public space on a coastal ecology project in Brooklyn. Similar structures could be integrated into energy infrastructure.

QUELL

There is literature on the ability of solar infrastructure to quell the noise pollution produced by motor vehicles. Including solar infrastructure where noise reduction is desired, such as near highways, is a useful synergy. Highways also receive ample sunlight from lack of nearby buildings. Solar panels used to quell noise could also diversify microclimates beneath them through the introduction of shade.

WINDBLOCK

Literature on biosolar roofs documents the synergy between plants and ground-mounted solar panels. It is important for solar panels to be on the ground in order to intercept lateral wind currents. This would be most applicable in exposed areas or in harsh climates.

SCREEN

Opaque or transparent energy infrastructure, especially solar infrastructure can function well on the facades of buildings in a vertical orientation. This same vertical orientation could be used in freestanding structures that dually function to generate energy and screen one area from another. Vertical screens could screen 'landscape rooms' from one another, they could provide a visual screen between motor vehicle traffic and pedestrian zones, or any other desire for a visual separation of space.

SAFEGUARD

Energy infrastructure can increase street safety for pedestrians and cyclists. Solar or micro-wind infrastructure could act as a physical barrier between travel lanes of different speeds, increasing perceptions of safety in non-car travelers. In addition, energy infrastructure could power and provide structure for street lighting, which can increase perception of safety for pedestrians and cyclists after dark.

SUPPORT

Kinetic energy ground pavers, a technology currently on the market (outlined in Chapter 3), can dually produce energy via footsteps, pave sidewalk surfaces, and provide visual wayfinding cues on the ground surface. This technology could also be incorporated into crosswalks, where cars and bikes would also contribute to energy generation as the roll across.

SIGNIFY

Energy infrastructure, especially solar murals (a technology outlined in Chapter 3) can act as wayfinding features and as a reflection of local character and identity. When the infrastructure's form or material is artistic itself, or when solar murals incorporate works of local artists, they can generate energy while adding beauty to public space.

STIMULATE

Energy infrastructure can stimulate the mind through the inclusion of energy education, visually clear energy generation, interactive and engaging elements. Play elements such as energy-generating seesaws or swings are examples of interactive elements which contribute to environmental literacy. Energy infrastructure can also power aesthetic lighting to add visual interest to public space, stimulating public space through the attraction of people to the area.

EXHIBIT

Energy infrastructure can be used as physical structure to display signs, pieces of art, information, or other cultural exhibitions in public space. In this case, energy infrastructure can both generate energy and act as a community message board.

TYPOLOGIES OF PUBLIC SPACE

Harnessing various combinations of Building Blocks from the previous section, these 9 typologies illustrate how energy could be integrated into different types of public spaces to increase hyperfunctionality. Although all typologies of urban public space host dynamic mixes of functions, the only functions that have been called out in diagrams are the ones that synergize with energy infrastructure.

These typologies are transferrable to any city. When using the typologies as reference for a real project, designers must decide which Building Blocks would resolve existing community needs rather than trying to incorporate every potential synergy that could be applied to the site. For example, a vacant lot in Eugene, Oregon and a vacant lot in Portland, Oregon may have vastly different needs based on context, population density of the site, and nearby community resources.

There are other types of public space outside of the 9 typologies that have been compiled in this chapter. It would be difficult to assemble every single type of public space into this document, and many sites are a combination of multiple typologies. Furthermore, every site has its own unique challenges and opportunities. Therefore, in order to use this document to its full potential, designers should use typologies as jumping-off-points for customizing their sites rather than emulating the examples verbatim.

COMMUNITY GARDENS

Needs of the community garden include appropriate conditions for plants that grow, people that garden, and neighbors that socialize. Synergies between energy infrastructure and community gardens center around the well-documented practice of agrivoltaics, or the coexistence of solar photovoltaics and agriculture on the same site. This can range from vegetable gardens to animal pastures, in which collocation benefits both functions. In the case of community gardens, plants can provide much-needed cooling for solar panels while solar infrastructure can be used to shade, to divert water into specified locations, and to shelter gardeners from precipitation. A full list of synergies is given:

- *Providing shade for the garden to increase diversity of microclimates for plants with varying sunlight needs, especially native plants and pollinator species*
- *Providing structure and support for climbing plants*
- *Diverting rainwater to fall on specific plant beds or swales*
- *Sheltering gardeners from sunlight or precipitation*
- *Sheltering plants from wind damage by using ground-mounted solar photovoltaics*

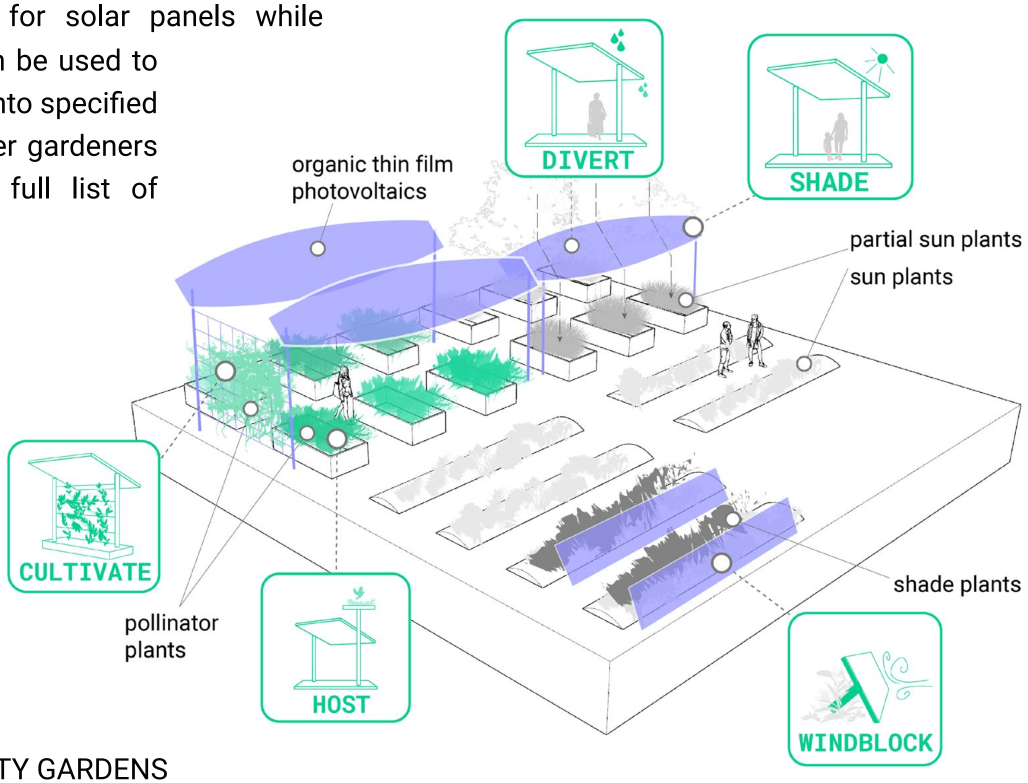


FIGURE 14: COMMUNITY GARDENS

VACANT LAND

Synergies between energy infrastructure and vacant land can be as varied as your imagination. Some needs may be revenue generation, stormwater management, or increasing community cohesion. Depending on the size and context of the plot of land, energy infrastructure can help provide amenities that are missing from neighborhood. This could be an opportunity for social gathering space, for displaying the work of local artists or school children, for charging personal devices or electric vehicles, for performing bike repair, for planting a garden, or for any number of other uses. A full list of synergies is given:

- *Providing space and structure for a habitat patch or community garden, as discussed above*
- *Providing shelter and seating for a social gathering*
- *Powering and emitting night lighting*
- *Creating an outdoor art gallery of professional or community work*
- *Utilizing solar mural technologies to display public art*
- *Carving out space and providing power to street vendors and performers*
- *Providing shade, seating, and power to rest and charge personal devices, electric bikes, and electric vehicles*
- *Providing shelter and power for amenities like a neighborhood fridge, an information kiosk*

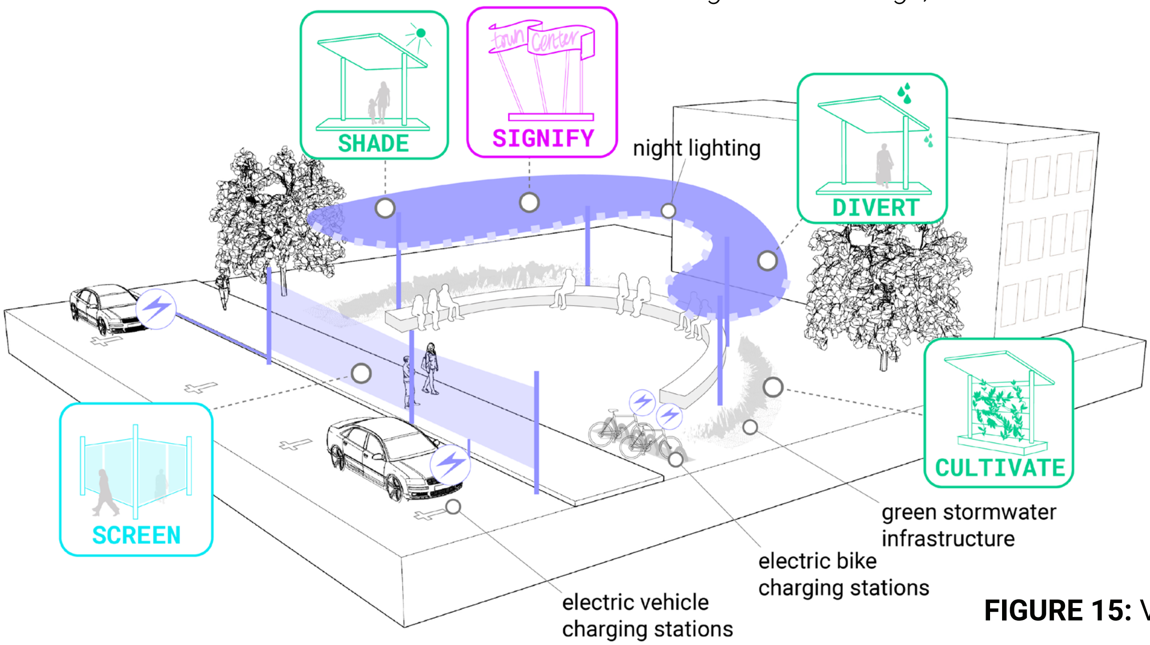


FIGURE 15: VACANT LAND

PARKING LOTS

Needs of parking lots may include a reduction in the urban heat island effect, a reduction in area of impervious surfaces, a more efficient use of space than the storage of cars. Parking lots have many potential synergies that allow space to be used for parking and other uses at differing times of the day or week. Switching the uses of parking lots to be more hyperfunctional means creating space for other modes of transportation such as biking and walking, not just driving. A full list of synergies is given:

- *Providing shade to reduce the urban heat island effect produced by asphalt*
- *Slowing and diverting stormwater towards specific plant beds or swales*
- *Creating shade and storing power for night lighting to host social gatherings*
- *Utilizing solar mural technologies to display public art*
- *Providing power and shelter to farmer's markets, art markets, or food trucks*
- *Providing power to create electric bike and vehicle charging stations*

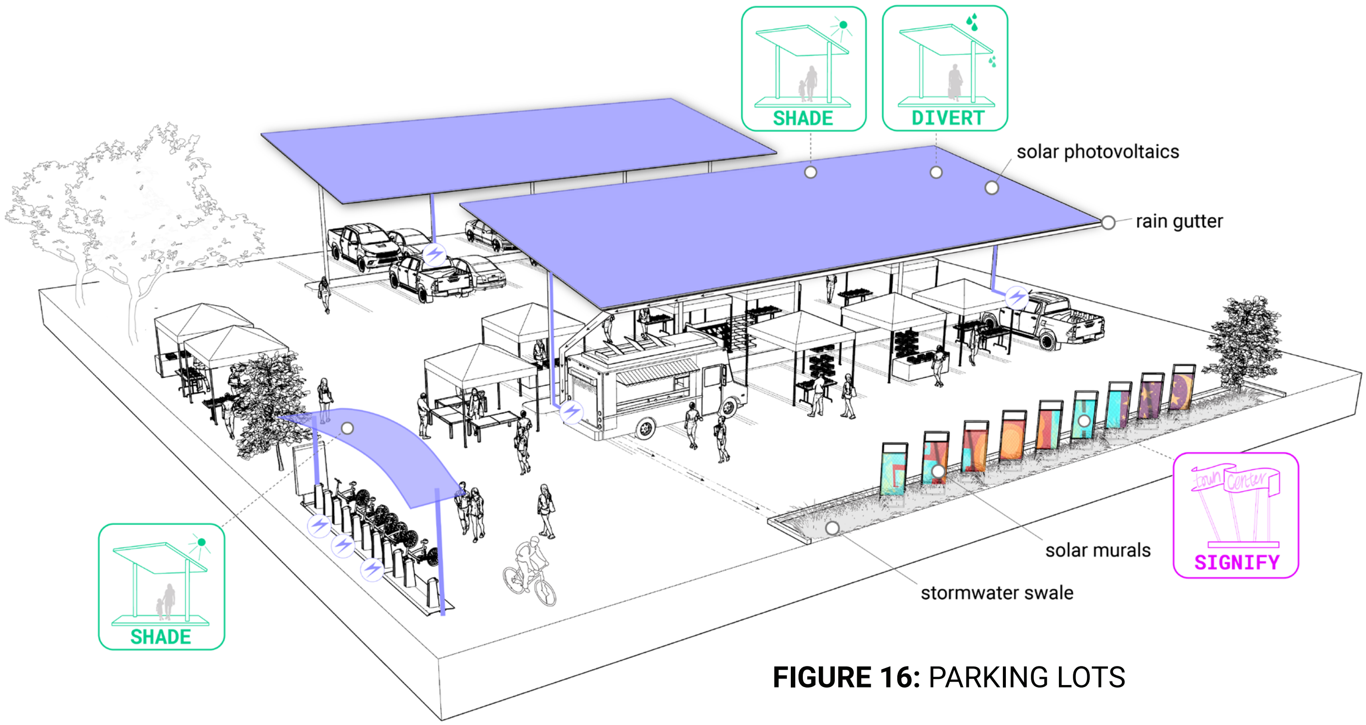


FIGURE 16: PARKING LOTS

SLOW STREETS | PLAY STREETS

Slow Streets or Play Streets are typically low-traffic streets which are closed down partially or fully to drivers for the purpose of play. These can act as linear parks in areas where public space is limited. They may be permanent or temporary, depending on the municipality. The needs of slow streets / play streets include a safe playing environment for children, slow or minimal traffic flows, and environmental comfort. A full list of synergies is given:

- *Providing barriers to limit vehicle entry at specific intersections*
- *Providing energy-producing play structures such as swings, seesaws, and in-ground trampolines, which would engage learners through responsive and interactive energy production*
- *Providing shade canopies in areas where trees are less desirable or difficult to grow*
- *Powering amenities like a community fridge, street vendors, street performers*

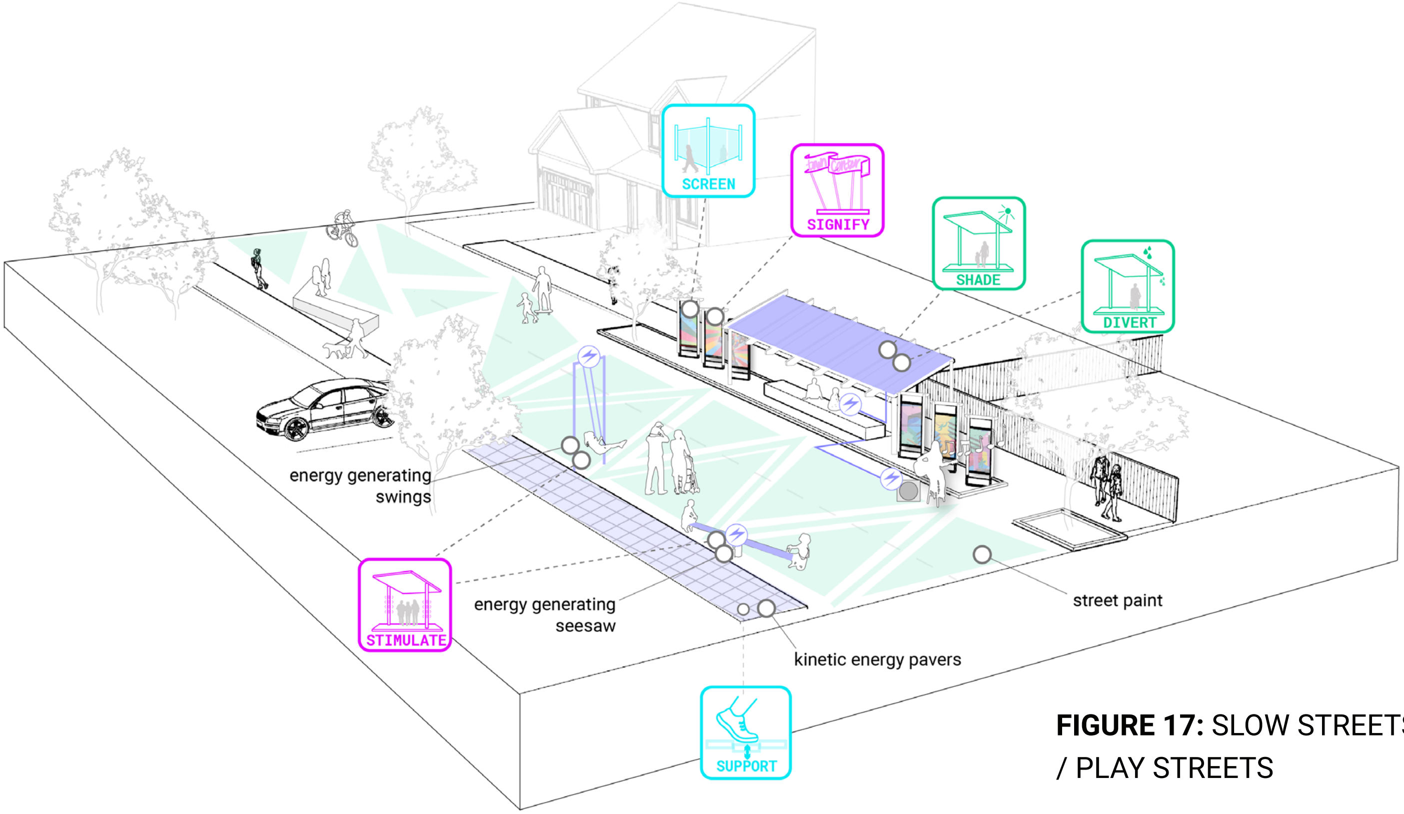


FIGURE 17: SLOW STREETS / PLAY STREETS

NEIGHBORHOOD GREENWAYS

Neighborhood Greenways are streets designated as walking and biking routes, usually connected in a line or loop. They require visible wayfinding, safe road crossings as they cross busier streets, adequate night-lighting, and environmental comfort. A full list of synergies is given:

- *Providing barriers to limit vehicle entry at specific intersections*
- *Providing shade canopies in areas where trees are less desirable or difficult to grow*
- *Powering amenities like a community fridge, street vendors, street performers*
- *Providing shade and power outlets, which, in combination with seating, creates micro-refuges*
- *Increasing a sense of safety for cyclists by providing physical, vertical lane separation*
- *Strengthening the visual impact and perception of safety of crosswalk bulb-outs*
- *Increasing sense of safety and beauty by powering practical yet beautiful night lighting*
- *Energy infrastructure used as traffic calming; chicanes, for example*

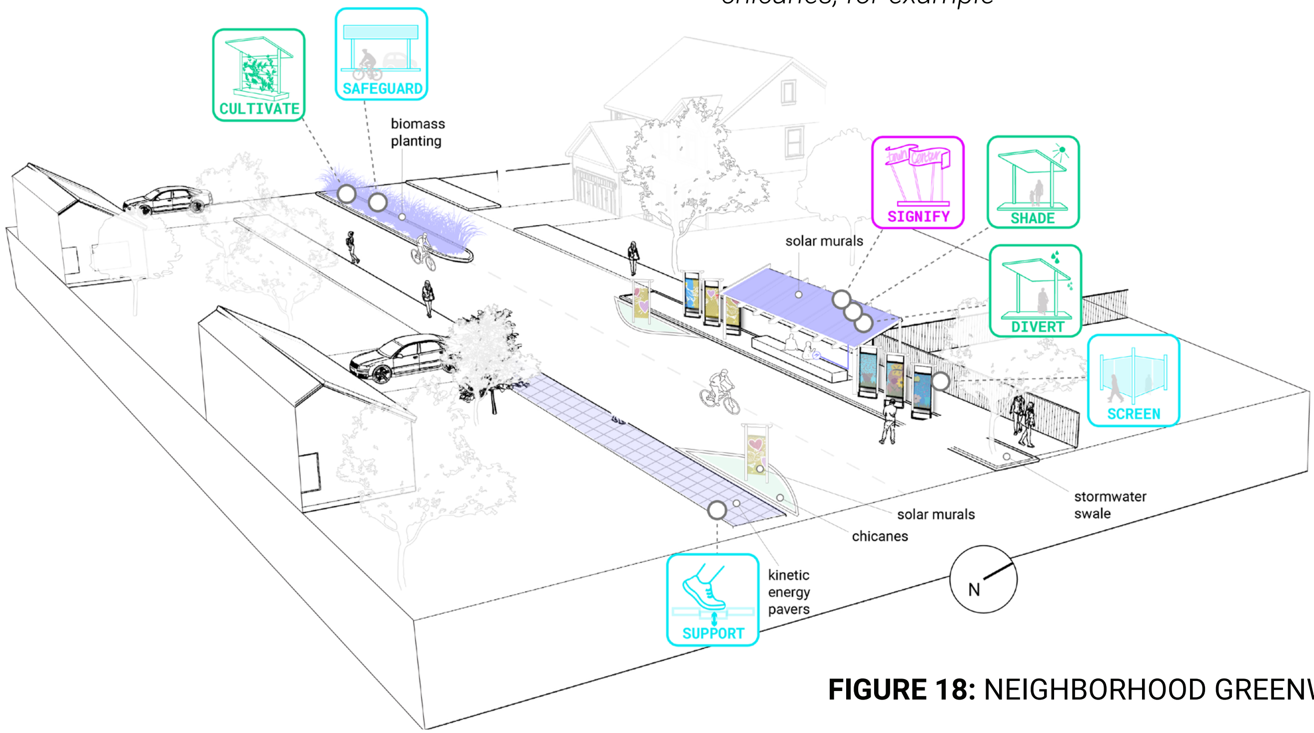


FIGURE 18: NEIGHBORHOOD GREENWAYS

URBAN DESIGN FRAMEWORK

URBAN STREETS

Urban streets, where higher-density development supports transit and a higher concentration of other community amenities have different needs than those of residential streets. They are busier and require increased safety precautions for alternative modes of transportation. In addition, with limited open space, they benefit from the inclusion of small patches of habitat or green infrastructure where possible. Busier streets also make way for a larger audience for art displays or food truck pods. In commercial areas, restaurants may benefit from pairing solar canopies with outdoor dining in the ROW. A full list of synergies is given:

- *Increasing a sense of safety for cyclists by providing physical, vertical lane separation*
- *Delineating street space for social pedestrian uses such as parklets*
- *Providing shelter from sunlight and precipitation for outdoor dining*
- *Diverting rainwater into designated stormwater bioswales*
- *Providing structure and power for night lighting, public charging outlets, public art displays, information kiosks, street vendors, street performers, and amenities like a community fridge*

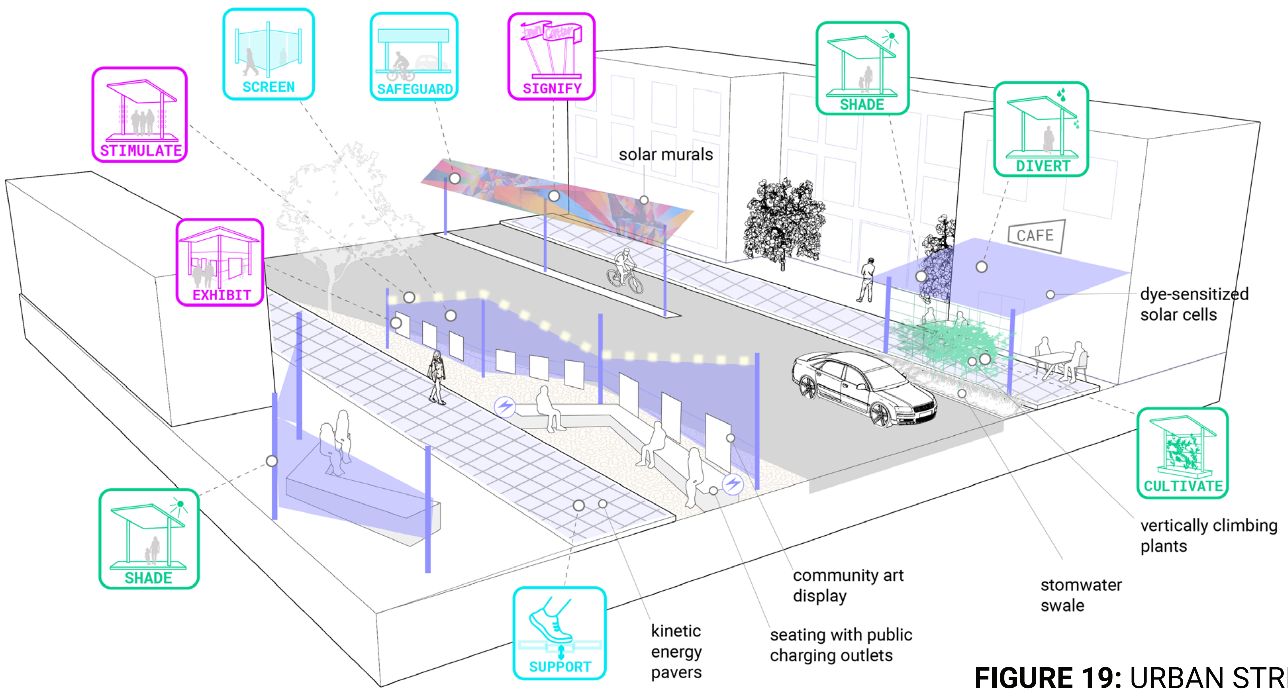


FIGURE 19: URBAN STREETS

INTERSECTIONS

Intersections differ from streets in that they are high activity, high-visibility nodes. Needs at intersections include visibility for turning vehicles, safe crossings for pedestrians and cyclists, protected left-turns for cyclists, and clear lane designations. This is also a great location for wayfinding and placemaking because of the high-visibility. A full list of synergies is given:

- *Increasing a sense of safety for cyclists by providing physical, vertical lane separation*
- *Diverting rainwater into designated stormwater bioswales*
- *Providing barriers to limit vehicle entry at specific intersections*
- *Providing shade canopies in areas where trees are less desirable or difficult to grow*
- *Strengthening the visual impact and perception of safety of crosswalk bulb-outs*
- *Increasing sense of safety and beauty by powering practical yet beautiful night lighting*

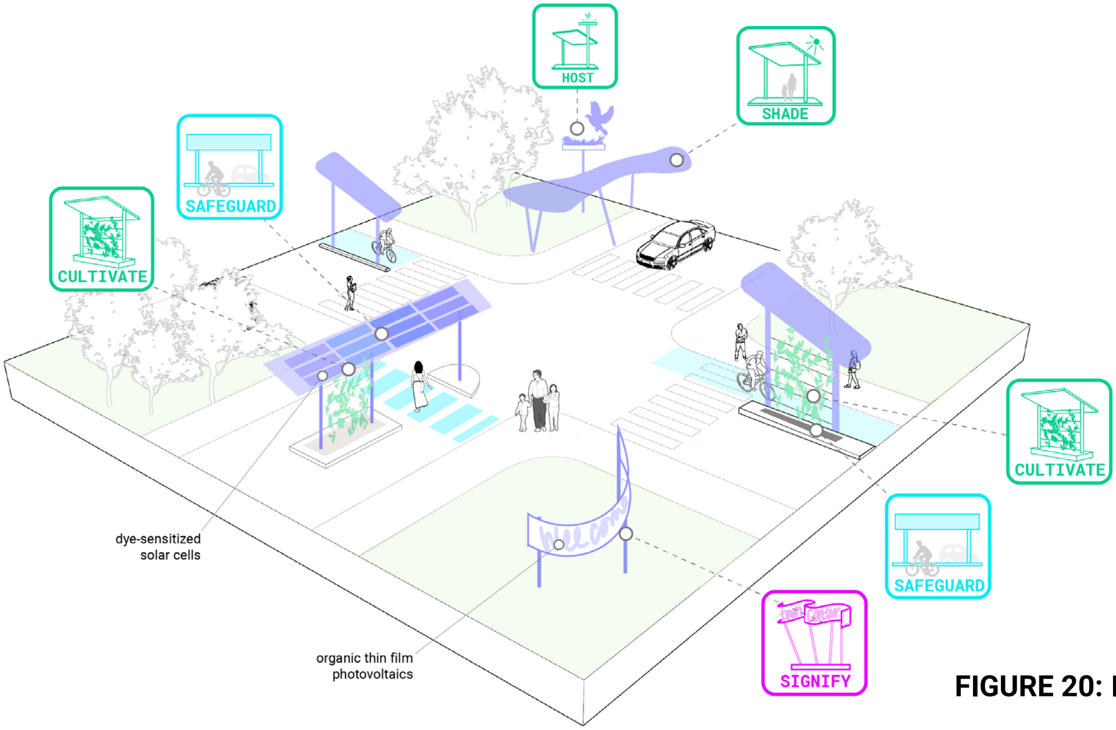


FIGURE 20: INTERSECTIONS

HIGHWAYS

Highways generate air and noise pollution which spreads to the surrounding area. Energy infrastructure has the potential to help counter these two negative affects by acting as a noise barrier and by promoting green infrastructure or pollinator habitat to combat air pollution. Micro-wind is well-suited to busy and high-speed streets because of the wind that cars generate as they drive by. Technologies like vertical axis wind turbines are compact and fit in human scale urban spaces in medians or on the side of roads. Underutilized grass strips that flank highways could instead house biomass plantings. A full list of synergies is given:

- *Creating visual interest and strengthening place identity with large solar murals or micro wind*
- *Reducing mowing needs and increasing visual interest with large-scale roadside biomass plantings*
- *Reducing noise pollution and diverting air pollution with solar paired with planted green walls*

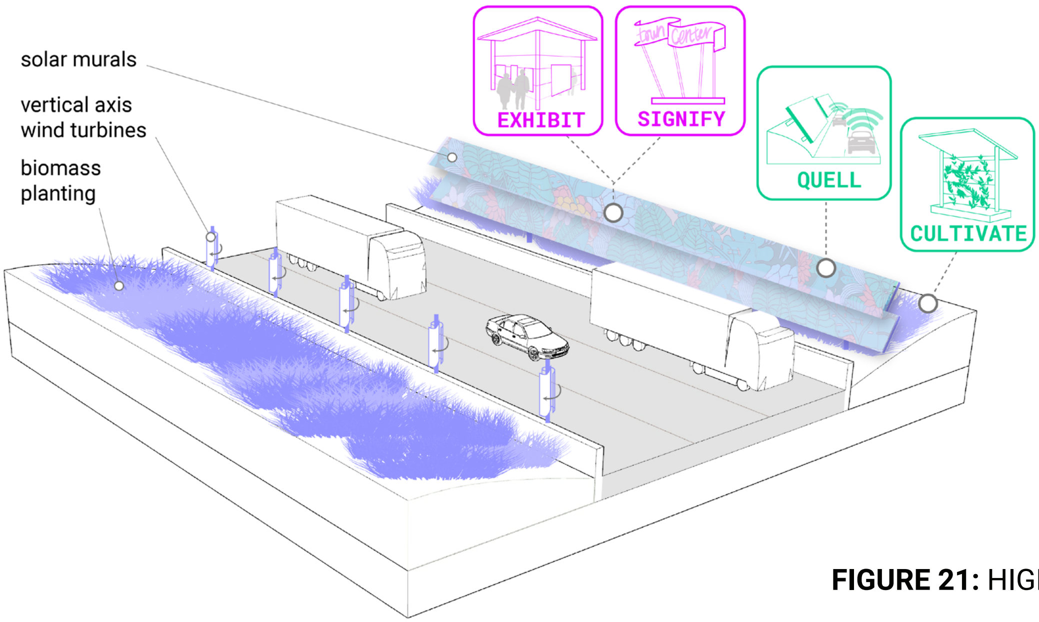


FIGURE 21: HIGHWAYS

UNDERPASSES

Highway underpasses are different from the highway ROW in a few ways including the lack of roadside landscape strips, and the dark and disquieting space created underneath the overpass. Highway underpasses are generally under-designed landscapes that offer shade and shelter yet minimal access to feelings of safety brought about by 'eyes on the street'. A promising synergy between energy infrastructure and public space could be the addition of solar and wind powered lighting. Colorful lights can illuminate a space day or night, reducing visibility barriers and introducing clarity to the public space. In addition, this inclusion of lighting and color could attract more people to pass through the space, thus adding more 'eyes on the street' and increasing the public perception of safety. Solar and wind infrastructure necessary to power these lights could be located above the underpass with access to solar energy and wind from moving vehicles. A full list of synergies is given:

- *Solar murals located above the underpass could strengthen artistic identity above*
- *Energy generated above could power colorful yet practical lighting in the underpass*
- *Light emitted below an underpass could contribute to wayfinding or placemaking*

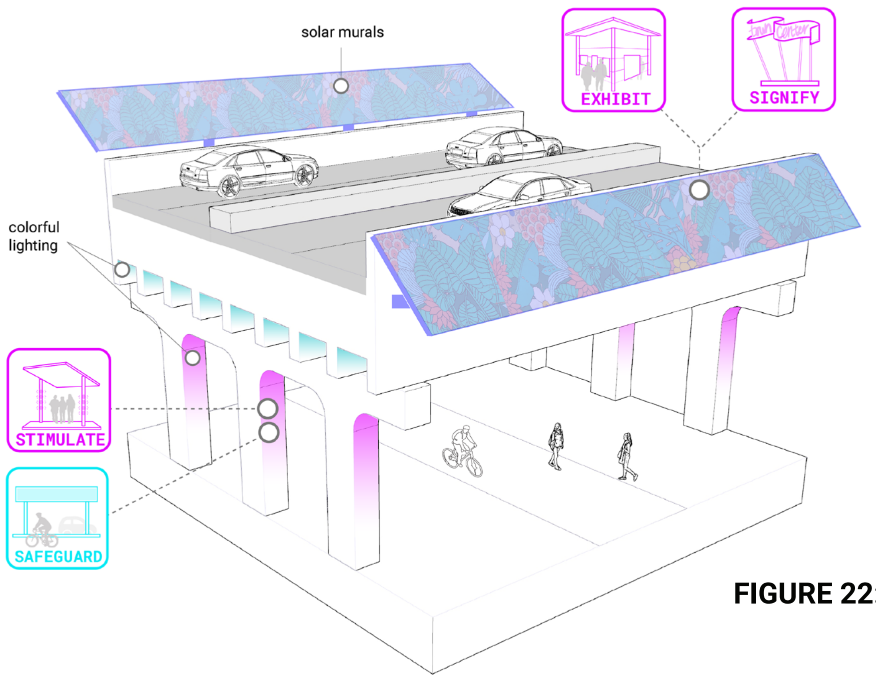


FIGURE 22: UNDERPASSES

5 | APPLICATION

SITE DESIGN IN PORTLAND, OREGON

CHAPTER OVERVIEW

In the preceding sections, I discussed basic methods for integrating renewable energy into the ROW and public space. I then proposed 9 typologies of urban space, and represented applicable synergies in writing and visuals. In this phase of Projective Design, I apply the Building Blocks to a site in the Lents neighborhood of Portland, Oregon using the typologies as examples. Here, I demonstrate how energy synergies can contribute to placemaking, wayfinding, and identity of a specific place, as well as demonstrating how to filter the typologies for a real site.

BACKGROUND ON LENTS

Lents started as a Portland suburb founded by William Lent. It was later annexed in 1912. Jewish, Chinese, German and Irish families called the area home during this time.

In the 1970's, the neighborhood was bisected by the construction of the I-205 highway, tearing a neighborhood apart. This decision was made after lobbying from more affluent residents of Portland's central city. While annexations in East Portland increase the tax base for city improvements, residents are largely left out of the improvements they fund.

As a sprawling outer Portland neighborhood, Lents has been left out of the sustainable and climate-positive advancements that have swept central Portland in recent decades and earning Portland a reputation as a green, forward-thinking city. There has been pattern of disinvestment in East Portland neighborhoods that has resulted in a lack of walkability and an overall excess of pavement. The I-205 corridor is Portland's most vulnerable area for extreme heat and flooding risks because of its excess of impervious surfaces. They hold heat with their dark surfaces and lack of planting or shade, while also causing sheet runoff because of the lack of permeable ground surfaces.

Lents is rich in culture and community. One in five Lents residents identify as a person of color, and two in five speak a language other than English at home. Lents International Farmer's Market is the only Portland Farmer's Market that specializes in international food, including locally grown Mexican produce and Asian greens. The neighborhood surrounding 82nd avenue is called the "Jade District" because of the high density of Asian and Asian American residents and businesses. There have been rapid demographic shifts in East Portland in the past ten and twenty years. There is a high percentage of immigrants from east asia, many displaced from their home countries. Jade District businesses found their home in East Portland after being price-out of downtown Portland and the historic Chinatown

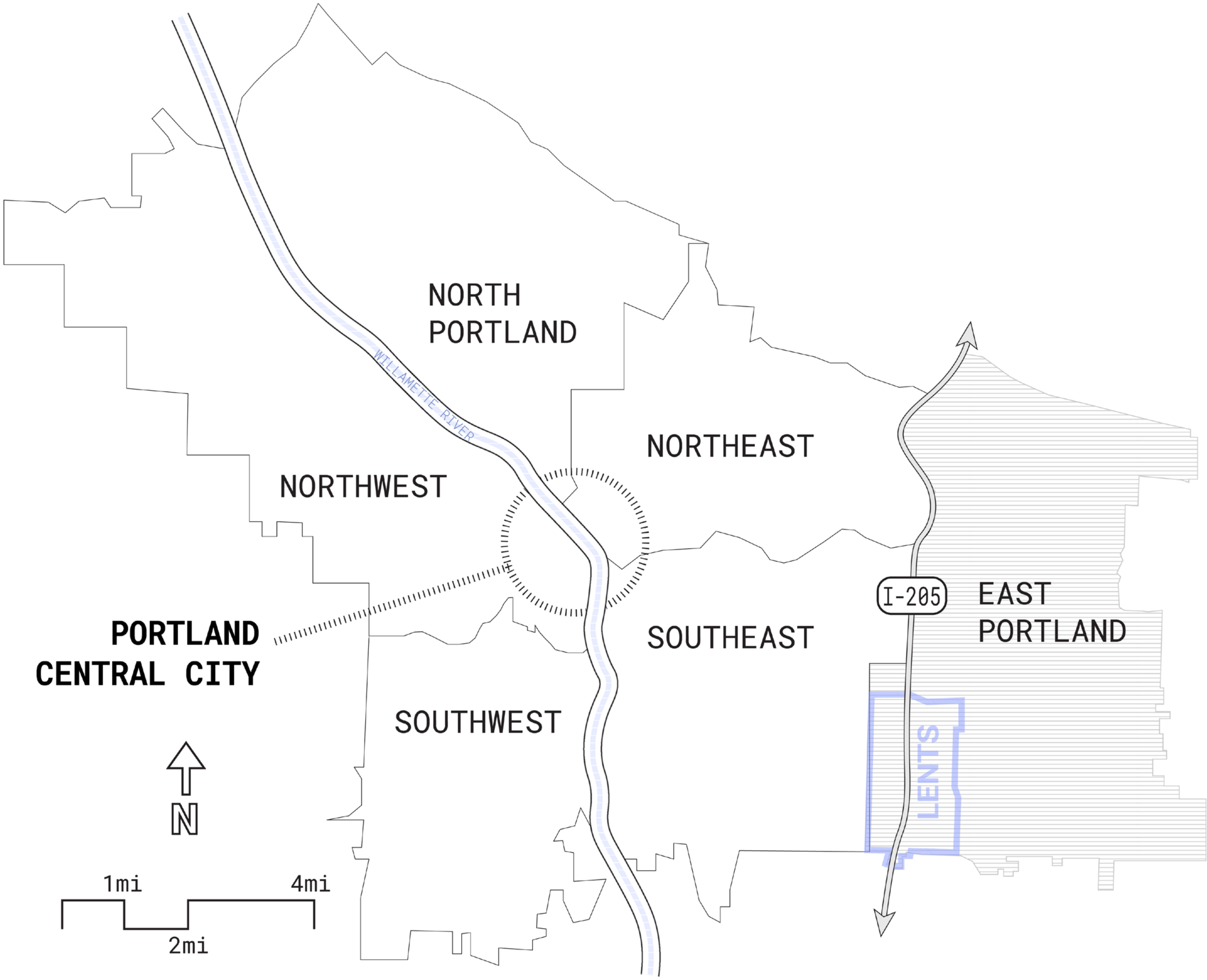


FIGURE 23: PORTLAND CONTEXT MAP

district. At the same time, black Portlanders are moving to East Portland, pushed out of the historic Albina neighborhood due to increasing property values. East Portland is a hub of displaced communities who enrich the area with their culture and diversity.

However, Lents is gentrifying. White and higher-income Asian newcomers could displace the low-income Asian, Hispanic, and Black residents who call the neighborhood home. Even public investments with intentions of benefiting the existing community can have unintended negative consequences, pushing property values up and forcing people to relocate. Many of these residents have been pushed out from other neighborhoods in the past and are familiar with being priced out of a neighborhood. Because Lents is vulnerable to displacement, a top priority for this project is to combat displacement, create a sense of place unique to Lents, and allow current residents to benefit from investment. Therefore, this project focuses on embellishing existing spaces rather than erasing and rebuilding anew. We must serve locals before serving visitors or tourists.

LENTS AND ENERGY

Since East Portland is less dense than the central city, it is more suitable for solar installations because of lack of shadows cast, and more roof area per capita (Ko et al. 2017).

In other parts of the city, Portland Public Schools is investing in solar technologies on a district scale in a program called "Solar 4R Schools". They have set energy goals in conservation, efficiency, and in the use of renewable energy in their schools. They provide trainings on how to incorporate these solar installations into classroom lessons because an important aspect of solar power in public schools is education and social engagement.

Portland also keeps track of energy usage in schools. The energy needed to power Lent Elementary is between 10,000 and 27,000 kWh per month, or between 330 and 900 kWh per day. Ideally, solar installations would have capacity for generating about 600 kWh per day, halfway between the minimum and maximum energy usage totals and a realistic goal for this project.

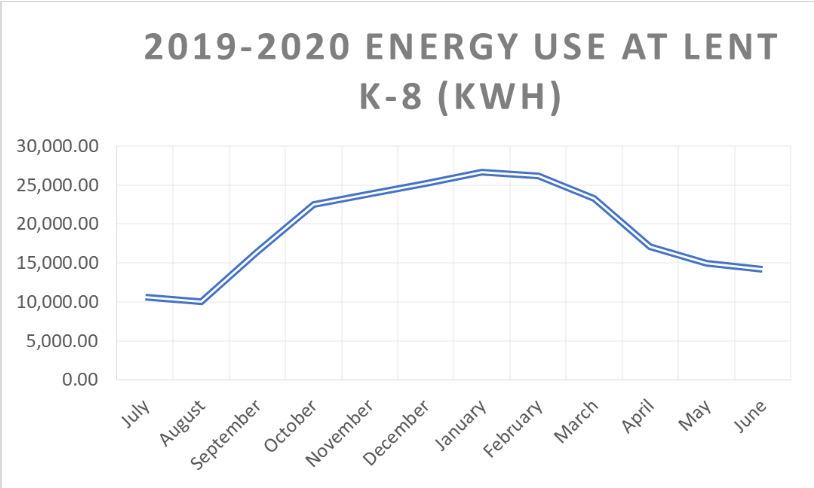


FIGURE 24: Graph of energy use at Lent Elementary [Portland Public Schools]

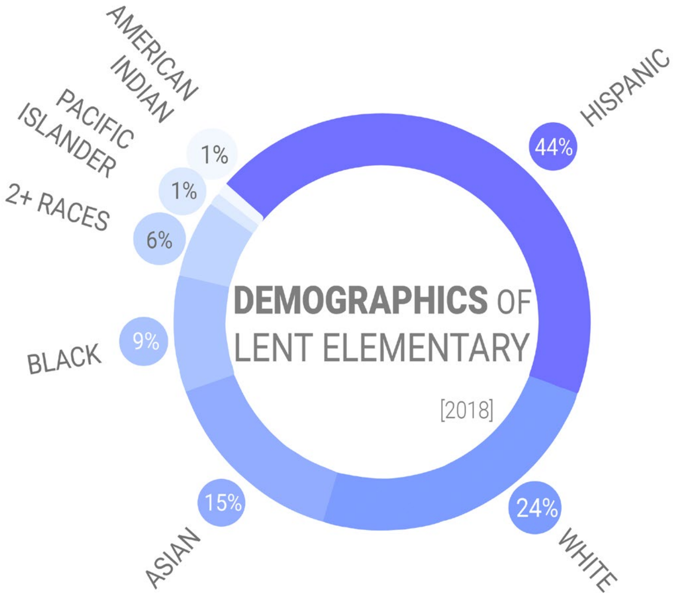


FIGURE 25: Demographics of Lent Elementary in 2018 [Portland Public Schools]

SITE DESIGN

THE LENTS GREEN RING

The Green Ring is an urban design proposal spearheaded by the non-profit Green Lents which would connect parks, schools, and community resources across Lents in a loop of neighborhood streets and greenways, prioritizing walking and biking. Green Lents describes the project:

"[The Lents Green Ring is] a community place-making project that improves neighborhood safety, accessibility, and enjoyment through conversations and collaboration across Lents' diversity and geography"

However, Green Lents also notes that "additional investments are needed to make the loop feel safe, family-friendly, and accessible to all mobility types".

Issues that the Green Ring seeks to address:

- Crossing upgrades
- Path connection upgrades
- Sidewalk upgrades
- Improved signage
- Better connections to popular Lents community spaces

Although there is currently no local champion for the project, there was site analysis conducted in 2016 and 2017 on bike and pedestrian conditions. In one report titled, "The Lents Green Ring: 2017 Community-Based Existing Conditions Assessment", a community engagement team of students and professionals documented 10 local walking tours of the Green Ring which involved over 70 community members. They also surveyed over 150 residents on their perceptions and concerns about the Green Ring. They documented community members concerns on each stretch of the Green Ring, and their documentation of Steele Street was used to inform site analysis for this study. Concerns on Steele street included lack of wayfinding, safe crossings, clear paths, and street lighting.

I use a segment of the Green Ring, called out on the right as the "Design Focus Area". The segment is low density, residential, and in need of many of the upgrades that Green Lents has listed.

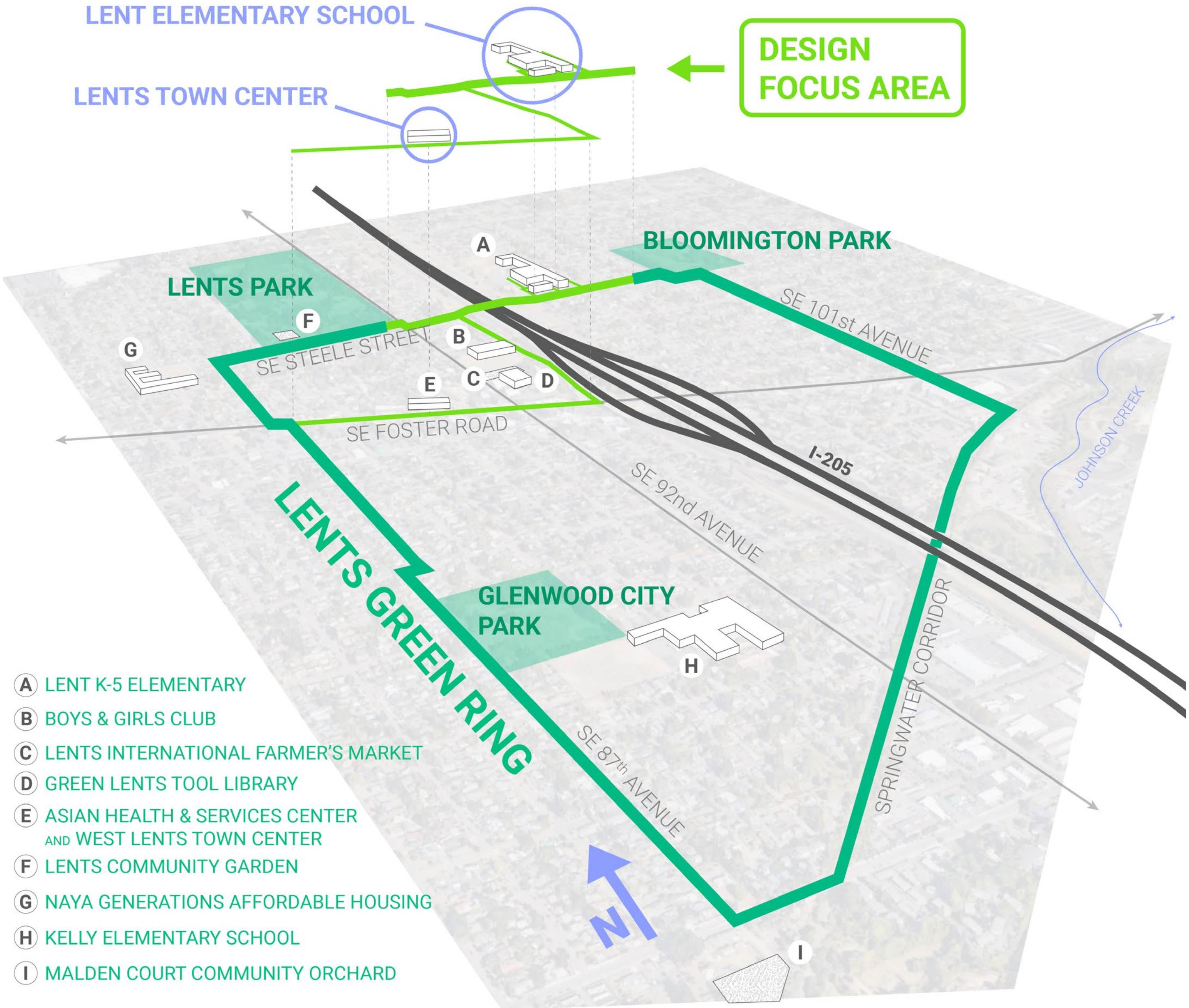
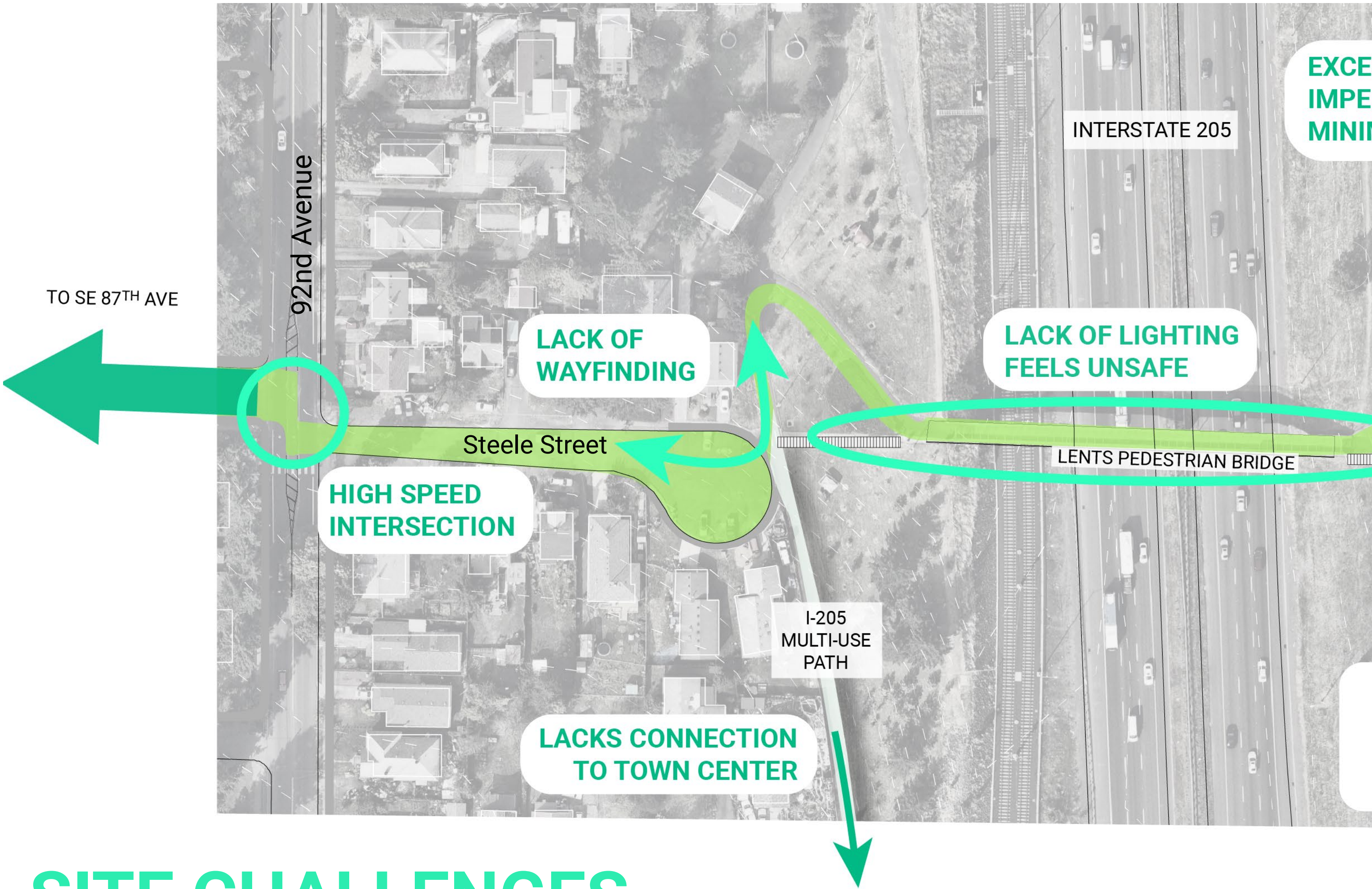


FIGURE 26: MAP OF LENTS GREEN RING



SITE CHALLENGES

A closer look at the design focus area reveals a series of challenges with the streetscape which, if solved, could increase walkability and accessibility of the Green Ring. These issues were documented in a 2017 community-based existing conditions assessment called “The Lents Green Ring”, conducted by Portland State University and Green Lents I also made my own observations through site visit and site analysis. Challenges identified in Figure 27 include busy intersections at 92nd and 97th Avenues, an unclear route connection between the Steele Street cul-de-sac and the Lents Pedestrian Bridge, a lack of connection to Lents Town Center, a pedestrian bridge experience with inadequate lighting to promote

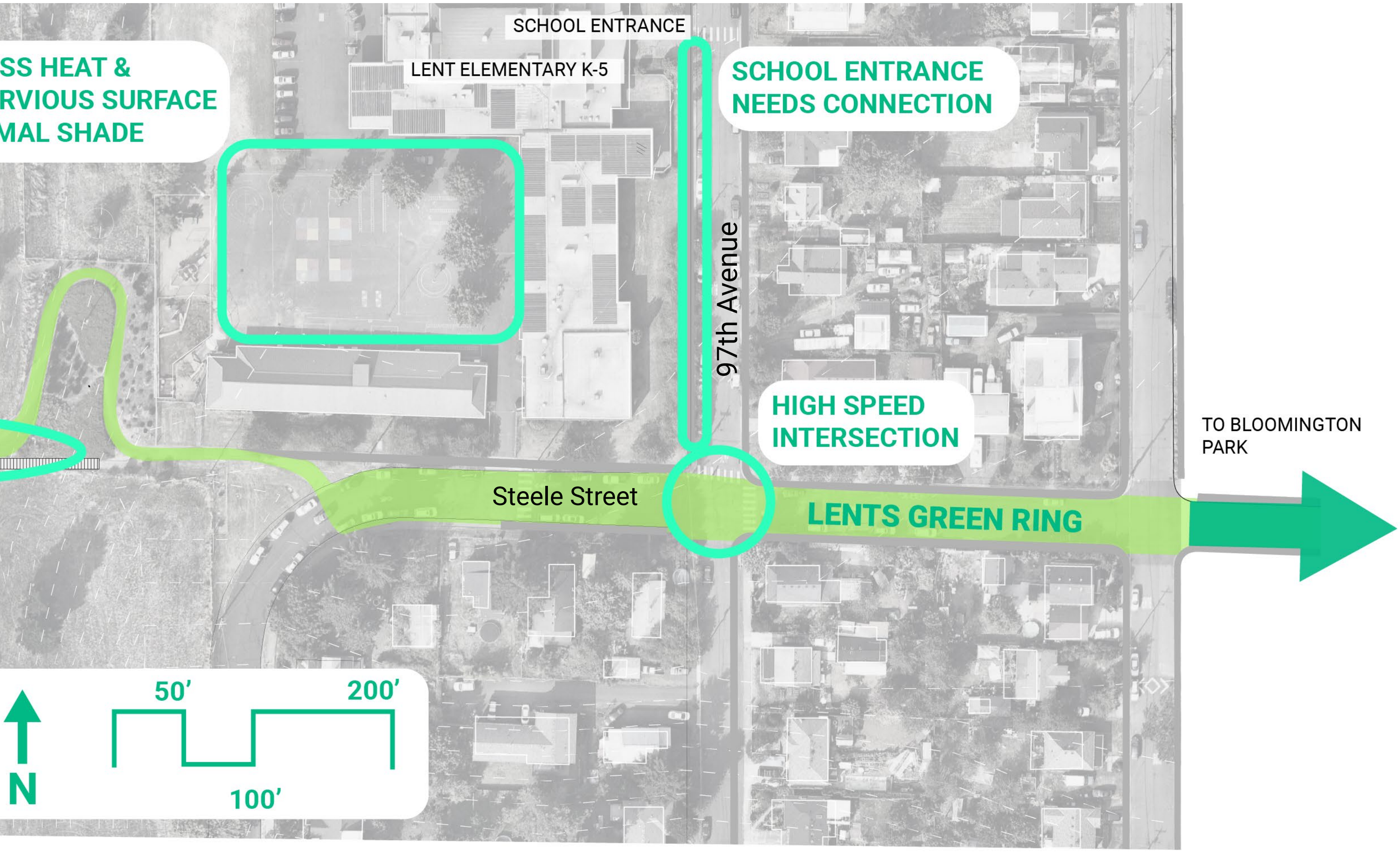


FIGURE 27: SITE CHALLENGES

safety, a schoolyard lacking shade, and a missing connection between the Green Ring and the entrance to Lent Elementary.

LOCAL CHARACTER IN LENTS

Street Mural by Lents Youth Initiative

Lents Story Yard

Mural on Lents Pedestrian Bridge

Murals at Lents Pedestrian Bridge

[PHOTOS BY AUTHOR]

FIGURE 28: LOCAL CHARACTER IN LENTS

Lents Town Center

“Four Directions” mural by local artist Rudy Serna

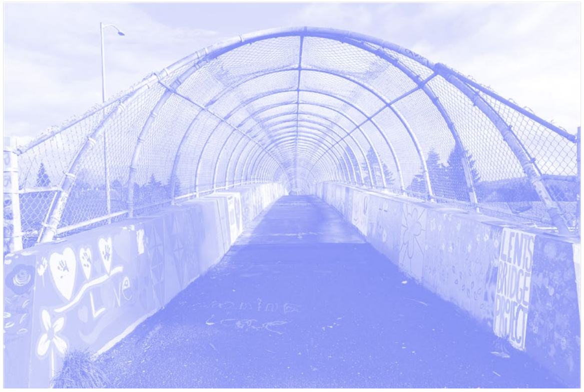
Slow Streets near Lents Park

Social justice intervention at Lents Park

UNDERUTILIZED LAND

ALONG THE GREEN RING

STEELE STREET CUL-DE-SAC



LENTS PEDESTRIAN BRIDGE

I-205 CORRIDOR

LENT ELEMENTARY SCHOOLYARD

97TH & STEELE CROSSWALK

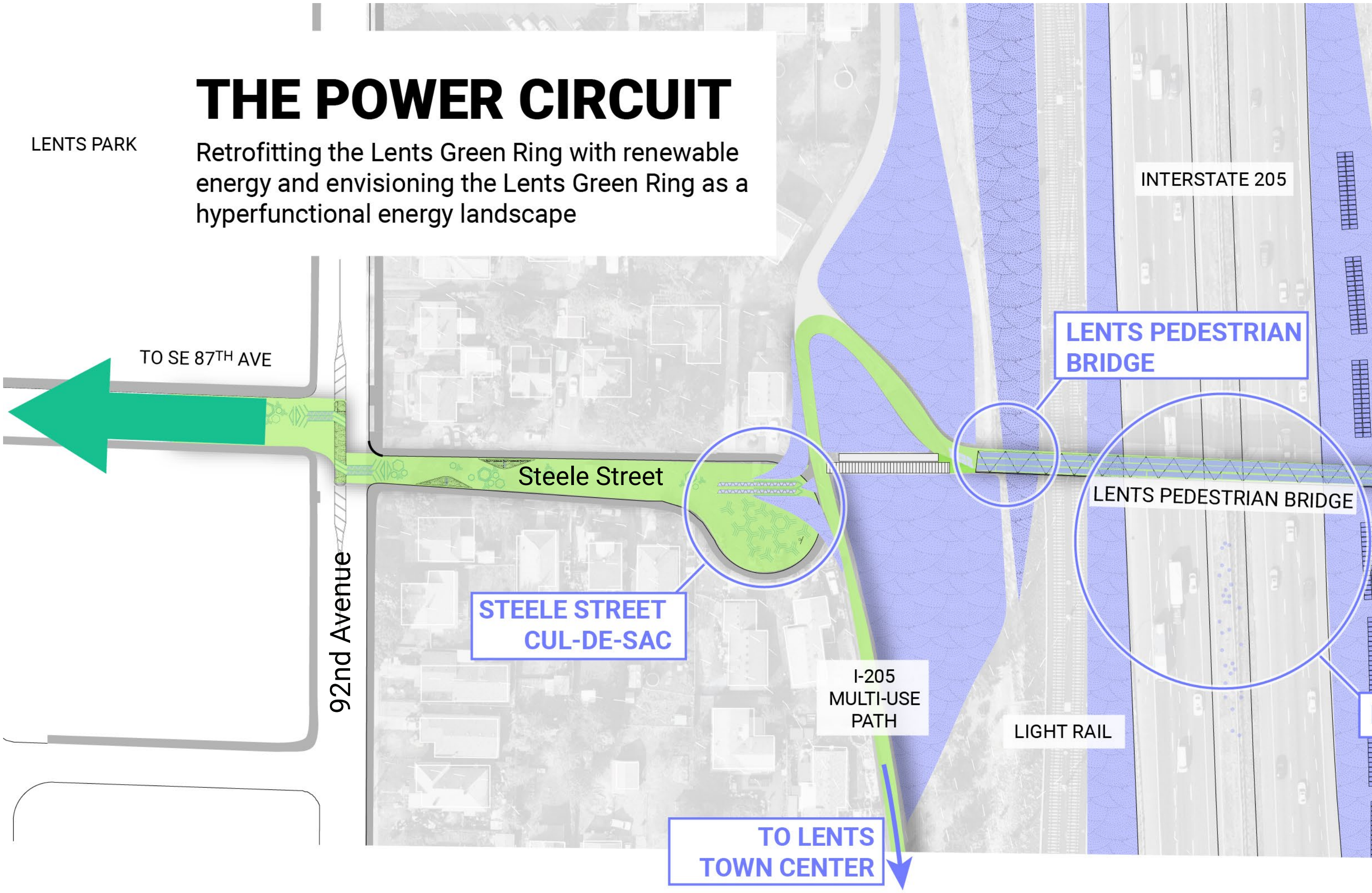
LENTS TOWN CENTER RIGHT-OF-WAY

These photos show 6 sites of interest along the Green Ring that are currently underutilized. From the Steele St. Cul-de-sac to the Crosswalk at 97th & Steele St, these sites are opportunities to introduce renewable energy infrastructure to the ROW while simultaneously addressing challenges onsite that are unrelated to energy, such as walkability and perceptions of safety. In the following pages, I show how each of these 6 sites of interest could be redesigned as hyperfunctional energy landscapes.

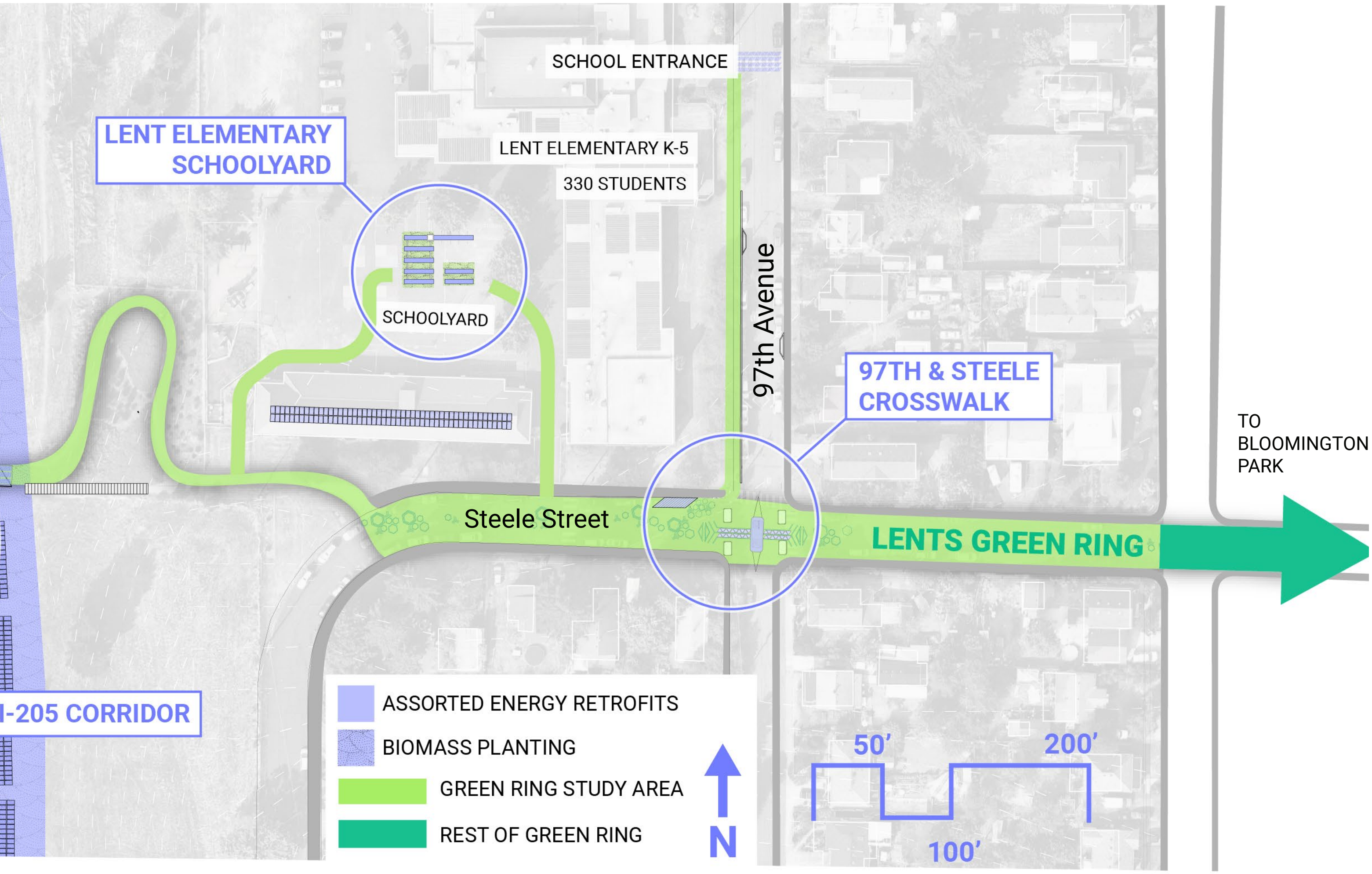
FIGURE 29: EXISTING CONDITIONS IN THE DESIGN FOCUS AREA

THE POWER CIRCUIT

Retrofitting the Lents Green Ring with renewable energy and envisioning the Lents Green Ring as a hyperfunctional energy landscape



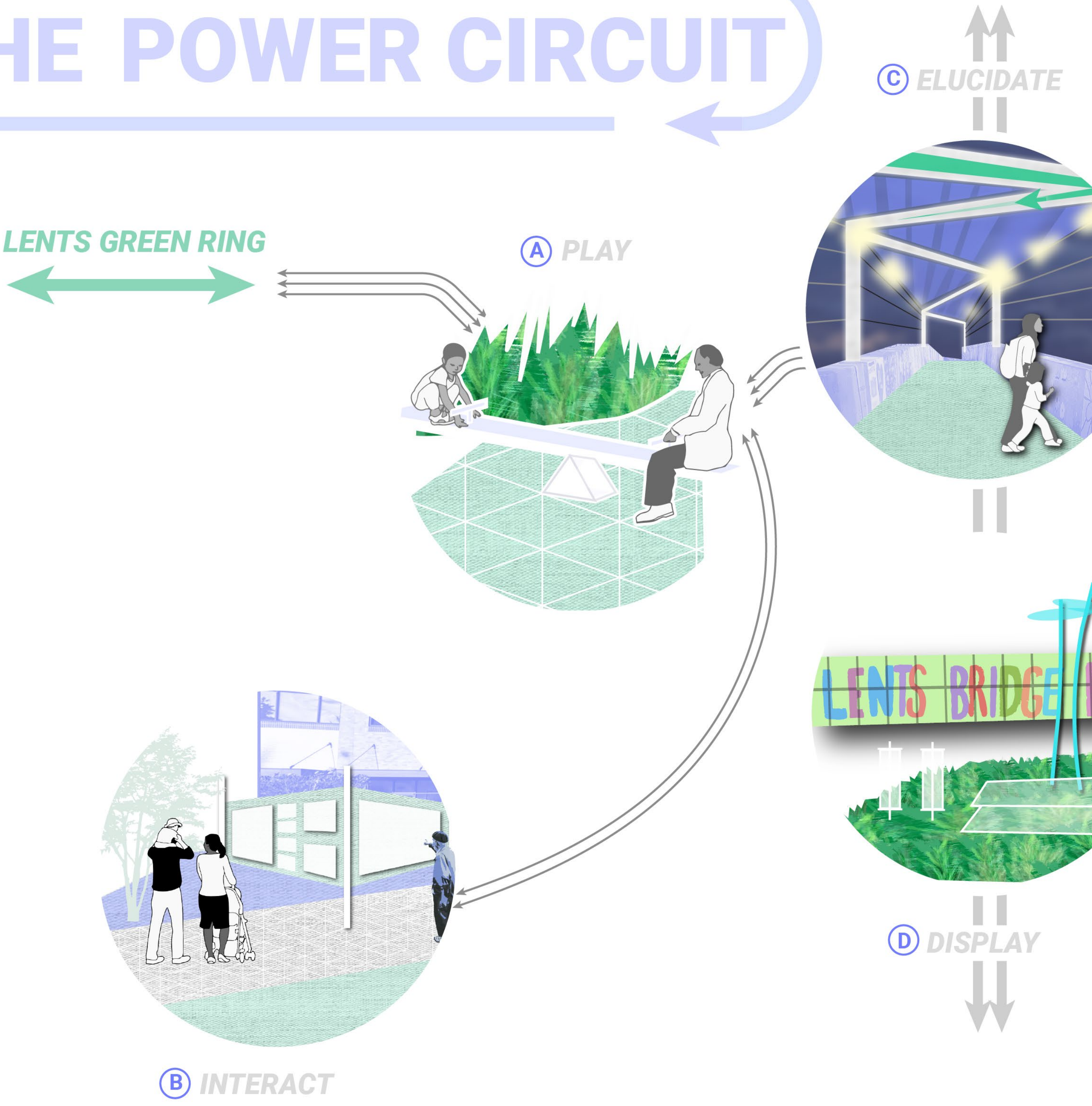
The Power Circuit is a potential solution for the challenges of the Design Focus Area. The 6 sites of interest are mapped in Figure 30, from west to east: the Steele St. cul-de-sac, the Lents Town Center, the Lents Pedestrian Bridge, the I-205 Corridor, the Lent Elementary Schoolyard, and the 97th & Steele Crosswalk. Together, these sites could create a continuous narrative of accessibility and energy democracy. I also propose connections between the Green Ring and Lents Town Center via the I-205 multi-use path, and a connection to the entrance of Lent Elementary via 97th Avenue. This design helps reclaim the ROW for pedestrians by closing some interactions to vehicles, by increasing clarity

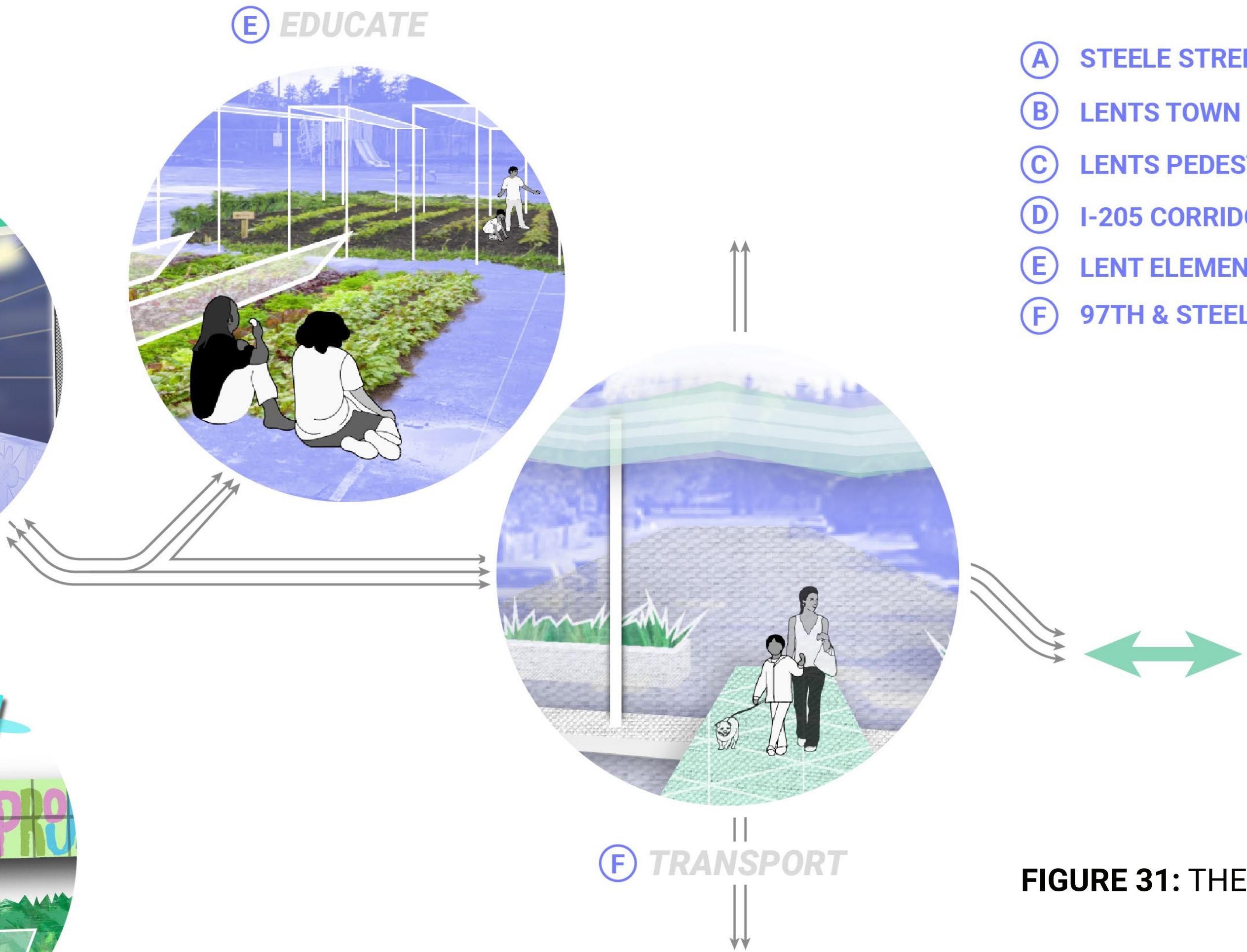


of wayfinding, and by increasing street lighting to the route. The highway corridor represents a unique opportunity to include large-scale plantings of biomass and large, continuous arrays of solar photovoltaics, drastically increasing the energy capacity of the Lents Green Ring as an energy landscape.

FIGURE 30: DESIGN SOLUTIONS

THE POWER CIRCUIT





- Ⓐ STEELE STREET CUL-DE-SAC
- Ⓑ LENTS TOWN CENTER
- Ⓒ LENTS PEDESTRIAN BRIDGE
- Ⓓ I-205 CORRIDOR
- Ⓔ LENT ELEMENTARY SCHOOLYARD
- Ⓕ 97TH & STEELE CROSSWALK

FIGURE 31: THE DESIGN CONCEPT

A designed walk that introduces visitors to a diverse array of energy generation technologies and synergies that can enhance public space

STEELE STREET CUL-DE-SAC

PLAY

This site is currently a wide expanse of asphalt, used as storage space for personal vehicles and a makeshift basketball hoop. Additionally, the connection from the street to the entry of Lents Pedestrian Bridge is unclear, especially for accessing the ramp.

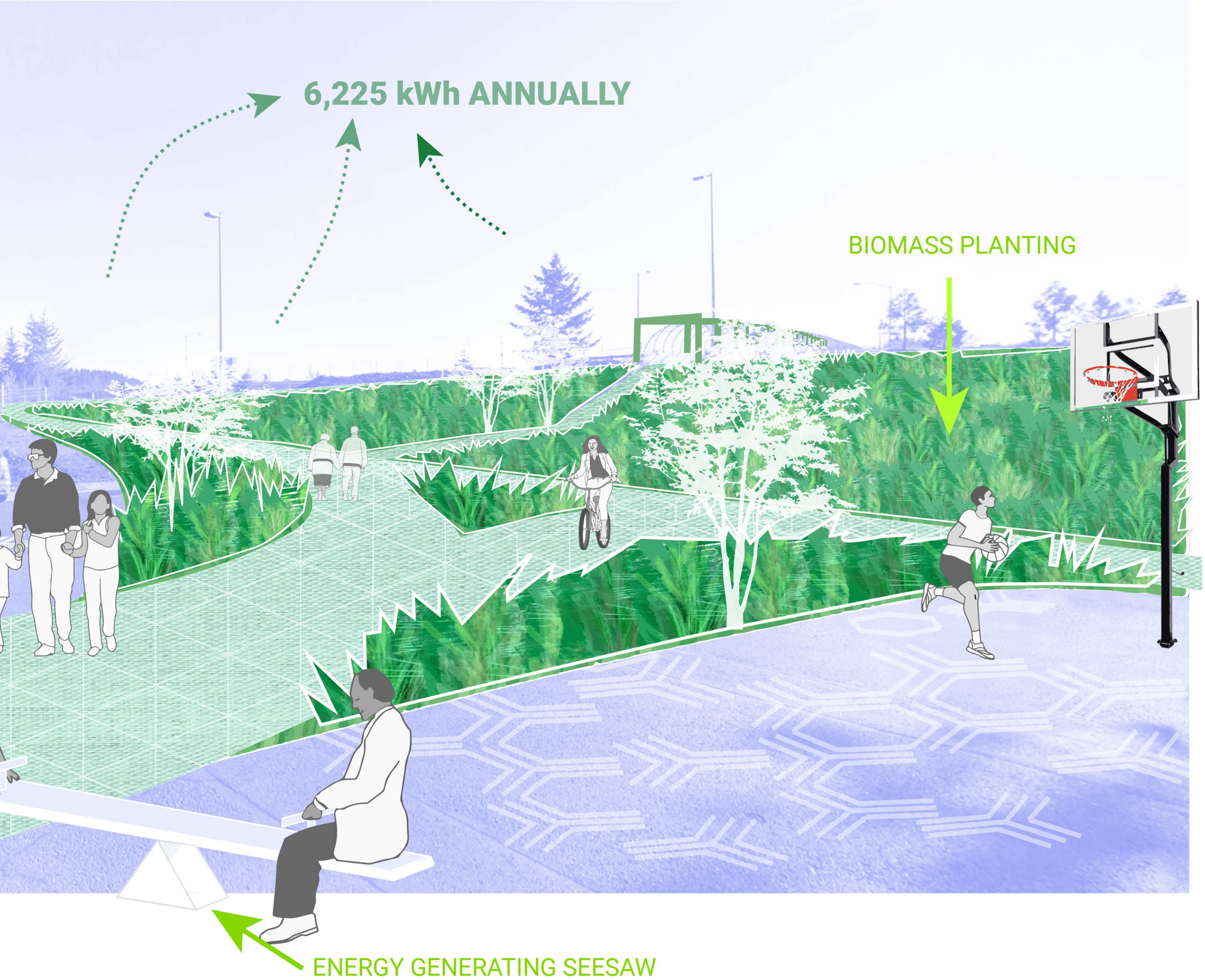
Traditionally, cul-de-sacs are spaces of play in American neighborhoods. Including energy-generating play structures such as seesaws could increase the functionality of this space. Making space for traditional play like basketball could enhance the program of this site. Kinetic energy pavers could be installed as in-ground wayfinding elements. Biomass planting as either miscanthus or switchgrass could be suitable for this site since as a plant, it matches the rustic aesthetic of residential streets.

This site is most similar to the Slow Streets typology. I filtered the ideas illustrated in that typology based on the needs of this site to achieve this design.

MOST SIMILAR TO

SLOW STREETS

FIGURE 32: STEELE ST CUL-DE-SAC

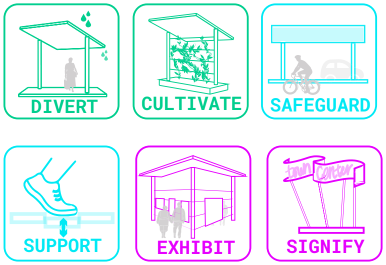

6,225 kWh ANNUALLY
BIOMASS PLANTING
ENERGY GENERATING SEESAW

LENTS TOWN CENTER

INTERACT

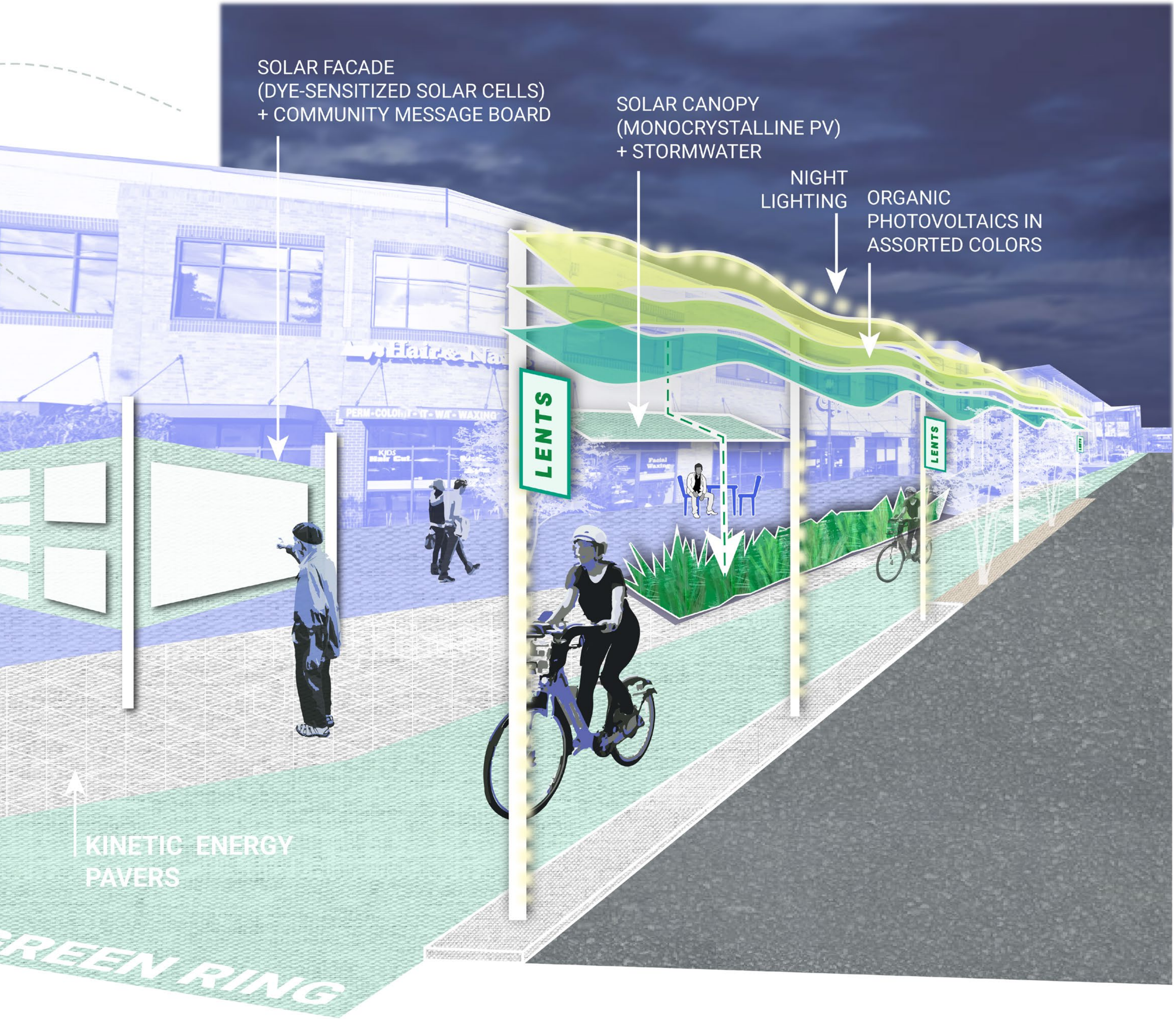
Using that framework again on this site, the Lents Town Center, I found 6 applicable synergies and was inspired by the Urban Streets typology.

My filter for this site was the needs of the site. This more urban area is about interaction of people, with so many people moving though the town center on a daily basis. It's important in town centers to show off Lents' specific character. Organic photovoltaics could mimic banners that many towns use to designate the commercial district. Solar facades could act as information kiosks or community message boards; and cafes could shade customers while diverting rainwater into on-street planters. Lighting powered by these technologies can add charm to the downtown district.



MOST SIMILAR TO

FIGURE 37: LENTS TOWN CENTER


SOLAR FACADE
(DYE-SENSITIZED SOLAR CELLS)
+ COMMUNITY MESSAGE BOARD
SOLAR CANOPY
(MONOCRYSTALLINE PV)
+ STORMWATER
NIGHT
LIGHTING
ORGANIC
PHOTOVOLTAICS IN
ASSORTED COLORS
LENTS
LENTS
KINETIC ENERGY
PAVERS
REEN RING

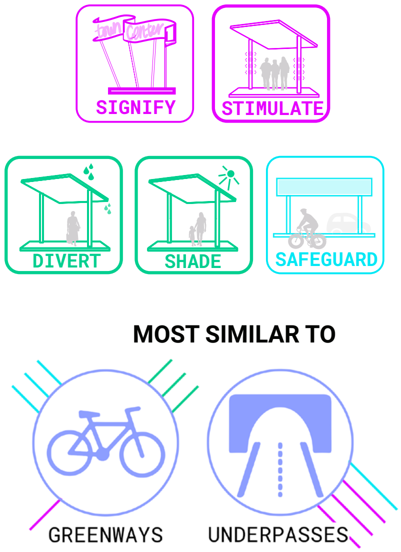
LENTS PEDESTRIAN BRIDGE

ELUCIDATE

At the Lents pedestrian bridge, a lack of lighting and a cage-like bridge structure made this space feel unsafe. This space is similar to greenways and to underpasses, and it takes inspiration from both of those typologies. By redesigning the upper portion of the bridge to accommodate a solar roof and using this energy to power street lighting, the atmosphere can be transformed into a more welcoming one.

Safety and therefore elucidation is important at this bridge because it is right next to the Elementary school. It's important for young students to feel safe walking to and from school. T

The solar roof should take design cues from the colorful murals that adorn the bridge walls, mimicking the vibrant character of the space. All of these design moves come together to elucidate the path, clarifying with lights and designating the path with color.



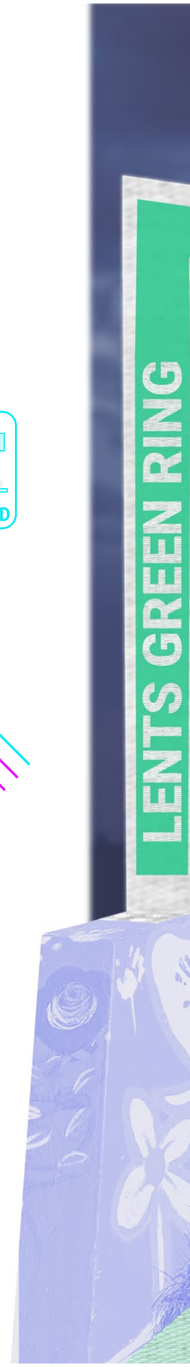
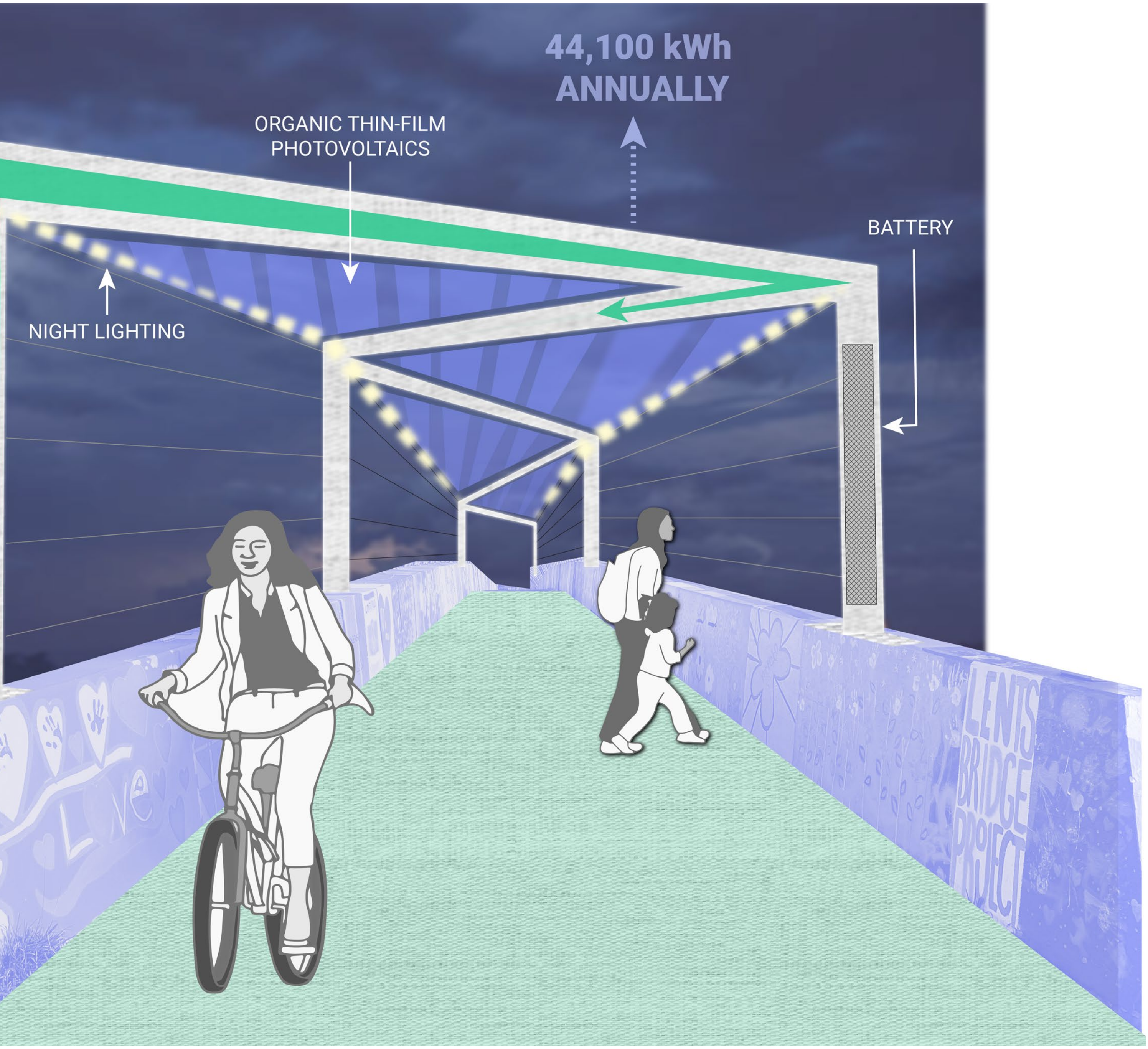


FIGURE 33: LENTS PEDESTRIAN BRIDGE

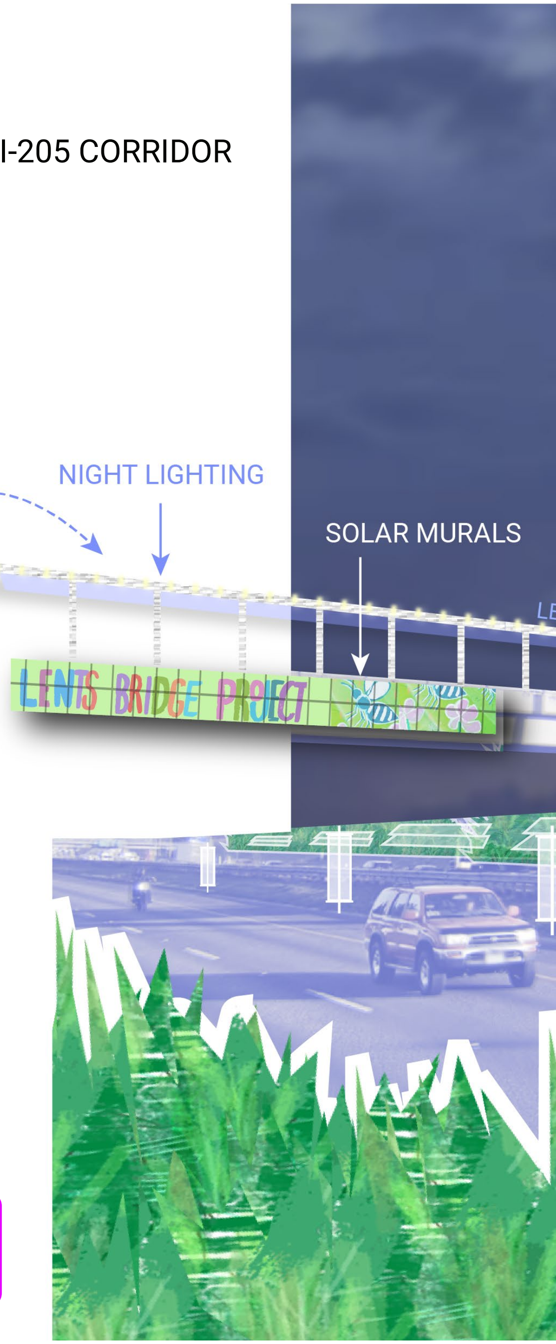

44,100 kWh
ANNUALLY
ORGANIC THIN-FILM
PHOTOVOLTAICS
BATTERY
NIGHT LIGHTING
LENTS
BRIDGE
PROJECT
Love

I-205 CORRIDOR

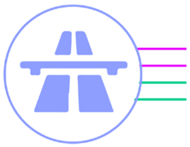
DISPLAY

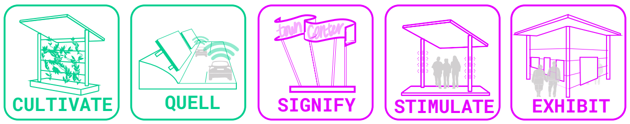
The Lents Pedestrian Bridge transports people over Interstate 205, a highway that severed the Lents neighborhood in the 1970's. We can repurpose the highway corridor with expansive displays of renewable energy. This view shows the highway with he pedestrian bridge in the background. From the perspective of drivers, solar murals could adorn the outside of the bridge and mimic the beautiful murals painted on the inside. In addition, piezoelectric poles could bring the colors from those murals to life on a larger scale, showing drivers passing by that Lents is vibrant and colorful. Biomass swaths could flank the highway, and photovoltaics could line the corridor as noise barriers. This site is about displaying on a large scale to broadcast messages to high-speed drivers.

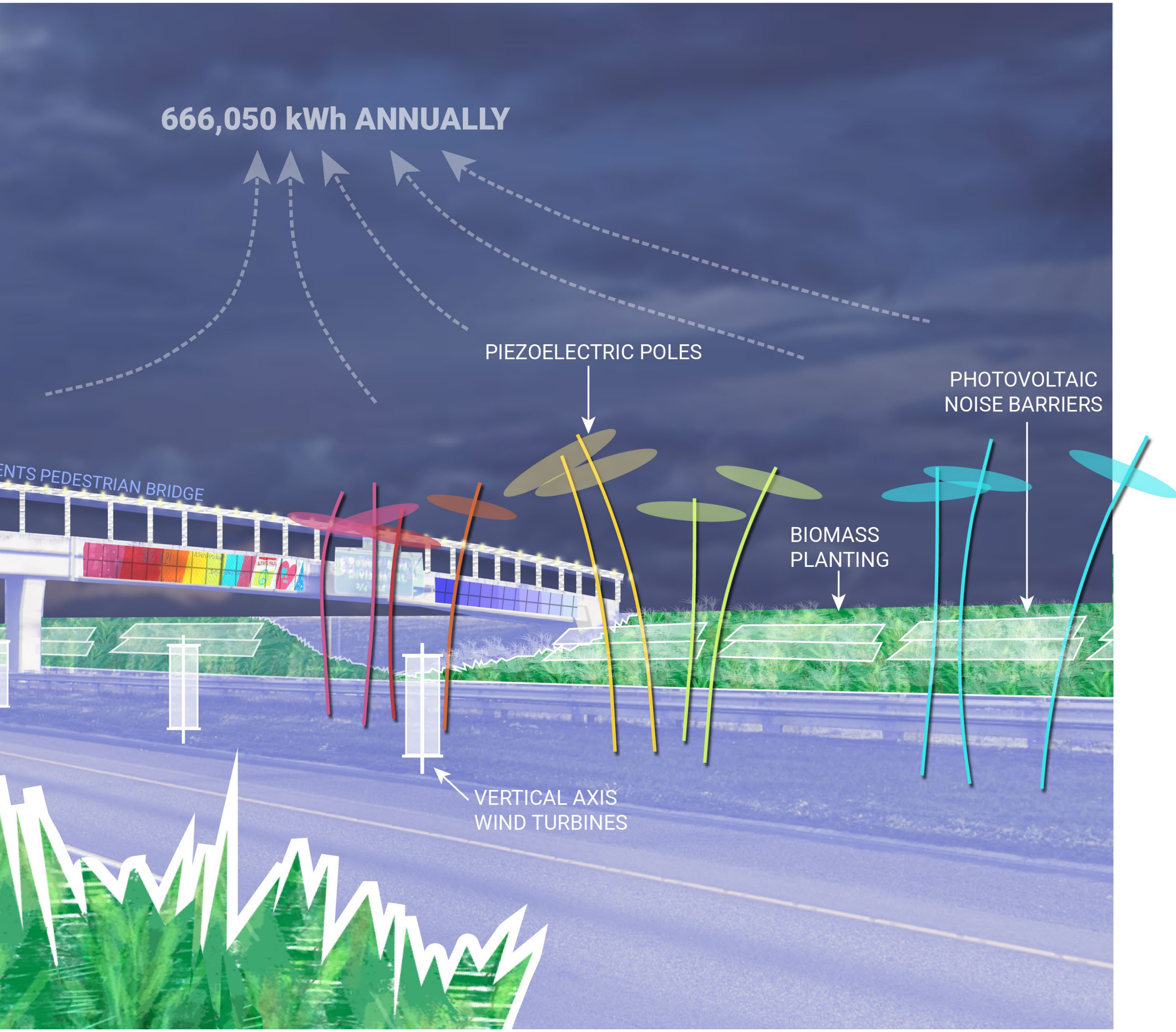
FIGURE 34: I-205 CORRIDOR



MOST SIMILAR TO



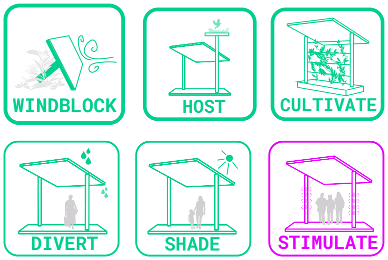



666,050 kWh ANNUALLY
PIEZOELECTRIC POLES
PHOTOVOLTAIC NOISE BARRIERS
ENTS PEDESTRIAN BRIDGE
BIOMASS PLANTING
VERTICAL AXIS WIND TURBINES

LENT ELEMENTARY SCHOOLYARD

EDUCATE

The schoolyard at Lent Elementary is currently a large blacktop, absorbing sun with little refuge from the heat. This space is about education, through gardening and through interactive energy elements like energy-generating swings. Solar technologies help increase shade to the area while improving the site for agricultural uses. Plant growth then in turn helps cool the area through evapotranspiration. Solar infrastructure is strategically place near existing trees to take advantage of their cooling effects, since solar requires an optimum, mild temperature to operate. Energy structures could support nesting sites for a family of osprey, and this element be included in the environmental education onsite. An osprey-cam could be powered by solar energy onsite to keep students in-tune with the growth of the birds. This site was inspired by typologies for vacant land, slow streets, parking lots, and community gardens.



MOST SIMILAR TO

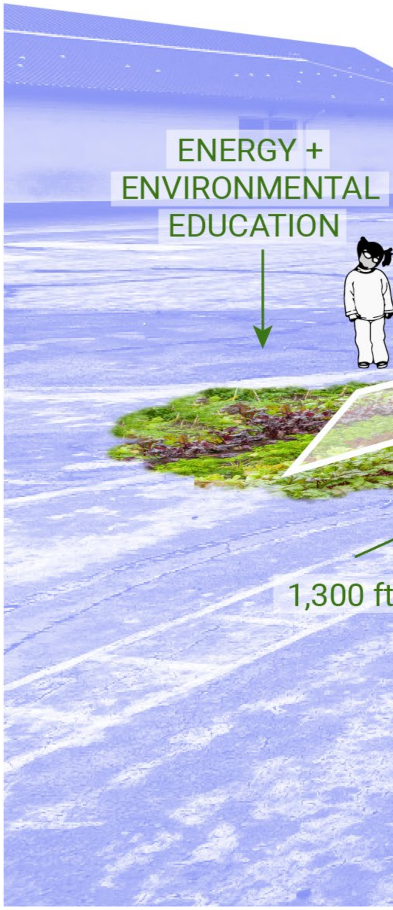
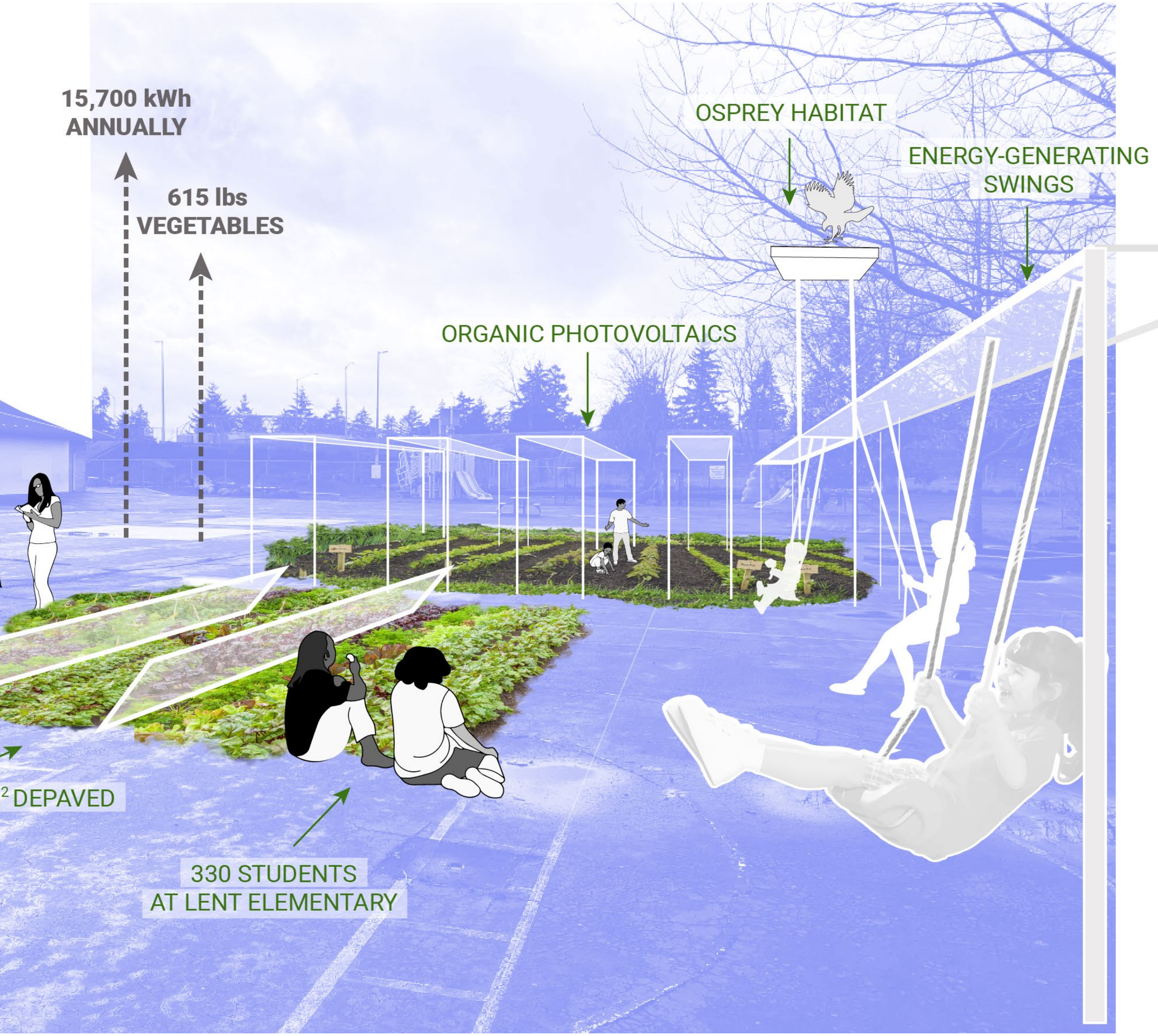


FIGURE 35: LENT ELEMENTARY SCHOOLYARD

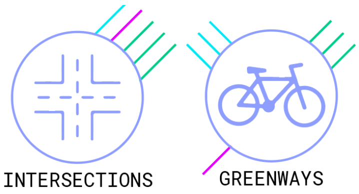

15,700 kWh
ANNUALLY
615 lbs
VEGETABLES
OSPREY HABITAT
ENERGY-GENERATING
SWINGS
ORGANIC PHOTOVOLTAICS
2 DEPAVED
330 STUDENTS
AT LENT ELEMENTARY

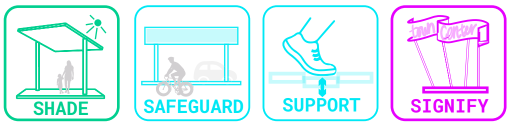
97TH & STEELE CROSSWALK

TRANSPORT

At the crosswalk of Steele Street and 97th, high-speed drivers are an issue, especially because this intersection is right next to the elementary school. In efforts to transport pedestrians safely, this site takes example from typologies of intersections and greenways. Creating a pedestrian refuge at the crosswalk could increase feelings of safety in walkers feel safe; and, creating shaded benches with charging stations makes the route more pleasant and accessible. Closing down parts of Steele Street with planters could open up the streets to walkers and bikers. This is important because so many kids are walking to school on this road, which is a Safe Routes to School designated route.

MOST SIMILAR TO





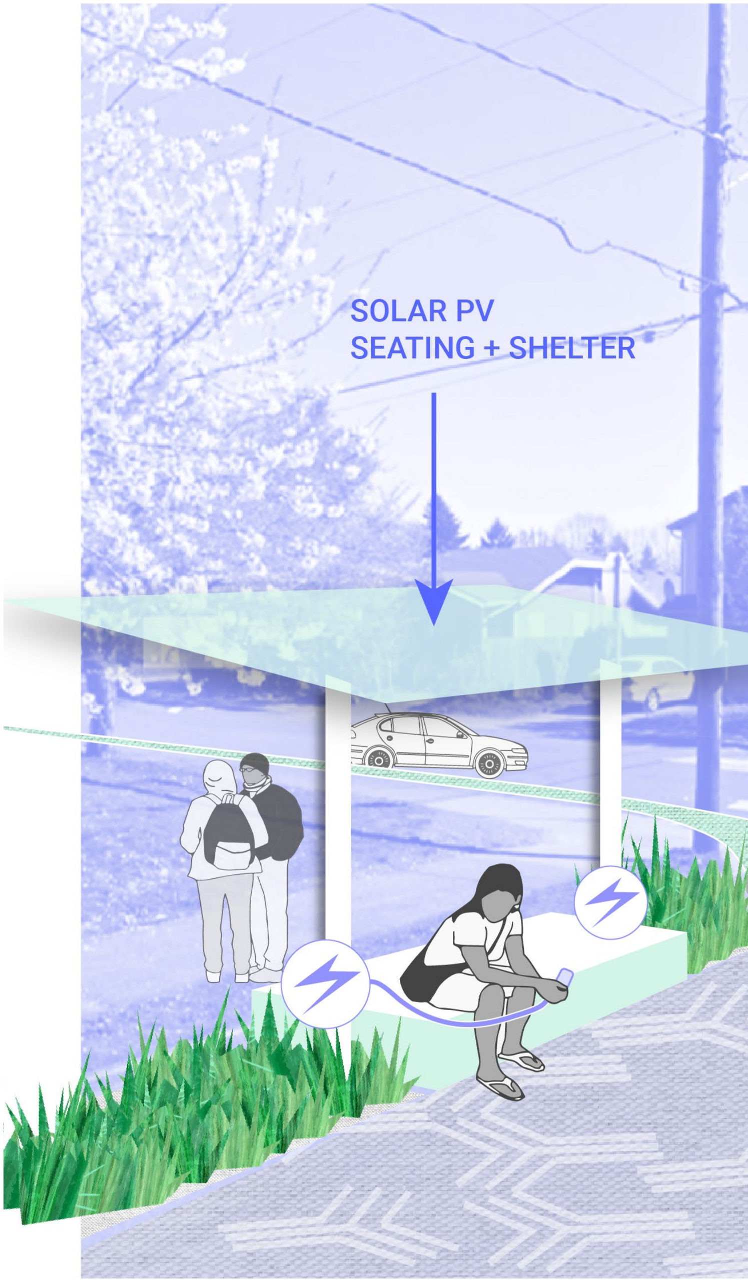
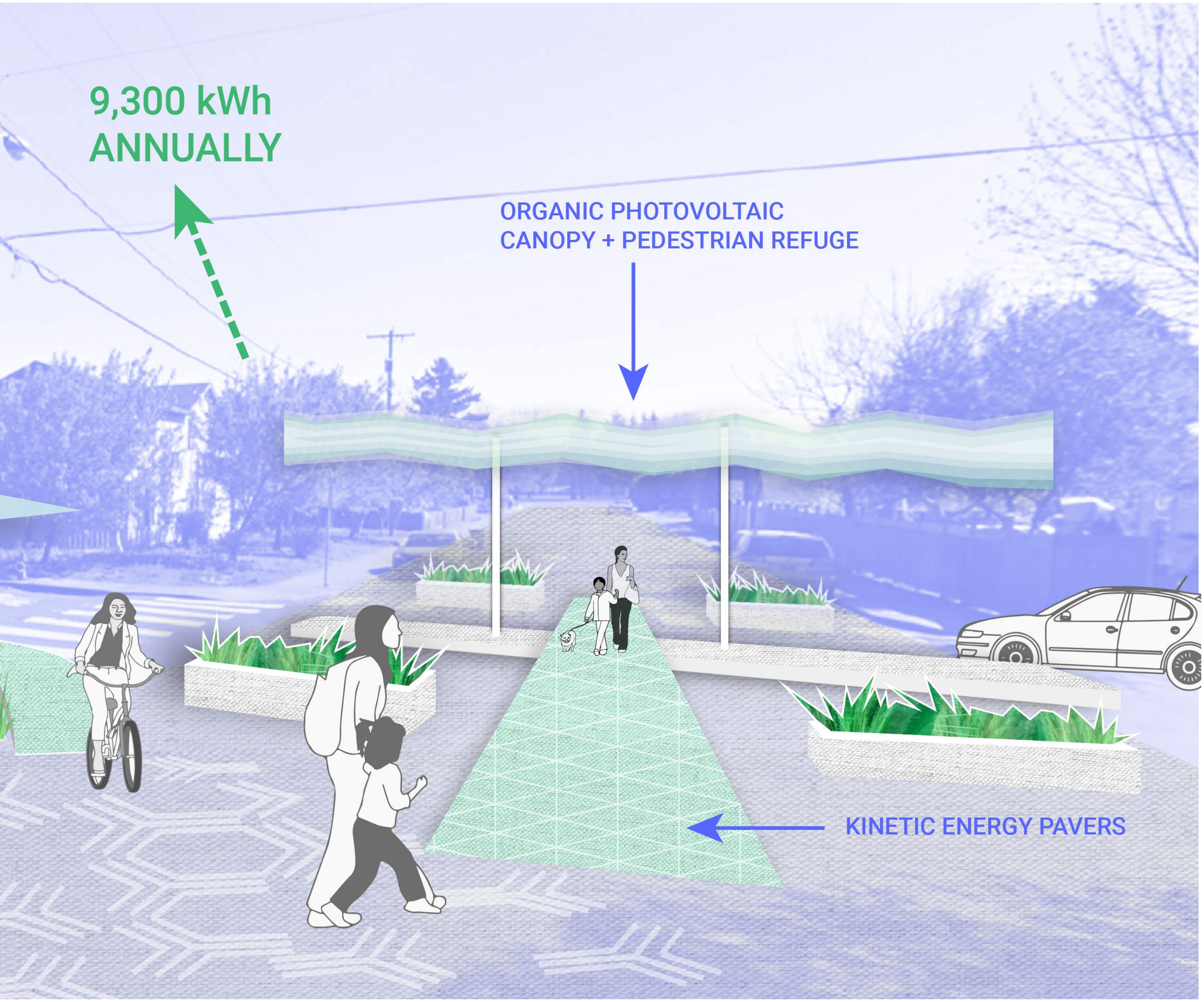


FIGURE 36: 97TH & STEELE CROSSWALK


9,300 kWh
ANNUALLY
ORGANIC PHOTOVOLTAIC
CANOPY + PEDESTRIAN REFUGE
KINETIC ENERGY PAVERS

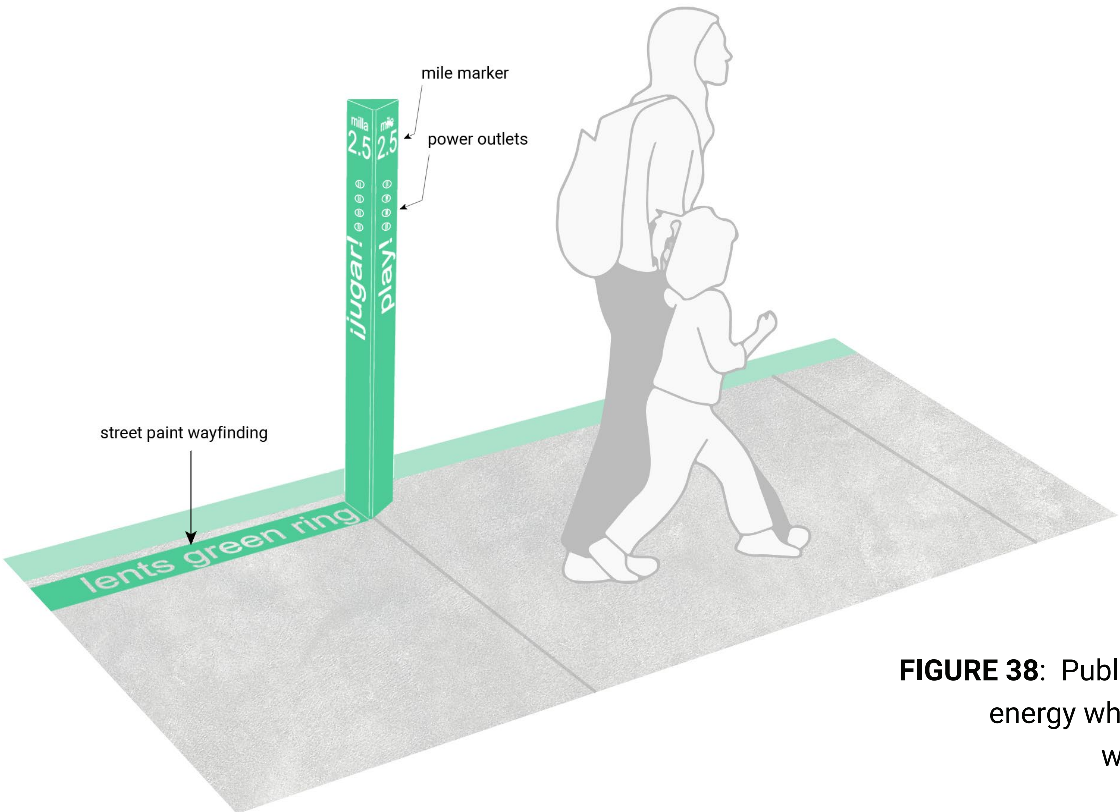


FIGURE 38: Public outlets distribute energy while synergizing with wayfinding elements

HOW TO DISTRIBUTE THE POWER?

The combined energy capacity across all 6 sites in the Design Focus area is **787.4 MWh per year**. This exceeds the electricity use by Lent Elementary in the 2019-2020 year, which is **200 MWh per year,** which is ideal since energy systems might not always produce as much as their capacity states. To distribute the energy usefully and beneficially, I use an example from Ozgun (2015). This author proposed a framework to allocate 1/3 of energy produced to economic gain, 1/3 to self-maintenance, and 1/3 to social engagement. I propose using this framework to distribute the energy that is generated on the Lents Green Ring. One-third will go towards capital for the community or local public schools like Lent K-5, one-third can be used for engagement, environmental literacy, and street lighting, and approximately one third can be used to power Lent Elementary as a resilience hub.

LENT ELEMENTARY AS A RESILIENCE HUB

Lent Elementary is already a community resource for the neighborhood. Aside from educating students, it also serves as a site for community events and classes during the summer, and a location for continued learning for adults. In the future, the school could function as a meeting point during a natural disaster, providing power, shelter, and warmth to community members. In line with the goals of this project to enhance community resources, the energy generated along the Green Ring on public land could be used to power the school as a public, community resource.

Energy education could be paired with the infrastructure along the route of the Green Ring and in the schoolyard of Lent Elementary. While students learn about solar photovoltaics, they may also be engaging in community gardening or stormwater observation.

Finally, a portion of the power generated should be readily available along the route via public charging outlets. Outlets could be paired with wayfinding elements such as mile markers and Green Ring signs, as well as with benches along the route.

6| DISCUSSION

ENERGY GENERATION AND PUBLIC SPACE

As demonstrated in the literature review, the inventory of LAGI projects, and in the projective design phase, it is possible to integrate energy generation into every day life using public space. While the ROW represents a large proportion of public space in cities, adjacent spaces such as vacant land, the edges of public parks, public campuses, public schoolyards or parking lots can increase multiply the impact of public energy installations.

Energy infrastructure should not be a burden or an eyesore. When energy is incorporated into public space, it has a duty to serve the public in a multitude of ways. Energy in proximity to people also has a duty to engage, teach, and captivate. Using new and up-and-coming technologies opens the possibilities for beauty in small-scale installations.

Not every parcel of public space is suitable for energy installations. Many spaces, either due to their suitability for trees, their historical architectural style, or other regulations are not ideal for energy placement. Energy is most suitable for areas that need shade but are unsuitable for trees, in areas that can accept a modern aesthetic, and in areas where energy is needed.

The impact of energy in public space is more than just the energy that is produced. In aiding the spread of renewable energy, placing beautiful and interactive installations near people acts to increase their familiarity and their acceptance of renewable energy. It is through this spread of ideas that small-scale energy installations perform well.

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APPENDIX: LANDSCAPE PERFORMANCE

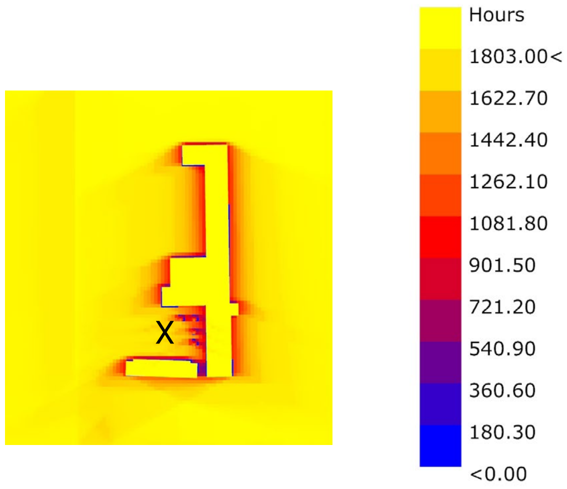
SOLAR ANALYSIS OF LENT ELEMENTARY SCHOOLYARD

I conducted a solar analysis on the Lent Elementary schoolyard site in order to determine the best placement for solar infrastructure. I used Rhino and Grasshopper for this analysis, utilizing the Ladybug component. I modeled the school buildings and nearby trees, and I measured both sunlight hours throughout the day and radiation levels.

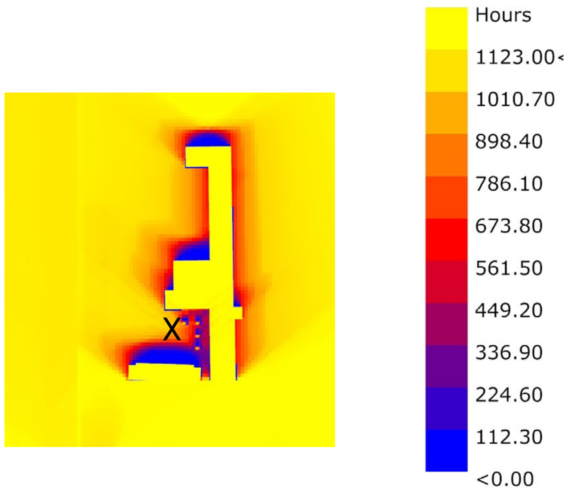
The results show that the area just west of the trees and the buildings, marked on the diagrams with an X, is ideal. It receives ample sunlight and is close enough to the trees to benefit from their cooling effects.

Both vegetable gardens and solar panels require ample sunlight. This analysis also reveals many other places around the school buildings that are suitable for agrivoltaics.

This analysis also reveals the difference in sun angles between seasons. In the summer, sun angles are higher, striking the rooftops more directly than in the winter. The higher sun angle accounts for higher overall radiation in the summer and smaller shadows. In contrast, lower sun angles in the winter create longer shadows.



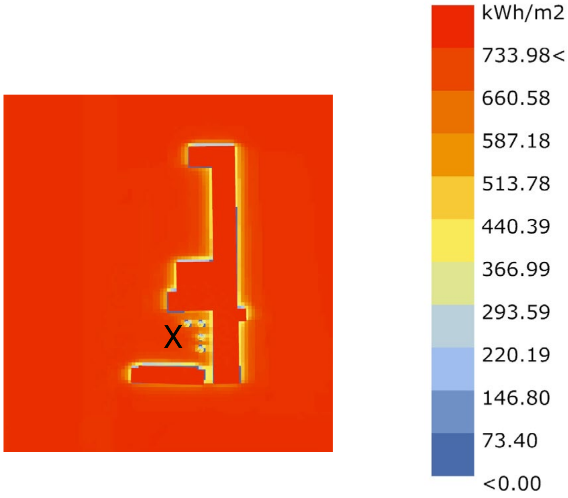
SunlightHours Analysis



SunlightHours Analysis

MAY-AUG

NOV - FEB



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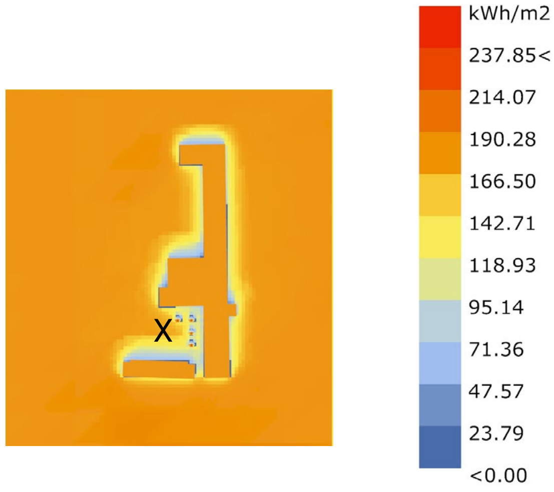

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