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PNNL-34218

Renewable Energy Landscapes

Southwest and Pacific Northwest Workshops

June 2023

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Richland, Washington 99354

Executive Summary

The clean energy transition is one of the greatest landscape-level and socio-technical challenges of our time. To engage the range of stakeholders needed to build sufficient infrastructure to achieve decarbonization goals will require a shift from traditional development objectives (i.e., maximizing energy production and economic outputs) to a broader set of goals. Incorporating a comprehensive suite of values and perspectives into deployment processes will promote greater acceptance of technology adoption and stimulate projects that maximize co-benefits while producing electricity. New collaboration and coordination across disciplines is needed to achieve this outcome in practice. Landscape architects and other design professionals are well-suited to support these efforts with strong capabilities in conducting holistic assessments of the social and environmental factors associated with infrastructure deployment.

To explore an expanded role for landscape architects in the energy sector, the University of Arizona and the University of Oregon hosted two virtual workshops with support from Pacific Northwest National Laboratory in January 2023. These workshops were intended to co-create new principles and perspectives for designing renewable energy landscapes for the Southwest and Pacific Northwest, respectively, balancing place-based perspectives and at-scale deployment.[1] While these workshops were primarily attended by landscape architects and design professionals, energy analysts, architects, sustainability experts, and community and tribal representatives also joined the dialogue. Given the events' focus on design innovations, processes and costs that often drive current siting outcomes for technology deployment were not core workshop components. These factors are inherently interconnected, thus arising in discussion, but not thoroughly unpacked given the workshop objectives and limited industry representation.

The Southwest Workshop structured discussion around three biomes: low desert, chaparral, and high desert and plains. In doing so, workshop participants worked top-down, categorizing ideas to address regional challenges that could then translate to individual site implementation. Working across six design pathways through three phases (Figure ES-1), participants in the Southwest Workshop established and prioritized design opportunities by identifying relevant actions that are high impact, low effort; high impact, high effort; low impact, high effort; low impact, low effort (Figure ES-2). These opportunities reflect the workshop exchanges and serve as an initial set of concepts that can be further explored in future research and discussion.

[1] Both workshops assumed the definitions of *place-based at scale* and *renewable energy landscapes* from O'Neil et al. (2022). Place-based at scale refers to the deployment of infrastructure systems in a way that balances the ability to be replicated widely (at scale), with careful attention to unique local character of specific places. Renewable energy landscapes are landscapes whose physical characteristics have been significantly transformed by renewable energy infrastructure.

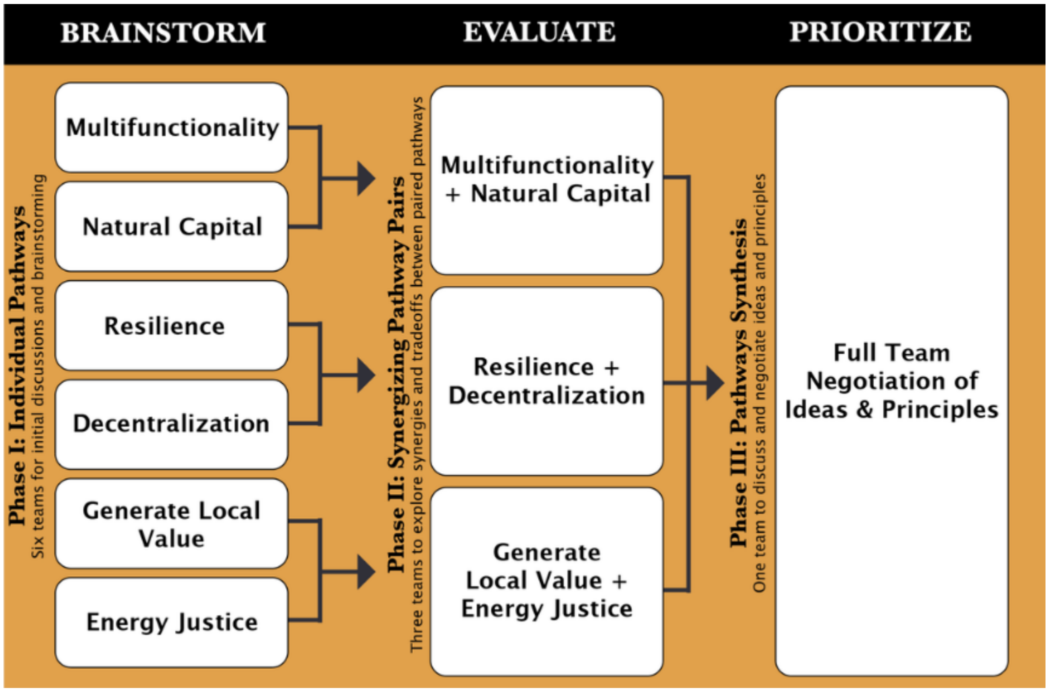


Figure ES-1 Southwest Workshop co-creation process with three phases of group participation.

In contrast, the Pacific Northwest Workshop targeted three specific sites across the landscape transect to address community goals that are representative of wider challenges faced by regional communities, essentially working bottom-up. The Pacific Northwest sites included: an elementary school in Portland, Oregon (urban), irrigation canals in Klamath Falls, Oregon (rural), and a heritage center for the Lummi Nation in the San Juan Islands, Washington (coastal). Participants in this workshop produced a series of design options (Figure ES-3-5) for the three sites by the culmination of the workshop, supporting broader efforts to visualize energy infrastructure deployment.

The authors of this report then synthesized the outcomes from both events and the feedback from participants to (1) create principles for designing renewable energy landscapes and (2) outline considerations for moving from concept to practice (See Table ES-1). These principles and considerations serve as a mechanism to account for landscape elements through intentional design and enhanced visualizations. They are not meant to be prescriptive, nor do they reflect a larger industry consensus. Rather, they highlight the perspectives and expertise of workshop attendees to stimulate continued conversation beyond the workshop.

The workshop outcomes, principles, and practical considerations reflect the current state of innovation in designing renewable energy landscapes. Collective understanding, as established through the events, is largely focused on the practical—what is feasible in this moment—rather than pushing the boundaries on what might be possible. Achieving that next step requires that we first catch up to existing innovation in implementation and design since it is not yet commonplace. These workshops served as the first step in reimagining the potential of energy infrastructure across landscapes. By continuing to bring together experts across disciplines and individuals from diverse sets of communities, the potential for supporting more meaningful infrastructure deployment becomes possible.

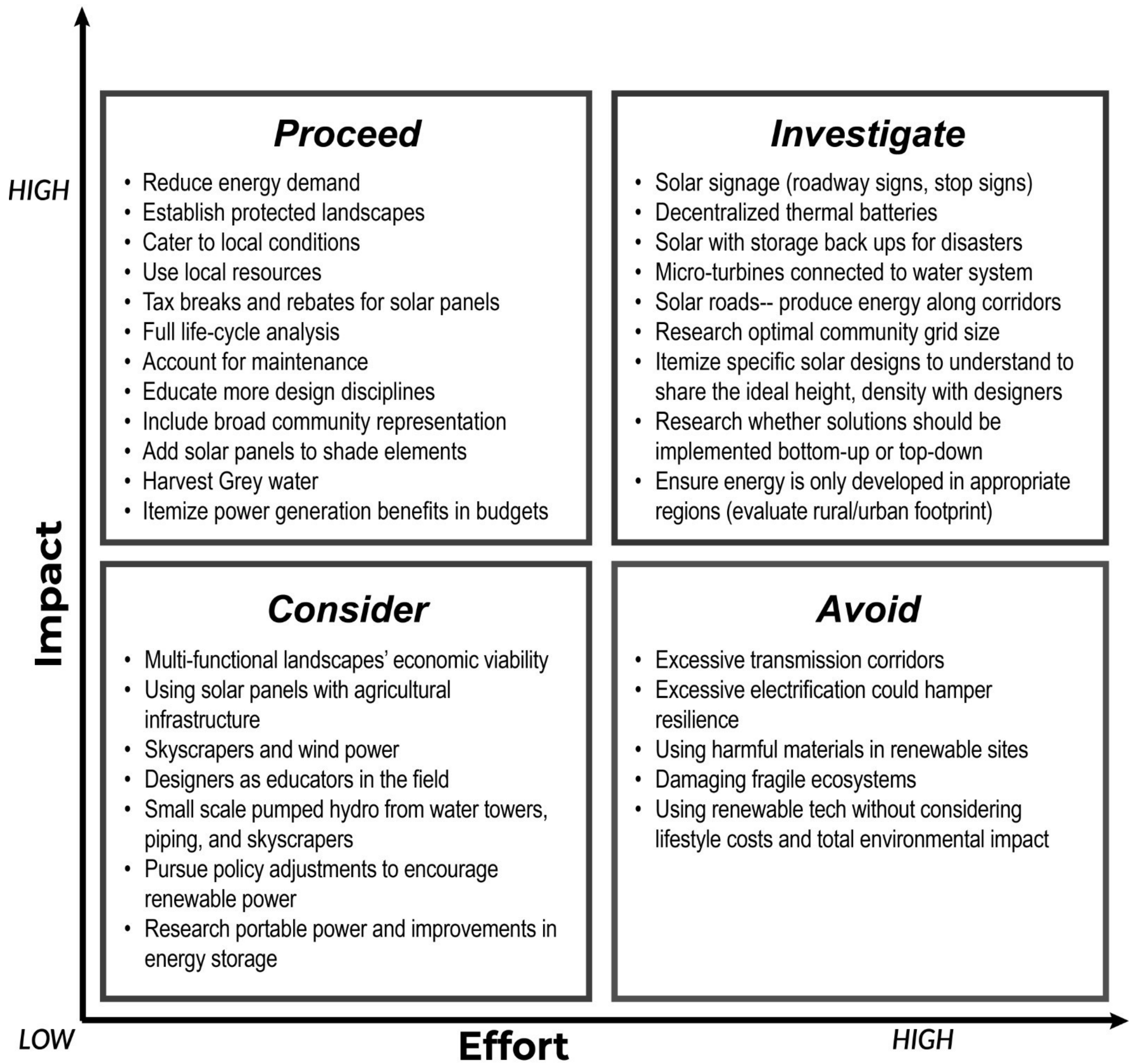


Figure ES-2 Southwest Workshop ideas and principles developed by participants.

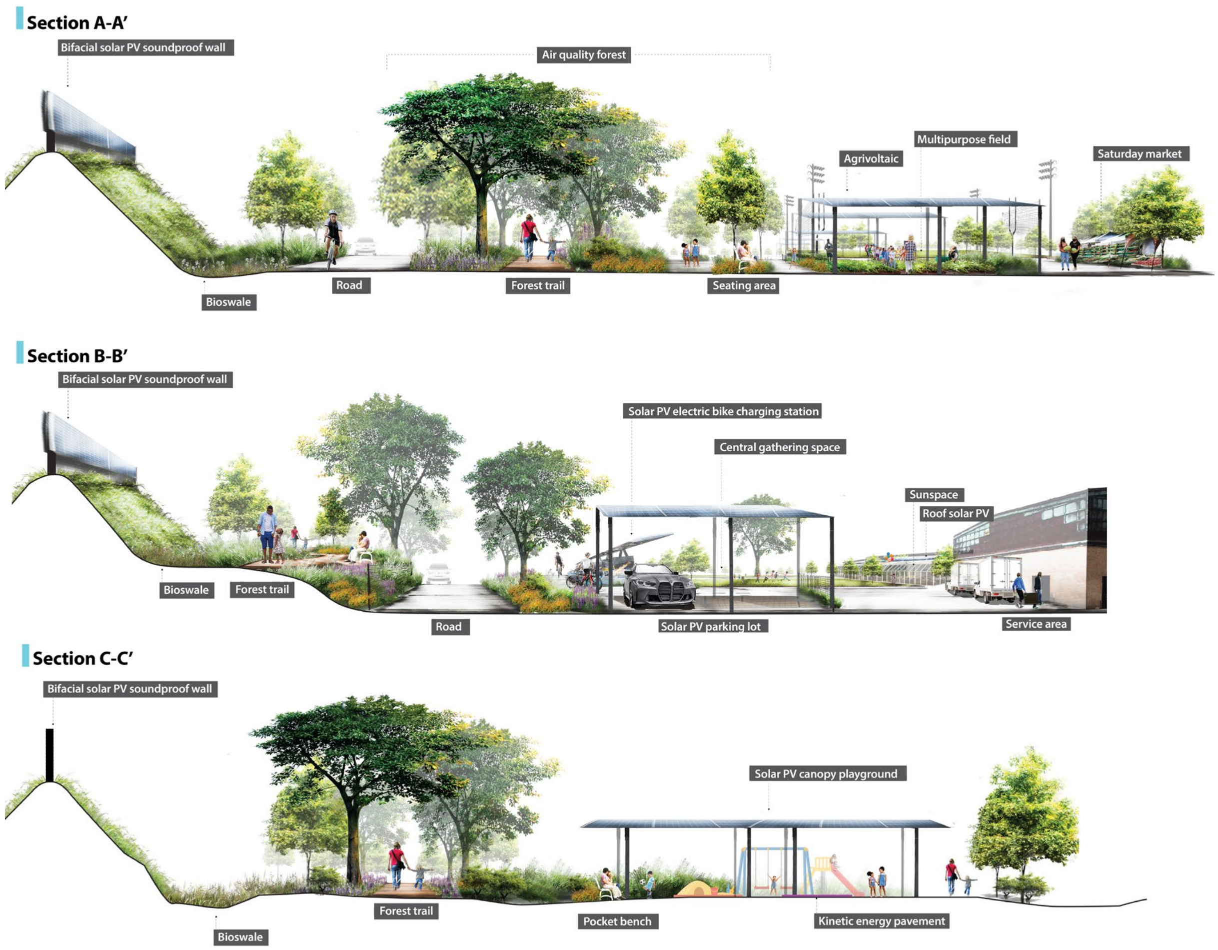


Figure ES-3 Landscape design concept for Oliver P. Lent Elementary School.

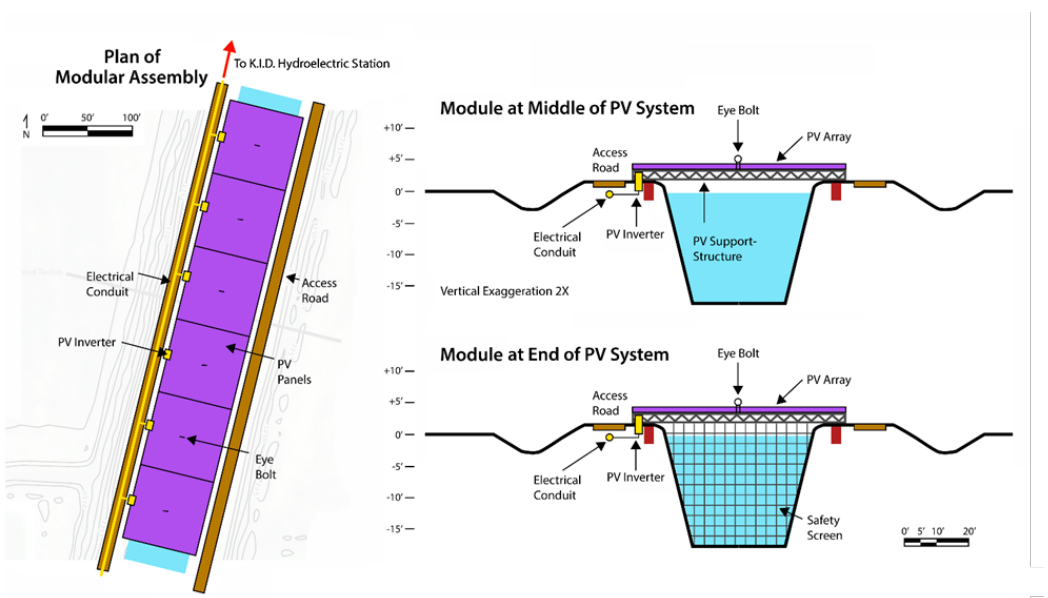
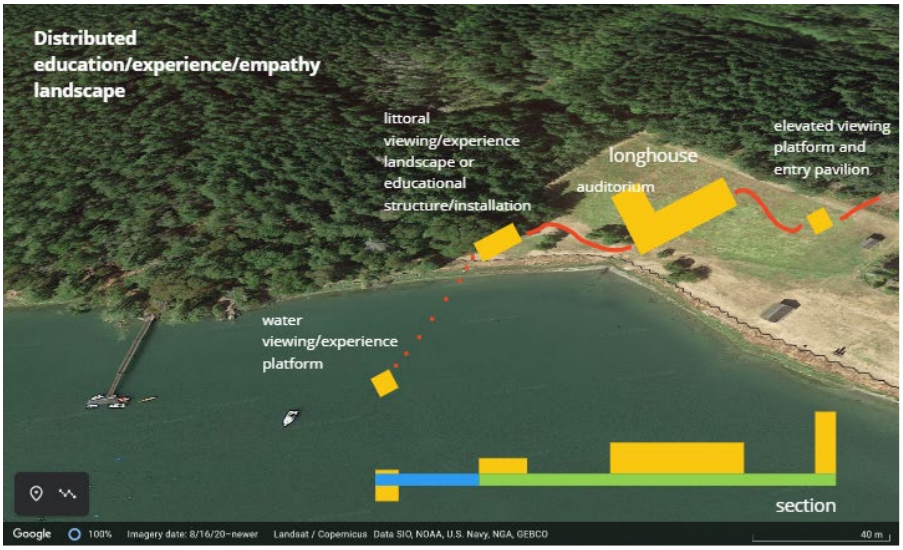


Figure ES-4 Plan and cross section of typical modules for mounting solar arrays over the Klamath Irrigation District's 'C Canal'.



PV panels on longhouse roof or elsewhere?

habitat bench (tidal shelves for salmon) along shoreline? [as in Olympic Sculpture Park, Seattle]

siting considerations:
-longhouse (L-shape) with doors at either end of main axis with potential auditorium on the small part of the L
-siting for communication over distance and strategic concealment
-sustainable solar and water integration
-want to site the building as part of a broader storytelling network / landscape that is more distributed, facilitates key views and interactions with the water to support empathy-based narratives

Coast Salish Institute longhouse as structure example

Justin Fowler

Figure ES-5 Design concepts for the Coast Salish Cultural and Natural Heritage Center included an elevated viewing platform to allow for views across the land and to the water to encourage interactions within non-human animals.

Table ES-1 Principles for designing renewable energy landscapes and considerations for moving concept into practice. The principles and considerations are complementary of one another but not explicitly linked.

PRINCIPLES	PRACTICAL CONSIDERATIONS
1. There is material value in viewing energy projects as landscape projects. Inter-scalar connections can be derived from a generalist landscape perspective in combination with a diverse group of technical experts.	1. Overcoming the challenges of convening a large and diverse set of stakeholders gives way to holistic and innovative ideas for designing and deploying energy infrastructure for public good rather than just energy production.
2. Supporting local identity can be achieved by improving landscapes through renewable energy development "packages" that provide more than infrastructure solely intended for electricity production.	2. Many disciplines understand the challenge of building out energy infrastructure to meet decarbonization goals, but knowledge and data gaps create silos in the solutions proposed to address them.
3. Deploying a variety of technologies, particularly at a finer scale, can diversify energy portfolios while supporting improved aesthetics and well-being of communities. This approach also capitalizes on the robustness of place.	3. Working across different scales—technology, site, and landscape—creates unique challenges and will require diverse sets of thinkers.
4. Landscape performance metrics for renewable energy development must reach beyond energy optimization.	4. With strong parallels between water and energy infrastructure design, landscape architects can draw on the discipline's vast experience with stormwater management and water conversation and apply those lines of thinking to energy systems.
5. A participatory design process can serve as a powerful tool to promote energy justice by amplifying the voices of communities.	5. Additional work to demonstrate the potential contributions of landscape and design professionals is necessary to fully derive the value of those disciplines in the energy transition.
6. Avoidance is as important as multi-objective siting for renewable energy in a place-based approach.	

Acknowledgments

These workshops were sponsored by the U.S. Department of Energy's Water Power Technologies Office. The authors wish to thank Simon Gore for his leadership on this task, as well as Rebecca O'Neil and Jacob Garbe for their review of this report.

The authors also extend their gratitude to all those who attended the workshop and contributed to the events—participants, panelists, moderators, facilitators, speakers, and communications and technical support staff. Your expertise, innovation, and willingness to engage around these ideas of how we can better design and envision our energy future is so greatly appreciated.

Acronyms and Abbreviations

PV – Photovoltaic
KID – Klamath Irrigation District
KBP – Klamath Basin Project

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1.0 Introduction

The clean energy transition is one of the greatest landscape-level and socio-technical challenges of our time. While traditional energy system development in the 20th century prioritized maximizing energy and economic outputs, the increased deployment associated with the transition will require a broader suite of values and stakeholder perspectives be incorporated into those objectives. Including a comprehensive suite of values and perspectives into deployment processes will promote greater acceptance for technology adoption and stimulate projects that maximize co-benefits while producing electricity. Community-centered and place-based design can support researchers and practitioners alike in addressing this challenge. Landscape architecture and other design disciplines are well-suited to support holistic assessments of social and environmental factors through well-established methods, offering a foundation for incorporating design considerations into planning and development processes.

To explore an expanded role for landscape architects in the energy sector, the University of Arizona and the University of Oregon hosted two virtual workshops with support from Pacific Northwest National Laboratory in January 2023. These workshops were intended to co-create new principles and perspectives for designing renewable energy landscapes at scale for the Southwest and Pacific Northwest, respectively. In doing so, the events aimed to broaden the scope of services provided by landscape architects in future renewable energy projects and influence at-scale deployment efforts.

Two complementary approaches were employed for the workshops to explore challenges and opportunities that will arise in balancing place-based and at-scale approaches. The Southwest Workshop structured discussion around three biomes in the Southwest United States: low desert, chaparral, and high desert and plains. In doing so, workshop participants approached the design challenge from a top-down approach, characteristically categorizing ideas to address regional challenges that could then translate to individual site implementation. In contrast, the Pacific Northwest Workshop targeted three specific sites across the landscape transect (i.e., across urban, suburban, rural, and coastal landscapes) to address community goals that are representative of wider challenges faced by regional communities, essentially working bottom-up. The Pacific Northwest sites included: an elementary school in Portland, Oregon (urban), irrigation canals in Klamath Falls, Oregon (rural), and a heritage center for the Lummi Nation in the San Juan Islands, Washington (coastal).

The workshops were collectively attended by landscape architects, design and planning professionals, community representatives, tribal representatives, academic scholars and educators, energy analysts, and undergraduate and graduate students (See Appendix A for attendee list and demographics). Landscape architects and design professionals made up the largest share of workshop participants. Given the events' focus on design innovation, processes and costs that often drive current siting outcomes for technology deployment were not core workshop components. These factors are inherently interconnected, thus arising in discussion, but not deliberately unpacked.

Through targeted breakout sessions, design synthesis, and critique, the workshop participants discussed key questions, expanded their knowledge of new disciplines, and provided insights into designing place-based, at-scale renewable energy infrastructure.[1] Prior to each workshop,

[1] Both workshops assumed the definitions of *place-based at scale* and *renewable energy landscapes* from O'Neil et al. (2022). Place-based at scale refers to the deployment of infrastructure systems in a way

facilitators created regional-specific design challenges (Dimond et al. 2023; Ko et al. 2023) that participants would address through the lens of six pathways for designing place-based renewable energy infrastructure: multifunctionality, decentralization, local value, natural capital, resilience to climate change, and energy justice (O'Neil et al. 2022) (See Figure 1-1).

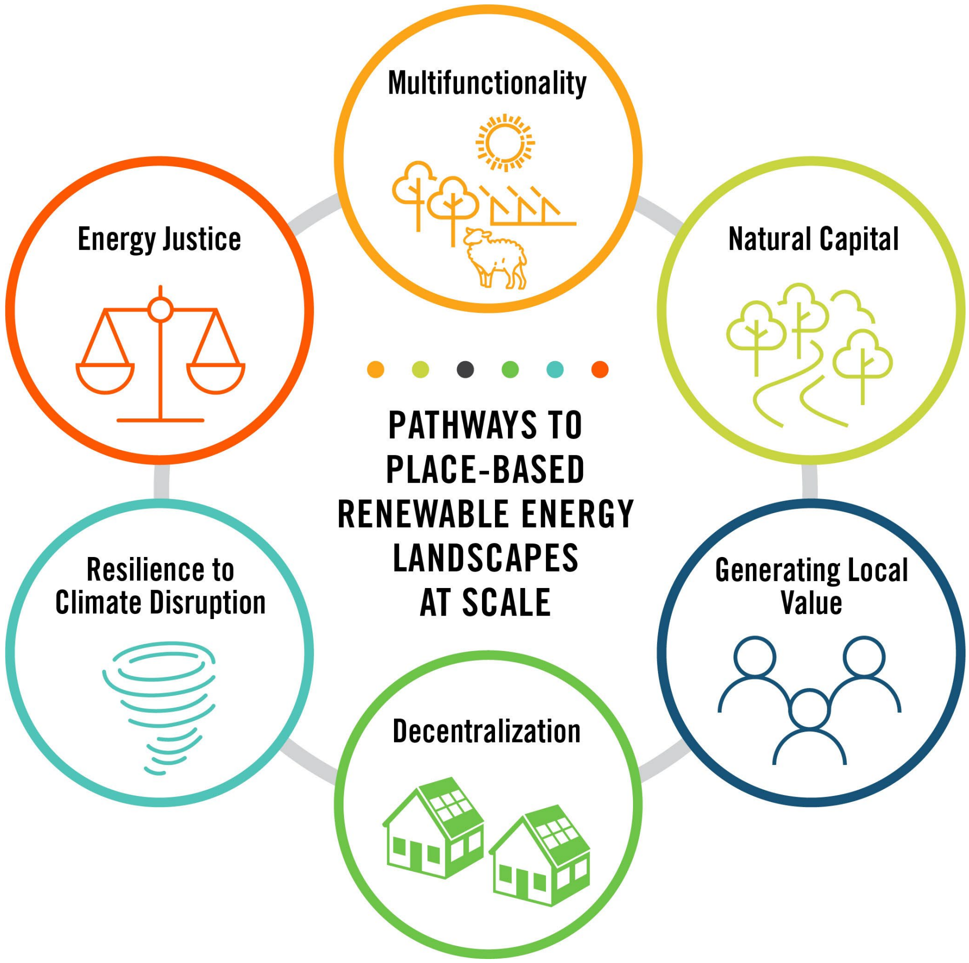

Figure 1-1 – Pathways for designing place-based renewable energy landscapes at scale.

This report documents the discussion and co-creation processes employed at the individual workshops and the outcomes they produced (Sections 2.0 and 3.0). Note that participant claims and contributions that are described herein have not been vetted by the authors of this report and reflect the perspectives of individual participants. The report authors then synthesized the processes and outcomes across workshops to create principles for prevailing landscape and design challenges associated with deploying renewable energy infrastructure (Section 4.0). Concluding remarks further categorize the lessons learned across the workshops and outline practical considerations for advancing these concepts in practice and the fundamental research needed to enable it (Section 5.0).

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that balances the ability to be replicated widely (at scale), with careful attention to unique local character of specific places. Renewable energy landscapes are landscapes whose physical characteristics have been significantly transformed by renewable energy infrastructure.

2.0 Southwest

2.1 Structure

The Southwest Workshop followed a co-creation process that facilitated the sharing and evolution of ideas between participants who had diverse experience and perspectives. In each phase of the process, participants were asked to engage in discussion around three general biome[1] contexts in the Southwest United States: low desert, chaparral and high desert and plains.

The workshop contained three phases (See Figure 2-1). Phase I began as a brainstorming session, with attendees grouped virtually into one of the six pathway breakout rooms. During this phase, attendees were invited by the pathway moderator to discuss ideas, share thoughts and images on a virtual workspace (Conceptboard – See Appendix B) and have conversations regarding the pathway and how it can relate to the low desert, chaparral, and high desert and plains. Phase II began by pairing two pathway groups, from the original six, into three groups. In this phase, participants were asked to evaluate synergies and tradeoffs between their paired pathways. This phase allowed attendees to collaborate and discuss their collective findings, as moderators prompted participants with questions to determine what they considered to be salient principles and new ideas to share in the final phase of the workshop. The final phase, Phase III, brought all attendees back together. Each of the three teams from Phase II presented their principal outcomes, and with each presentation, attendees and facilitators engaged through the virtual workspace to prioritize and subsequently record key ideas and principles.

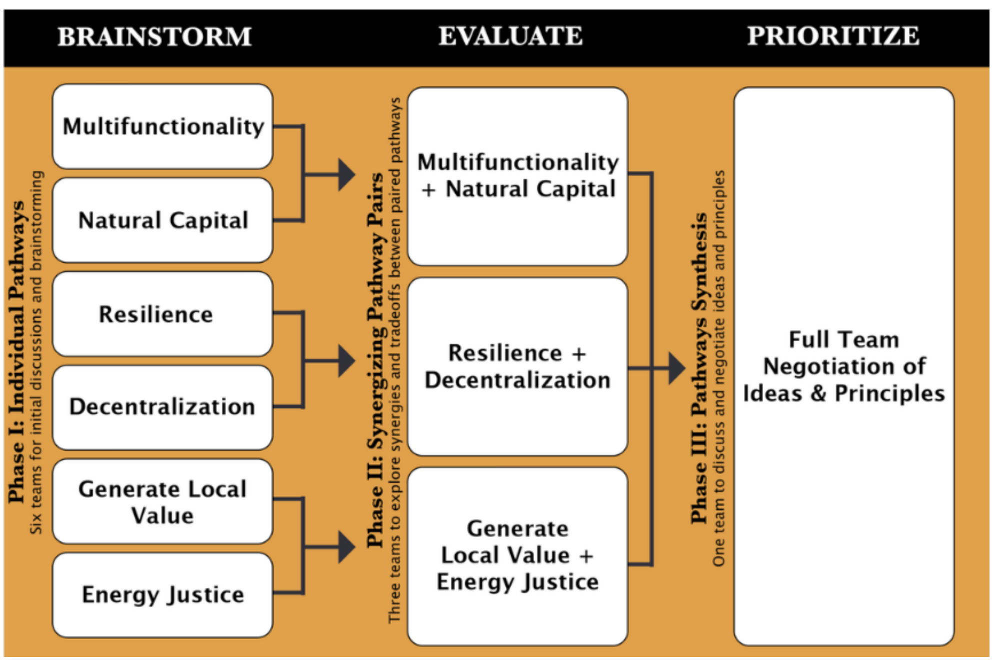

Figure 2-1 - Co-creation process with three phases of group participation.

[1] Biomes are regions defined by a shared group of organisms that inhabit the area. Biomes offer an apparatus for assessing areas with similar landscapes.

2.1.1 Low Desert

The low desert is one of the largest biomes in the Southwest region at over 300,000 square miles and envelopes the large metropolitan centers of Phoenix, Arizona; Las Vegas, Nevada; and Tucson, Arizona. Seasons are generally hot through the year with peak highs of 120 Fahrenheit and winter lows below freezing. Clear skies and low humidity allow for large daily swings in temperature and high sun intensity. Precipitation tends to be concentrated in short time periods with long rainless periods totaling one to 12 inches per year. Evaporation rates often exceed the rainfall rate resulting in landscapes dominated by ground hugging shrubs and short wooded trees with few to no canopy trees (University of California Museum of Paleontology 2007). The social infrastructure includes roughly 14.6 million people living in just 40 counties across five states with few high population centers with small towns surrounded by vast regions of agriculture and desert (Mackun 2019). Historically, indigenous people have thrived in the region for thousands of years with innovations in irrigation and architecture, including cliff dwellings and earthen structures. Technologies such as solar photovoltaics (PV) and concentrated photovoltaics prevail due to the abundant sunlight and limited obstructions (low vegetation and flat land). Wind power is also viable near canyons. The low desert is also home to many important water and infrastructure projects such as the Central Arizona Project[1] that pumps water hundreds of miles across the desert to population centers. Additionally, low deserts are mineral rich, and especially support the copper mining industry.

2.1.2 Chaparral

The chaparral makes up roughly 61 million acres in the Southwest and is characterized by a hot, dry climate with slightly cooler, wetter winters. The biome is usually located near coastlines and has gentle rolling hills with densely packed shrubs. The landscape is prone to fire due to the high density of shrub species combined with low summer rainfall (Conserve Energy Future n.d.). The mild climate, terrain, and coastal location is home to 70% of California's population including the Los Angeles, California and San Diego, California metropolitan centers (NOAA Office for Coastal Management 2018). Highways connect between the two cities with a nearly continuous corridor of development interspersed with pockets of protected native landscapes on public land. The terrain, climate and location enable the use of many forms of renewable energy technology. The topography enables wind and pumped hydro-storage, reliable sun exposure encourages solar technologies, and the coastal proximity provides potential for wave power. It is also a common region for mining interests, including recent interests in lithium discovered near the Salton Sea.

2.1.3 High Desert and Plains

The high desert and plains of the Southwest generally consist of flat grassland or scrub plant communities. They are sunny and experience wide ranges of temperature from below freezing to roughly 100 degrees Fahrenheit. They are semi-arid with 10-15 inches of precipitation a year, with the high plains receiving slightly more than 20 inches. The high plains are consistently windy with speeds on average of four-five miles per hour greater than the rest of the United States (High Plains Gardening 2019). The moderately sized metropolitan centers of the high plains and high deserts include Lubbock, Texas; Amarillo, Texas; El Paso, Texas; and Albuquerque, New Mexico, along with other active rural communities, supported by agriculture and particularly cattle ranching (U.S. Geologic Survey 2010). The Puebloans historically relied on the fertile plains for the Rio Grande for growing maize, squash and beans to support their

[1] See https://www.cap-az.com/ for additional information on this project.

communities. The regions also play a large role in the oil and gas industry with rich deposits and, consequently, are extensively developed by commercial energy interests. The high deserts have great solar, wind, and geothermal potential, and similarly the high plains have potential for solar, but particularly wind (Lozano-Carver 2022). Many wind projects are already in operation with plans to support much more with the coming of extensive interstate transmission upgrades.

2.2 Phase I Outcomes

2.2.1 Multifunctionality

The multifunctionality group primarily discussed the challenges associated with achieving multifunctionality within renewable energy infrastructure design. Many participants recommended prioritizing non-traditional benefits, such as aesthetics and community buy-in, rather than solely focusing on optimizing energy production. Given the locale and the widespread adoption of the technology, the group had significant conversation around combining solar PV production with other land uses, such as with parking lots, stages for concert venues, over water corridors, and with other areas that can benefit from being shaded when trees alone may be insufficient. Optimizing production with a tilt angle was seen to sometimes conflict with aesthetics when installed without regard for neighboring forms and views (See Figure 2-2). A major theme of discussion included prioritizing building in developed areas as opposed to green field landscapes, and the group pointed out the opportunity for water savings through adding solar canopies to canal systems such as the Central Arizona Project, which was cited by a group member to have a 9,000-acre feet per year loss from evaporation. The discussion did not lead to specific differences for the three subregions, suggesting these ideas could be universal throughout the Southwest.

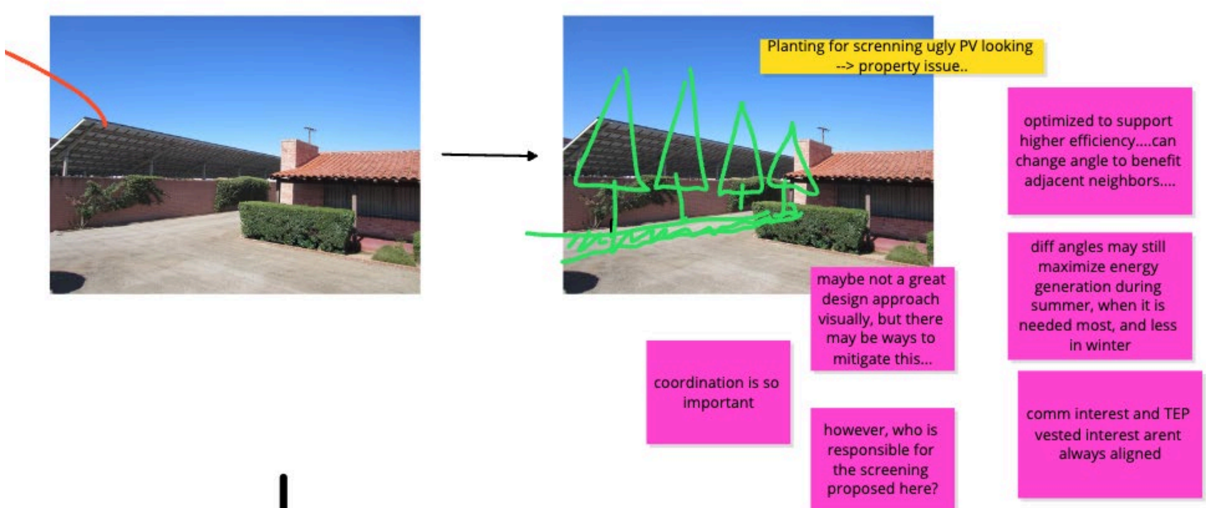

Figure 2-2 – Snapshot of the Conceptboard workspace describing challenges with photovoltaic canopy tilt and orientation.

2.2.2 Natural Capital

During the initial phase, the natural capital group discussed the negative impact of destroying ecosystems to make room for large-scale renewable energy projects in rural areas. Many in the group emphasized the importance of protecting nature, pointing to long-term consequences and cumulative impact of landscape destruction such as soil erosion, changes to hydrological systems, and possible extinction of species. Participants noted the negative environmental effects of renewable energy systems when blading landscapes for development, but specifically referenced a wind-energy development project that had been found to have impacts extending over a kilometer beyond the project footprint, even with a relatively small system. Concerns were raised with the political/economic structure that favors remote development with cheap lands and lack of oversight for and transparency for environmental impact. In terms of addressing these challenges, the group proposed policy changes and Best Management Practices along with educational campaigns to raise public awareness to shift incentives to developing on already built landscapes in cities and towns closer to the use of energy. The group ended this phase by acknowledging that the costs of destruction to natural landscapes must be considered when designing for renewable energy systems.

2.2.3 Resilience

The resilience group focused on reconciling the many definitions of resilience to overcome the varying perspectives on this term among participants (See Figure 2-3). The group discussed current energy consumption patterns and ways to reduce the impact of the built environment through passive design and the use of native landscapes and water harvesting. Storytelling and other ways to display and communicate with communities emerged as an important theme, as well as understanding local needs and conditions to toward creative adaptability. The concept behind storytelling is to foster creative adaptability by generating awareness to people and the community on their use of energy, and how that may impact the load on the infrastructure. Group members posited that communities should be educated on their use and how to optimize toward building efficiencies and better consumer behavior. This principle works toward applying no- to low-cost strategies that may reduce consuming "unnecessary" energy, lowering demands and overall need for renewables.

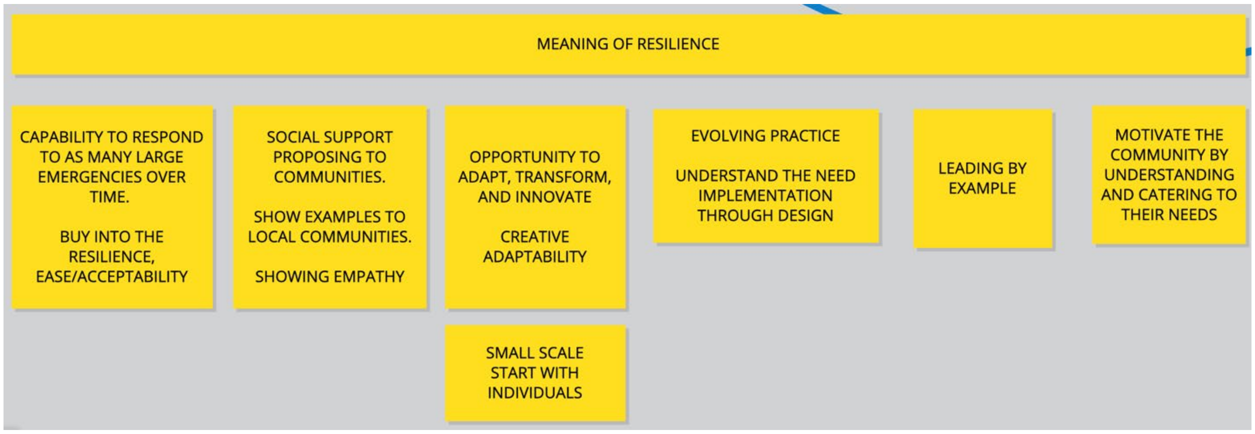

Figure 2-3 - Snapshot of the Conceptboard workspace describing various meanings of resilience.

2.2.4 Decentralization

Participants in the decentralization group shared unique perspectives on the future and merits of the concept, identifying several key ideas. There was a collective agreement among participants that solar energy remains an ideal technology for decentralized systems in the Southwest given its modularity. The group discussed the advantages of decentralization in reducing the need for large transmission corridors with their associated financial and environmental costs. They also mentioned the energy losses involved in long-distance transmission being a motive for encouraging decentralization. Implementing solar PV technologies within community microgrids was favorable among participants given the presumed scale of those systems, and policies were recommended for maximizing space for solar PV on warehouses and other large buildings. Finer scale uses for signage and shade structures were also mentioned although to a lesser degree. Resilience against national security concerns and environmental risks were cited as additional solar PV benefits within decentralized systems. Participants also discussed parallels and synergies with water in avoiding steam-based turbines and capitalizing on the opportunity to harness grey water and sanitized black water at community scales from community outputs.

2.2.5 Local Value

Conversations within the local value group discussed aesthetic, functional, and development values that solar PV can create. Participants commented on renewable energy systems being aesthetically unattractive due to monotonous forms, colors and orders, which led to discussion of more artistic designs of solar flowers and solar trees. These were generally considered a more attractive option to bring local aesthetic value compared to rectilinear and expansive systems. There was some skepticism regarding scalability of such features and some suggested that manufacturing and installation costs outweigh the benefits to begin with. However, value was identified in the potential for infrastructure to support economic development opportunities for local/small businesses and to combine solar technologies with affordable housing efforts, particularly for cities in the chaparral sub-region. Value was also seen in adding shade as a resource for microclimates. Participants paralleled overhead solar canopies with nurse trees, which protect young cacti and other plants under their canopy from the extremes of heat and cold in the desert environment. The opportunity and benefit of using solar to create a microclimate, particularly in the low desert, can also help moderate temperature extremes as well as reduce irrigation water use, particularly for Southwestern agriculture with agrivoltaics.

2.2.6 Energy Justice

Participants in the energy justice group discussed the importance of equitably distributing the benefits and costs of renewable energy systems. Emphasis was placed on how considerations for the needs and perspectives of marginalized and low-income communities, are responded to in the development and implementation of renewable energy projects. Participants suggested that a participatory design process is necessary to engage communities. For the low desert, they called for the need of strategies that allow vulnerable communities to have access and direct benefit from renewable energy systems. They particularly mentioned prioritizing unhoused populations given the extreme weather. They also cautioned about conflicts between energy and climate goals and noted the need for clearly defined and well-implemented climate action plans and municipal codes. For the chaparral biomes, discussion centered on respecting protected native lands and landscapes by understanding and prioritizing the goals and values of local tribes. Further discussions included the importance of increasing proximity of the renewable energy system generation to the source of use to provide economic opportunities in these communities. However, participants highlighted that equitable distributions of resource must be given throughout the community, not just a few.

A call for action was initiated for landscape architects to seek local leadership positions to become active decision makers with the holistic view of considering and accounting for people across landscapes.

2.3 Phase II Outcomes

2.3.1 Multifunctionality and Natural Capital

The combined multifunctionality and natural capital group found clear overlaps in the themes across the two design pathways (See Table 2-1). Key synergies involve encouraging policies and regulations to incentivize renewable energy development away from naturalized landscapes and within already developed and disturbed landscapes that can be enhanced through multiple purposes. Both groups emphasized the importance of renewable energy development being sited in already disturbed locations with short distances between energy production and where that energy is consumed rather than remote green fields. They considered the opportunities and constraints of urban versus rural and within biomes, pointing out a lack of wind in the low desert, compared to the high planes, and the need to work around more trees in the chapparal.

A shared challenge between these two pathways includes the higher upfront costs associated with multifunctionality on disturbed lands versus the, typically, less-costly installation on remote and naturalized lands due to land value difference between the urban and rural. Participants emphasized the importance of policy and regulation in helping combat this challenge. Group members suggested that landscape typologies, such as impervious surfaces, suitable for renewable energies should be incentivized or regulated for new renewable energy development siting. However, there is also the potential for competition of space within developed areas between green infrastructure and renewable energy. Identifying urban ecological corridors and patches, which can include tree-covered parking lots, within the larger matrix of the city may also be important to avoid disturbance at an urban scale. Participants also highlighted the need for incentives to support sustainable energy production and lessen consumption practices.

Overlap in the groups related to the ability of creative design solutions for mutually beneficial relationships between other systems, including urban ecology, water, and transportation. Examples included synergizing or balancing solar PV with urban trees and vegetation in combating the urban heat island effect while reducing plant evapotranspiration, as well as covering roads and parking lots as part of the energy network. Participants cautioned that displacing trees could be a potential tradeoff and acknowledged the potential expenses as well as the need to potentially break up panel installations to integrate trees. This requires more research into optimization for heights and spacing to allow for ecosystem services to continue to function. See Table 2-2 for additional synergies and tradeoffs.

Table 2-1 Phase I Venn diagram between multifunctionality and natural capital pathways.

MULTIFUNCTIONALITY	BOTH	NATURAL CAPITAL
Interests of communities and interests of utilities not always aligned	*Prioritize building in developed areas vs. building in green fields*	*Shift policies and incentives to develop renewable energy systems near demand*
Designs should benefit more than renewable energy	*Create typologies for what land characteristics are suitable for renewable energy projects*	*Need to consider cumulative impacts*
Arts, cultural, social need to be considered	*Consider mutually beneficial relationships through design solutions*	*Consider what losses could occur into perpetuity*
Aesthetic properties of designs should be valued		*Protect natural resources and improve coordination amongst agencies*

Table 2-2 Synergies and tradeoffs that workshop participants identified between all Phase II pathway pairings.

	SYNERGIES	TRADE-OFFS
Multifunctionality & Natural Capital	*Benefit from enhanced policy and regulation-based change* *Benefit from habitat corridors along parking lots and medians* *Offer immense opportunities for shade structures and preservation of trees* *Effective land management helps reduce the impact of new systems* *Can be integrated into a sense of subjective aesthetics in civic centers if natural aesthetics are desired*	*Breaking up panel installation to integrate trees may be more costly to maintain and less energy productive* *If you build a multifunctional site, you can still disturb the environment* *Solar panels and other energy generation shade structures are not as pretty or natural as trees* *Multifunctional development could result in disturbing regions that are currently being used, putting additional stress on the local ecosystem*
Resilience & Decentralization	*Benefit from the removal of national, governmental red tape and a greater empowerment of local communities* *Empower communities to respond to disasters more quickly* *Decrease the odds of total community blackouts and power outages* *Can be leveraged to systems outside of energy generation that quickly empower communities to chart their own destiny* *Mitigate systemic biases in the political and economic sector by empowering people directly*	*Most desired scale of power generation* *Not always compatible with government interest and establishment conventions* *How locally generated energy is managed, stored, and used* *Decentralization can decrease resilience if a decentralized system is pursued to a far enough extent that it is removed entirely from a main grid*
Local Value & Energy Justice	*Benefit from being smaller scale* *Allow for equal protection for all in a community* *Encourage communities to determine what is most important to them and engage in self-governance* *Providing power from a source directly to the end user can help with cost but may require an outside*	*New hydro dams can displace residents and hurt local communities by not considering them in the decision process* *How local are benefits concentrated* *Who owns the output of community-based energy systems* *Avoid furthering local discrepancies in living conditions and economic mobility*

	SYNERGIES	TRADE-OFFS
	party to own the system to control overall energy flow *Community perceptions towards energy and renewables can expedite acceptance* *Opportunities for micro-finance and local and decentralized banking and money lending*	*Community perceptions toward development and renewables can hinder development in key regions* *To what extent do experts and expertise limit a community's ability to engage with renewable energy*

2.3.2 Resilience and Decentralization

In both the resilience and decentralization pathways, participants noted that safety and security relate to locally driven benefits (See Table 2-3). Long distance transmission creates vulnerabilities and inefficiencies, while both pathways promote more localized solutions. Connections to water conservation in using solar panels to reduce transpiration and evaporation, and reuse through incorporating active water harvesting, were agreeable between the two groups including watershed scale considerations tied to finer scales.

Many synergies were described around empowering communities with autonomy and control over their energy systems, while noted tradeoffs resulted from differences in scale and approach of technology deployment. Participants suggested that extreme decentralization can reduce resilience by fragmenting energy communities with only local generation and no backups in the case of failure (See Table 2-2).

One of the key synergies between these pathways was that having multiple small energy generation sites was found to be a more resilient strategy to climate disasters, as it decreases the likelihood of all sites being impacted by a single event. In contrast, the current model with a few large energy generation sites has a higher risk of failure due to these concentrated points of vulnerability. To illustrate, group members cited that decentralized community microgrids were inherently more resilient than centralized energy generation sites, particularly with interconnectivity for backup. Participants in this group believed that community microgrids could reduce reliance on the grid, promote local energy production, and foster a sense of shared ownership and responsibility.

Another key synergy that participants identified was that decentralized energy systems could not only reduce the risk of man-made disasters but also minimize the impact of natural disasters, particularly in fire-prone communities in chapparal biomes. The prospect of capitalizing on local labor to minimize disaster risk while bringing economic opportunities is a unique benefit of decentralization. Moreover, decentralized renewable energy systems could be more easily maintained and repaired by the local community, increasing the grid's resilience in crisis situations. Participants also stressed the importance of adjusting policies to remove bureaucratic obstacles in the reconstruction and construction of energy infrastructure

One key trade-off that participants discussed between resilience and decentralization is the scale of power generation. While decentralization offers many benefits, such as greater local control and improved resiliency, it may come at the cost of limiting the scale of power generation. This is because many key renewable technologies are intermittent, and a small-scale grid may not have the energy storage capacity or complimentary energy sources to level out the highs and lows of the in both energy production and energy use.

Table 2-3 Phase I Venn diagram between resilience and decentralization pathways.

RESILIENCE	BOTH	DECENTRALIZATION
Understand that every system tells a story	*Harness water from community outputs for irrigation purposes*	*Community microgrids*
Communicate with the community	*Avoid steam turbines in water-poor regions due to water loss issues*	*Solar signage, solar shoulders, solar shade structures*
Importance of regional watersheds should be explained	*Avoid long transmission corridors to prevent forest fires*	*Policy as a requirement for large warehouses to have solar on their roofs*
Cost of investments must be justified	*Focus on locally driven benefits*	*Incentivize developers to include small energy generation sites in all new planned communities*
Designers need the ability to make decisions early in the process before clients can set the agenda	*Creative adaptability*	
Cater to local conditions	*Allow communities to lead by example*	
Garner social support from community members on all new projects		
Continue to push for beneficial policy		

2.3.3 Generate Local Value and Energy Justice

The generate local value and energy justice group agreed on several points from the previous breakout sessions (See Table 2-4). The broad theme driving the discussion was that there is a need for a different approach to renewable energy than what is currently accepted as status quo, one that prioritizes communities. Participants determined this is best approached with balance between top-down and grassroots efforts to level the playing field with institutional policies and economic incentives that focus on the needs of the community. They encouraged greater involvement of landscape architects in decision-making roles at the community level and mused on what various scenarios could look like if the development of renewable energy systems prioritized those who lived in proximity, focusing on those individuals receiving social, cultural and economic benefits. They included multifunctional PV combined with water harvesting for local communities and infrastructure that supports local/small business development, such as improving environments for food trucks and farmers markets. One participant also asked, “can these be synergistic with services for vulnerable populations?”

Synergies tended to be more numerous than tradeoffs (See Table 2-2). Synergies included a discussion of scale, that the smaller the scale, the better to decrease the visual impact and costs. Participants favored the use of smaller scaled systems and microgrids, citing reduction in costs from what would be necessary for increasing grid connections. They also discussed the potential benefits of providing opportunities for local and decentralized financing, possibly with microfinancing or similar opportunities. Participants saw community perception as important to expediting approval processes. Many participants agreed that balance is needed between top-down and bottom-up initiatives and decision making.

Discussion on tradeoffs included concern of local community benefits potentially creating or furthering wealth disparities depending on how those benefits are distributed. Participants agreed that the negative impacts of disparities tending to affect minority groups, with one commenter highlighting hydropower dams displacing Native communities without their consideration in the decision-making process.

Table 2-4 Phase I Venn diagram between local value and energy justice pathways.

GENERATE LOCAL VALUE	BOTH	ENERGY JUSTICE
Combine RE with affordable housing	*Prioritize actions that address broader needs of the community*	*Community energy models that integrate land stewardship*
RE infrastructure should support local/small business development	*Approach should be balanced, both top-down and bottom -up*	*Minimize ecosystem impact*
Must be economically viable and long-term viable	*Institute policies that level the playing field using economic incentives*	*Equitable distribution of resources throughout community*
Foster growth for community		*Rethink municipal codes and LAs as decision makers*

2.4 Phase III Outcome

Phase III brought together the three groups from Phase II to share the outcomes of previous sessions and begin to prioritize ideas. Session moderators presented their findings from Phase II and the full group of participants used an adaptation of an Eisenhower Decision matrix to sort ideas based on impact and effort (see Figure 2-4).

Although the original Eisenhower matrix focuses on categories of urgency and importance, the matrix used for the breakout session aimed to focus on impact and effort to understand what actions would have the greatest impact for the least amount of effort. Four categories helped organize ideas and thoughts from participants and researchers to understand which interventions and ideas should be pursued immediately with low effort and high impact, investigated with high impact and high effort, considered (and workshopped) with low effort and low impact, and which should be avoided due to low impact with high efforts.

Many of the high impact, low effort strategies and principles relate to reducing energy demand and protecting landscapes. Understanding and designing with local conditions and resources can aid in land-use planning and site design to factor in a full gamut of values in addition to power output, including shading, habitat restoration and other externalities, which are generally favorable from a community perspective. Full life-cycle analyses can further help toward optimization and reducing embedded carbon while encouraging use of local resources and materials. Overall, using existing metrics and developing new metrics to communicate the ecological, cultural/social and economic values of renewable energy investments beyond solely energy production and financial profit was seen as favorable.

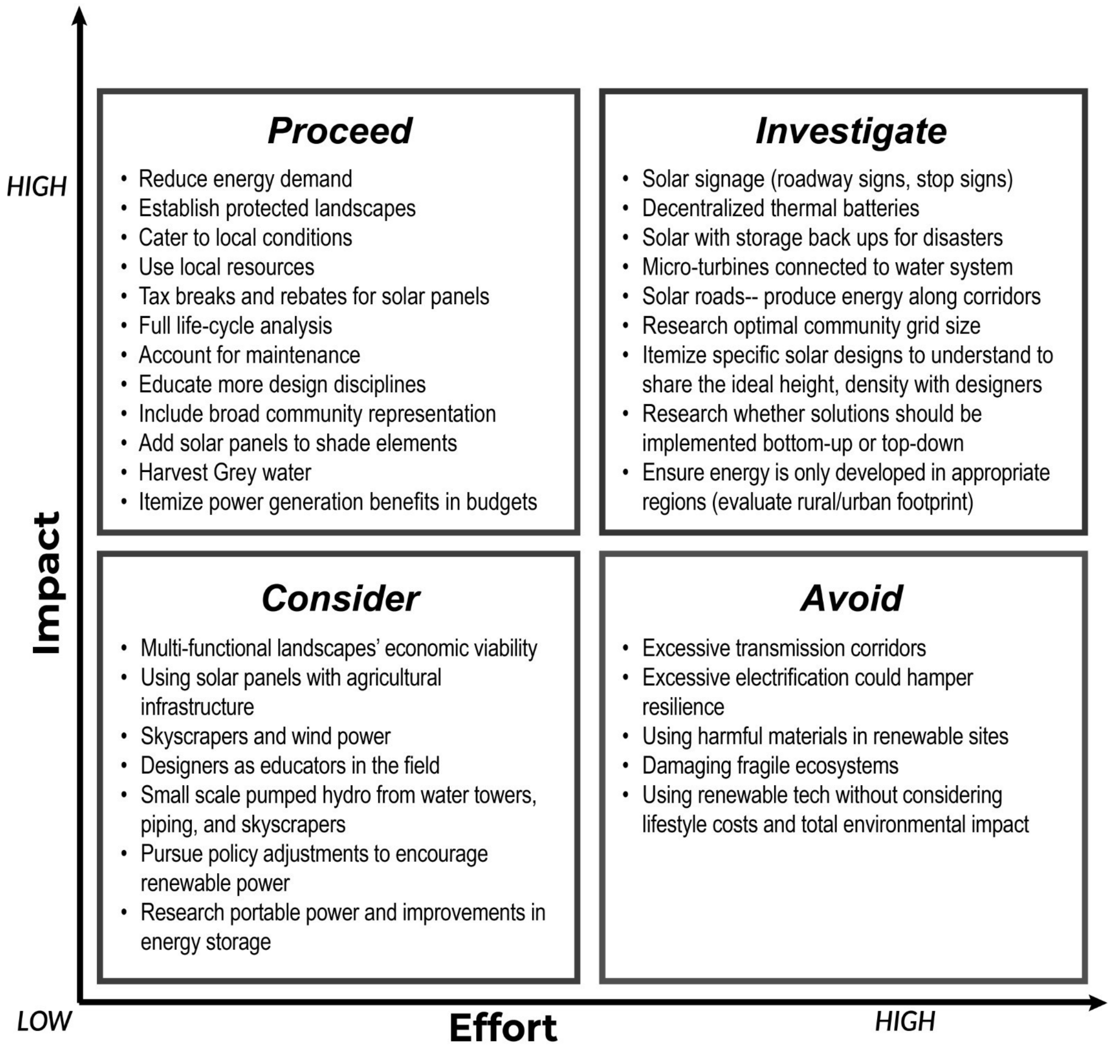

Figure 2-4 – Phase III negotiation and prioritization of ideas and principles by workshop participants

Areas of consideration with low effort, but maybe less impact, included strategies such as agrivoltaics, building integrated wind, small-scale hydro associated with water towers, piping, and skyscrapers, as well as opportunities for portable power. This may be due to the novelty of these technologies and the time needed to implement at a broader scale.

Areas of investigation with high impact and high effort included research and optimization. This was evident not only in studies involving physical layout and dimensions for optimization, aesthetics, plant material compatibility and other synergies to preserve or enhance ecosystem functions, but also in finding balances in top-down/bottom-up efforts, and what impacts it has on social equity and value generation. The high effort may be due to time and costs necessary in further research along with the need to cross more disciplinary boundaries.

For avoidance, topics included inefficiencies of excessive transmission, postponement of integrated design processes and blind deployment of development, including lifecycle inefficiencies that cut into the net benefits.

3.0 Pacific Northwest

3.1 Structure

The workshop discussions were conducted via Zoom with supplemental exchanges on Miro, a virtual live whiteboard. University of Oregon faculty facilitated discussion in each breakout group, and Pacific Northwest National Laboratory and U.S. Department of Energy experts contributed in each session to provide additional guidance. The workshop included three breakout groups, each representing a specific landscape transect typology and two pathways, as detailed below. Each breakout group conducted three meetings to identify site opportunities and challenges with stakeholders, collaboratively explore design options while considering synergies and tradeoffs, and visualize proposals. The separate groups came together at the end of the workshop to present design ideas related to their pathways and discuss the insights gained from their design process.

3.1.1 Oliver P. Lent Elementary School, Oregon: Multifunctionality and Distributed Energy Generation

3.1.1.1 Project Overview

The first group explored the multifunctionality and decentralization pathways through the integration of renewable energy and passive building conditioning strategies at an urban site. This work addressed the Oliver P. Lent Elementary School in southeast Portland, Oregon. One sub-group integrated wind and solar power with landscape design to enhance existing land uses and support outdoor activities (Landscape Group), while the other focused on passive cooling of the building, using cool night air, wind, shading, and evapotranspiration to support a new use for the school as a cooling center during heatwaves (Building Group).

3.1.1.2 Site Opportunities and Challenges

The Oliver P. Lent Elementary School was chosen as a site that categorically reflects the broader challenges and communities in the Pacific Northwest region. The school is located on the northern edge of the Lents Green Ring,[1] a network of roads that is a focus of extensive community-initiated improvements for walking, bicycling, and place-making. Additionally, like much of the neighborhood, the site experiences pronounced summer urban heat island effects due to the extensive use of asphalt and concrete for sidewalks, roofing tiles, and roads, particularly including I-205 (See Figure C-1). At the same time, no nearby cooling center exists to help residents during heat emergencies. The school is also the focus of enthusiastic ongoing efforts to mitigate noise and pollution emanating from I-205, including the design of an air quality forest (See also Figure C-2) between the school and the highway and a butterfly garden on the school's east, neighborhood-facing side. Finally, the school represents typical public schools of the region in its prominence as a neighborhood landmark yet limited use for community benefit when school is not in session, as well as its possession of under-utilized outdoor space.

The Landscape Group viewed the school's extensive, underutilized hardscape as an excellent opportunity for the installation of solar PV canopies and greenspace, and local stakeholders noted plans to renovate the outdoor amphitheater, grass fields, and playground, as well as the Green Lents initiative to create an air quality forest and butterfly garden on the site. Between the

[1] See https://www.greenlents.org/lents-green-ring.html for additional information.

school and I-205 is a substantial earthen barrier (~22 feet in height) that could support further development as a sound barrier. The Building Group, in turn, was intrigued by the space along the east-facing school front. Aligned with current security practices, this space is open mowed lawn, denying the privacy an intruder would need to break in. As a result, the east-facing windows, roof, and concrete entry are fully exposed to summer sun; additionally, the space is desolate and unwelcoming. Instead, participants felt, this space could be lively and well-used, allowing it to resist break-ins not only through window visibility from the street but also through school and neighborhood attention.

Participants also viewed the desire for nodes of community gathering as an opportunity because it implied motivation for people to participate in planning processes such as those already underway. Additionally, participants felt that the public nature of the school; the familiarity of schools as places of innovation and experimentation; and the easy access to the site throughout the neighborhood by bike, bus, and foot, allowed the school to be an appealing node for community gathering and to feel safe for refuge as a cooling center during heatwaves.

Finally, architects with experience in passive cooling design viewed the site's climate as ideal for passive cooling. The combination of cool night air and cold night skies that Portland typically experiences throughout the summer was expected to provide extensive resources for night ventilation of the school and for night radiant cooling from the school's roof, respectively. Additionally, recent evidence has shown that these resources can persist in Portland even through extreme heat waves (Rempel et al. 2022).

Participants of both sub-groups viewed the greatest challenges as those external to the site. These included the extensive nearby impervious pavement in the form of I-205, Steele St., and neighborhood streets and asphalt roofing, which contribute to the widespread urban heat island effect across Lents. Additionally, participants observed that the prevailing wind during Portland summers comes from the northwest, potentially carrying particulates and fumes from I-205 toward the school. Challenges associated with the site itself, in contrast, were viewed as addressable and even as opportunities for productive, community-led interventions. In addition to those described above, these included the lack of high-quality (i.e., exterior or insulated, edge-sealed interior) operable shading on school windows and the lack of window security to allow night ventilation. The most vexing site challenge was viewed as the limitations typically imposed by school districts on tree cover and other vegetation near school walls to maintain classroom visibility and security.

More broadly, participants felt that the greatest overarching question was: How can the school facility support the community during emergencies or climate crises? For example, can it provide cool spaces for neighbors without air-conditioning during heat waves? Can it provide refuge from smoke or smog, or a warm, dry place or place to charge a phone during winter power outages? They felt that these questions could be answered positively, with effort and outside support.

3.1.2 Klamath Falls, Oregon: Generating Local Value and Respecting Natural Capital

3.1.2.1 Project Overview

The second group addressed challenges at the Klamath River in south central Oregon by exploring the placement of solar PV arrays over Klamath Project canals. This design solution is particularly relevant as the Pacific Northwest faces increasingly severe and prolonged droughts, creating similar challenges to other rural communities in the area. Water is drawn from Upper Klamath Lake at a northern corner of that city into a large canal called the ‘A Canal’. This is the largest ‘trunk’ canal in the distribution system of the 58,000-acre Klamath Irrigation District (KID) and on to other such districts. It flows deep and wide through the city, sending water to hundreds of distribution canals and many dozens of farmers throughout the Klamath Basin Project (KBP) to the southeast. That project was constructed by the U.S. government in the early 1900s. It converted extensive wetlands and dry prairies into irrigated farmland and national wildlife refuges – that fostered a century of economic development for the region. Not far beyond the east edge of the city, the A Canal splits where a drop in water level produces hydropower for the KID. Much of the water flows south along the long ‘C Canal’ to another redistribution point.

The region, KID, and these canals are beset with new problems. Watersheds have been supplying reduced average flows into Upper Klamath Lake over the last 20 years. Contentious controversies have erupted about how to distribute these reduced supplies. Legal and political litigation has prioritized water for fish and wildlife in Upper Klamath Lake and the Klamath River downstream. This has left much less water, on average, for the farmers and the wildlife refuges at the ‘tail’ end of the irrigation and drainage canals of the KBP. Financial stress and difficult adjustments have beset the farmers, and ecological stress and depletion besets the refuges. These have been exacerbated by reduced water quality in the canals and refuges, attendant new canal maintenance problems (i.e., algae), dropping water tables, and other challenges. Energy costs have also grown for the farmers, the KID, and the region and energy supplies will be impacted by impending removal of hydropower dams along the Klamath River to benefit fish.

Participants explored design options to reduce the loss of water from the two case study canals and improve their water quality by covering them with photovoltaic arrays. There are two main mechanisms: (1) reduced evaporation by shading the water and preventing air flows across its surface, and (2) reduced biological evapotranspiration due to less aquatic biological activity (due to reduced insolation) and to lower water temperatures. Such new canal designs might arguably be a more economically efficient contemporary form of irrigation canal[1] in a time of increasing water scarcity than has been implemented elsewhere in the world.

Participants did not research the financial, technical, hydrological, or biological performance of their designs. Their concept designs are a first step searching for viable forms to support engineering work that would enable such robust feasibility investigations. They speculate that PV over canals might be a form of multi-functional infrastructure that can be scaled up to substantially reduce water losses and to provide greater supplies for farmers and wetlands as well as improved water quality and significant new supplies of low carbon electricity.

3.1.2.2 Site Opportunities and Challenges

The A Canal winds through Klamath Falls (See Figure 3-1). It averages about 87 feet wide when full, and the water depth can be as much as 22 feet at 900-1,000 CFS. The flow is higher in the growing season and varies according to the varying level of water allocations to it by the Bureau of Reclamation in concert with other agencies.

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[1] For more information on this approach, see: McKuin, B., Zumkehr, A., Ta, J., Bales, R., Viers, J. H., Pathak, T., Campbell, J. E. (2021) Energy and water co-benefits from covering canals with solar panels. Nature Sustainability: 4, 609–617. https://doi.org/10.1038/s41893-021-00693-8

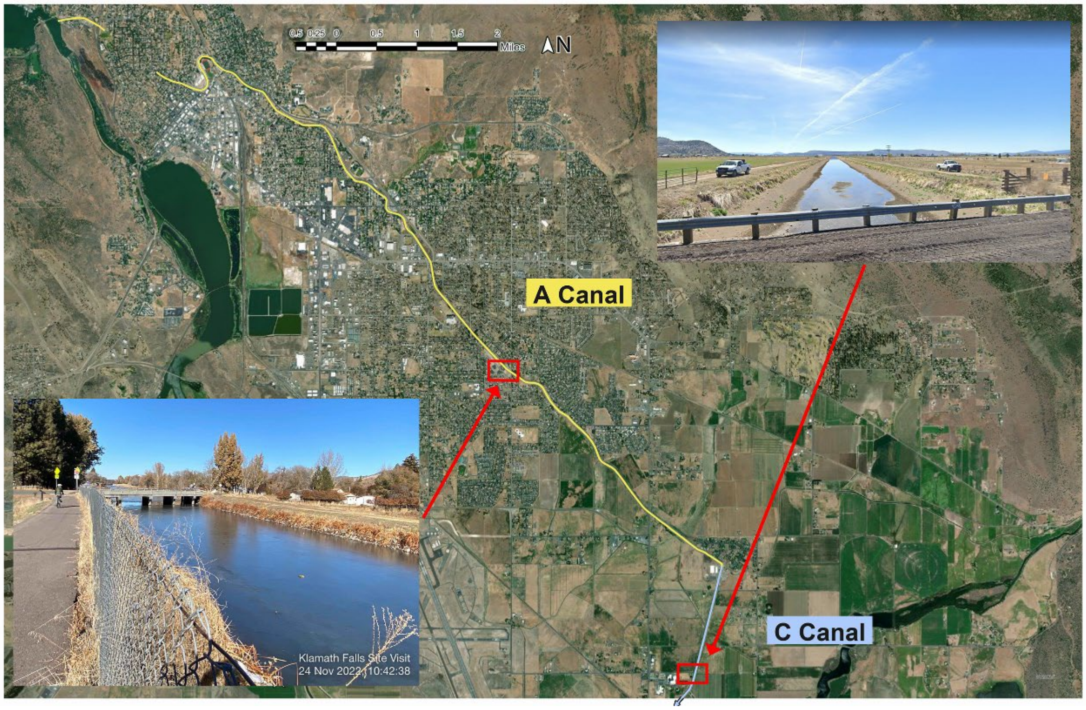


Figure 3-1 - Location of the Klamath Irrigation District A and C Canals with photos at design study sites in red.

The most challenging feature of the A Canal is that it was constructed in 1905-1907 by simply regrading the native soils as a cut and fill across a gradual slope. This problematic embankment material produced a hydrologically unstable south embankment which has regularly failed, causing floods in urban and suburban areas south of the canal (See Figure 3-2). Whenever such a failure occurs or is evidently imminent, KID must quickly access the hazard area and make repairs. Any solar array covering of the canal must either allow for rapid emergency access to the south embankment or permanently repair it to greatly reduce the probability of failure.

The geologic substrate of the A Canal, including that of the canal floor, is chalk rock. This is a hydrologically relatively impervious surface geology that exacerbates embankment failure and attendant flood risks. This occurs because water that leaches from the canal's water column into the pervious embankment material does not flow down, but rather across, the underground bottom of the embankment at the chalk rock interface. This promotes piping and embankment failure, a risk that can be worsened by rodent burrows, erosion, or plant roots. The chalk rock also imposes design constraints because it is prone to fracturing if piers or other structural members are driven into it.

Any PV covering would have to be made of modules that would abut each other for a robust or full length of the canal. The sometimes-windy form of the A Canal will make use of identically manufactured modules impossible. Participants assumed that this would be possible for the straighter lengths of the canal and that the remaining lengths would require custom modules or be left uncovered. A conduit with connections to the modules would need to be placed along the top of or under an embankment to electrical substations with links to the city's electrical grid.

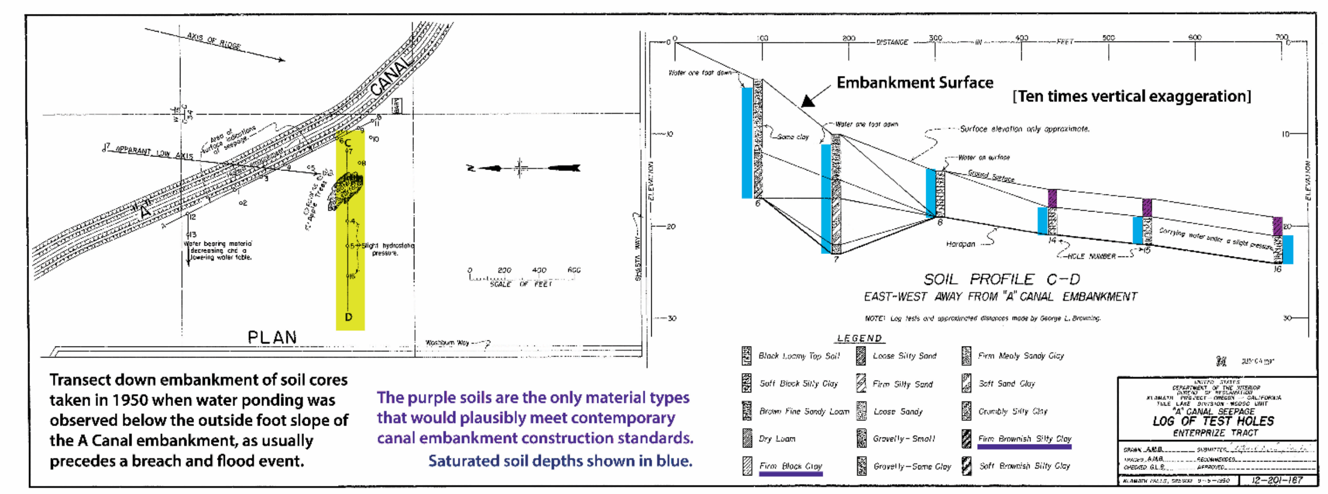


Figure 3-2 – Color-annotated page from a 1950 soil core section survey of a failing location along the south embankment.

There is a multi-modal recreation path on the south embankment along the west half of the A Canal through the city, with a roughly four-foot-high chain-link security fence between it and the canal. Any design would either accommodate or eliminate these features. Glare from PV arrays could impact path users or nearby homes and businesses. An elevated structure over both the canal and path could provide a recreational experience that is sheltered from the sun and rain. It might be cooler than the surrounding outdoor landscape in the summer due to shade and some evaporative cooling by the canal water.

The visual impact of a PV covering of the A Canal could be an important consideration. If the PV covering were low and just above the water – which reduces ventilation induced evaporation – its visual impact might be minimized. If an elevated PV array-covered structure were built, it would need to be designed to be a beautiful, landmark visual asset for Klamath Falls.

The C Canal is a bit narrower than the A Canal and about half as deep. It is large enough to gain substantial reductions in evapotranspiration from PV coverings and its slower flows than the A Canal likely favor more efficient reductions in evapotranspiration than the A Canal. The C Canal is mostly straight and readily receptive to assembly of modular PV arrays along its length. It has maintenance roads on wide and flat embankment tops for ease of design, construction, and maintenance. It is less prone to flooding due to embankment failures and lower embankments with lower water flows should make emergency repairs easier than along the A Canal.

The C Canal is in a rural setting with private farmland along most of its edges, and interventions would probably entail fewer adverse visual or land use impacts. There is a high school adjacent to it with more likely 'recreational' uses along it near the school. Securing the space under the PV cover could be important, as could measures to inspect under the covering and rescue people or wildlife who might be trapped there. The cross section of the C Canal is representative of many other irrigation canals in Klamath Basin irrigation districts, so a feasible design there may be readily replicated elsewhere.

3.1.3 Coast Salish Cultural and Natural Heritage Center, Washington: Resilience and Energy Justice

3.1.3.1 Project Overview

The topic of resilience and energy justice was investigated with a specific lens toward tribal justice and a case study of an envisioned Coast Salish Cultural and Natural Heritage Center led by a nonprofit organization called Se'Si'Le. This session tackled a very important general problem and a specific problem - how to listen and talk with tribal stakeholders who are working to reclaim their cultural heritage and traditional lands through an integrated landscape and architectural project. The primary aim of this third group was to provide an opportunity for designers and renewable energy professionals with an opportunity to acknowledge and learn about Indigenous values and approaches to landscape design.

The group began with a general introduction to the ideas of resilience to climate change for vulnerable communities such as 1) mitigating blackouts and loss of critical services, 2) resilience hubs and microgrids, and 3) diverse set of energy technologies and demand-side management. Facilitators also introduced various issues around energy justice such as 1) fair distribution of costs and benefits and equitable participation, 2) site-sensitive energy development and thoughtful decommissioning, 3) countering legacies of harm, 4) prioritizing development in communities facing disproportionate energy insecurity or energy burden, and 4) understanding historical and cultural context. Design methods of ecological systems and the San Juan Island site background, including maps of geography, wind speed, energy infrastructure, and Lummi cultural images, were briefly described and placed in the digital whiteboard space for future workshop reference.

Next, a vital part of the workshop occurred when a Lummi stakeholder spoke to the spirituality of the Lummi people, their sustainable practices with nature, the harmful history of the U.S. government displacing the Lummi Nation, and the harmful impact of non-tribal migrants on the water, energy and animal systems of the region.

> "The Treaty of 1855 was 168 years ago. This agreement was only six generations ago. My great grandparents were one hug away from pre-contact. We are trying to share that story of existence, of what once was, to help us understand where we are going to be, the trajectory we are on. What we've done in 168 years is catastrophic disruption when it comes to climate change, when it comes to everything that was here before. With the heritage center, you can imagine a longhouse out here in our territory out on the island and you can be teleported back in time and you can ignite your senses through virtual reality. In this place this vision is to be able to become an orca and see what it was like to live 300 years ago and what it is like to be facing starvation today."
>
> --Jay Julius, Lummi tribal member, President and founder of Se'Si'Le

A case was made to shift the narrative to the perspective of the Lummi people and their values and spirituality – toward empathy and the start of an understanding of their perspective on life and how that would impact discussions about energy and justice. Examples of these values include "landscapes holding spirit songs, all that is has agency and the water is inspirited." Another participant asked, "Challenge: we're immersed in a culture of colonization, how we can shift our own biases and thinking in an active way?" A project partner spoke to opportunities he saw with the use of his business background in virtual reality to connect tribal members and non-tribal members to the site and ideas of the Lummi remotely across space and time. It was important for the workshop structure to empower a time and space to listen to the Lummi people and for the participants, mostly non-tribal, to listen, try to understand and offer any acknowledgement of how to proceed.

Reactions to Problems and Opportunities were recorded on sticky notes organized around ideas of “LOVE - have enjoyed, will remember,” “WISH - something you’d tweak somehow or something you’d add,” and “WONDER - are thinking or curious about.” LOVE comments included ideas such as using empathy as a guide for justice, utilizing virtual reality as a valuable tool, and providing educational opportunities to make this very current and pressing topic more visible.” WISH comments included a desire to “make the Lummi and Coast Salish presence visible where it is invisible on these islands,” to create “sustainable connection with natural systems,” and to use VR for connections to place and policy processes. WONDER comments were the greatest in number with ideas of immersive sensory experience, using the cultural center as a mechanism for community resilience and empowerment, energy infrastructure of wind and solar versus wave and ocean thermal energy conversion with grants and subsidies and technology to support virtual experience from the eyes of the animals and humans across time. This process allowed participants to learn how to communicate together and how to pause to think about nature and people before each individual could jump into short design processes together.

3.1.3.2 Site Opportunities and Challenges

Facilitators prompted participants to think about a system of values and environmental qualities and how they could share their thoughts through methods using systems diagrams of ideas as icons and words. Diagrams of values could be organized around tribal justice such as economic sovereignty, physical access to site, spiritual access at and beyond the site, and resilience problems such as security in case of disasters for food production, energy production, and air quality.

The diagrams produced by individual participants were most valuable for the way they organized big ideas and the relationships between those ideas. The diagrams were organized as descriptions of values, lists of numerical or bullet values, linear sequences of thought, bifurcating decision paths and circle diagrams of parts of a holistic system. These diagrams attempt to summarize tribal values and ways the tribal center would be a physical structure with necessary demands for energy. Energy being deeply connected to both ecological systems and the spiritual experience of the Lummi perspective of life emerged as a common idea in the diagrams. An interesting aspect of the diagrams is trying to find where they begin. When beginnings are identified, they often relate to “ancestral knowledge and perspectives,” “sacred spaces,” “low impact...land as a person,” or “understanding the feeling of the Lummi People through empathy.” Next levels of diagrams read as systems of the natural elements or energy production of “wind, sun, water, earth,” engagement in-person or virtual off-site visitor experience, and spiritual perspectives of animals and humans.

One diagram showed ancestral knowledge and uses the natural elements to organize types of renewable energy sources and various spatial and governmental scales of equitable recognition of policy, planning and management tools to renewable energy (See Figure 3-3). The thinking and graphic organization of the circle of this diagram implies a holistic system such as earth and a way that earth and the elementals are central – an approach that relates the Lummi spiritual understanding of life not in competition with scientific knowledge. That diagram and other diagrams suggest a map for thinking using arrows to reflect decision-making or selections of systems with implied use only by stakeholder engagement.

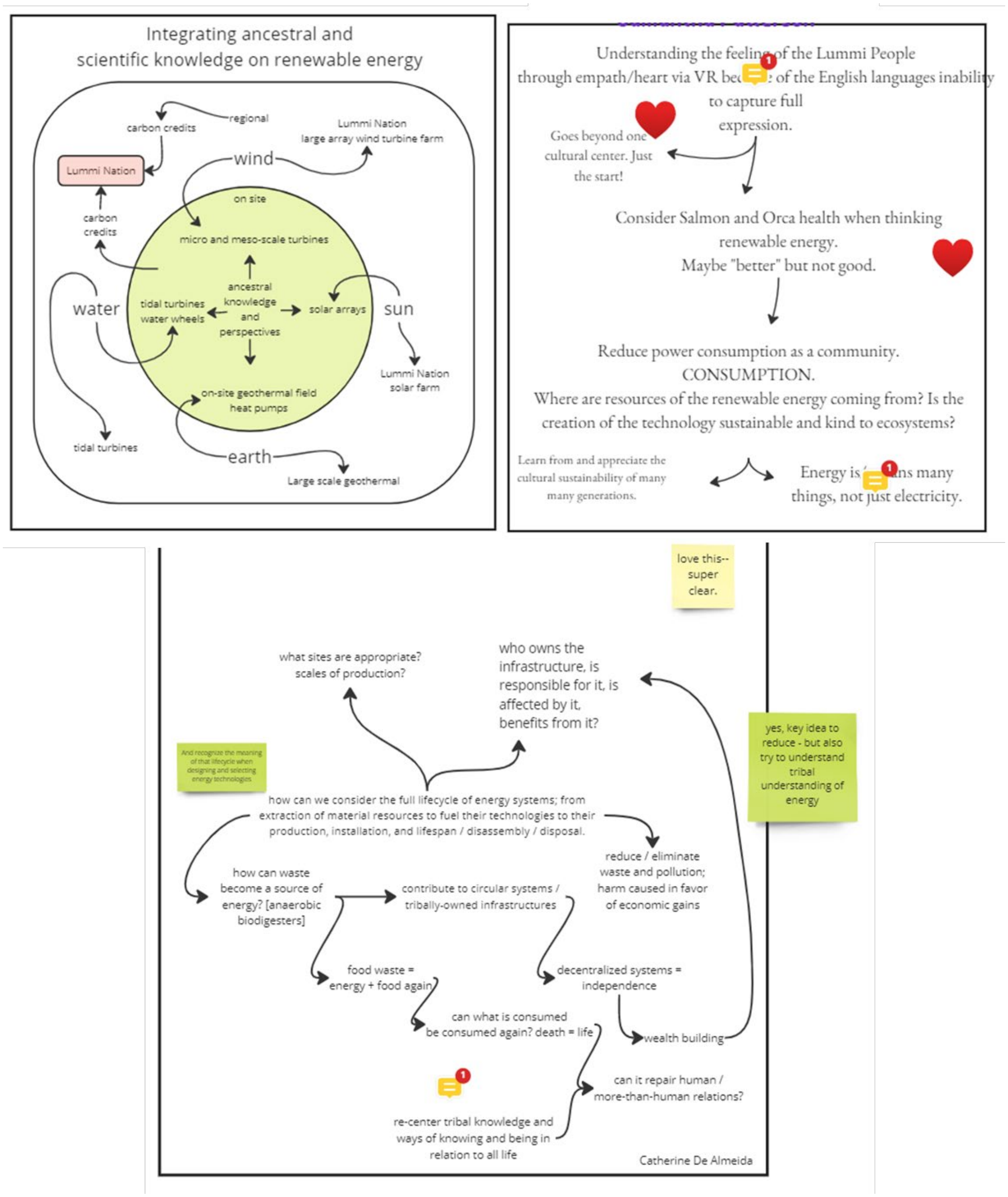


Figure 3-3 - Values diagrams by workshop participants.

Reflections from workshop participants to others' diagrams seemed to think through how such diagrams would play out in energy systems design processes, and the way they would be experienced. A general understanding of the reflections suggests the importance of integration of the impact of energy choices and the impact on experiencing the local site and the broader site of the regional natural systems. The reflections and comments demonstrate a criticality to think from the perspective of the Lummi in the way they communicate, the way they lightly impact nature, and how they might evaluate renewable energy sources for the Heritage Center.

Synergies between systems and values were also discussed. The most elaborated comment explained the importance of communication by stopping to listen, reframing and pausing from traditional processes of renewable energy design –

> *"The discussion must be framed from a context of responsibility. To establish that it must have a foundation in truth telling. Historically/present, practically/politically before you can get to where you need to start which is naturally and spiritually. Then you restart the discussion from that point with right and respectful communication."*
>
> *JoDe Goudy, former Yakama tribal chairman and Se'Si'Le Vice President*

This comment and others included repeated themes of "cultivating empathy," "big impact, light touch," "Indigenous knowledge-systems + culture" and "is energy only technology." Only one of the seven reflections on synergies propose a specific solution such as a "new renewable energy infrastructure coupled with new salmon hatchery infrastructure." The others implied that a just design process is one with further participation from tribal stakeholders.

3.2 Outcomes

3.2.1 Oliver P. Lent Elementary School: Design Concepts and Visualizations

3.2.1.1 Landscape group

PV canopy structures over paved surfaces. Participants noted that several environmental synergies could be achieved by installing PV canopy structures over the hard paved surfaces of the playground and parking lots. Shade from PV canopies would provide places to rest and support outdoor activities under cool thermal conditions when installed on the playground. The spaces under the canopies could also become temporary shelter from harsh weather conditions such as intense sun or rain, allowing students to play outside. The shades would also cool vehicles, and the electricity produced could be used for charging electric vehicles. The participants were concerned, however, about damage to PV panels from sports activities nearby, as well as potential negative impacts on the aesthetic quality of the school and the surrounding neighborhood.

PV canopy structures over vegetated surfaces. Participants highlighted synergies that could be achieved by installing PV canopies over vegetated surfaces such as gardens or lawns. The shade cast by the arrays could increase soil moisture levels, for example, which could reduce water stress for plants during summer months. Rainwater collectors could be placed beneath the panels to supply water for irrigation, as well, reducing the demand for municipal water. Finally, the co-location of PV and school gardens in agrivoltaic arrangements could provide educational opportunities. If local residents were involved in such gardens, the site would also be monitored after hours. Participants noted that the canopy could limit the crops or fruit trees that could be grown, however, and that well-conceived solar PV configurations would be important to support both energy production and agricultural productivity.

PV soundproof walls, kinetic paving, and PV pavement. Most participants supported the use of soundproof walls and buffer planting strategies to block noise and pollution from the highway while producing energy. However, some noted that the necessary orientation of the wall, facing east or west, could lower its generation efficiency. This could be addressed by installing PV on both sides of the soundproof wall: in Germany, at latitude 51° N, bifacial solar panels reduced peak electricity demands in both morning and evening when installed facing east and west (Reker et al. 2022). Some participants suggested the use of kinetic and solar PV pavements to combine electricity production with other uses, but some expressed concern about the low generation efficiency and maintenance requirements of these newly emerging applications.

From these themes, participants developed seven initial concepts before synthesizing them into a conceptual site plan (See Figure C-3). This common plan divided the outdoor spaces into three zones: Site 1 (near the highway), Site 2 (paved playground), and Site 3 (grass fields and school farm) (See Figure 3-4).

Site 1 (near the highway)

Participants suggested installing a soundproof wall, supporting PV panels, on the berm along the highway to enhance its noise-reducing effect. Participants also recommended designing a stormwater management system at the bottom of the berm to prevent runoff from flowing toward the playground. Landscape planting with trees and shrubs in this zone could serve as a wind block and secondary buffer against noise and air pollution from the highway. Deciduous trees should be used to provide shade in the summer and allow sunlight in during the winter.

Figure 3-4 - Landscape Group's design flow, concept, and site master plans.

Site 2 (paved playground)

Participants suggested installing PV canopies over the paved playground, parking lot, and amphitheater, which have been underutilized. The canopy would enable outdoor activities even on rainy days. New PV panels over parking lots could also support electric vehicle or E-bike charging stations, and buffer planting would clearly separate each parking space from the road for safety. Benches with PV canopies could also be installed around the perimeter of the playground for teachers and supervisors.

Site 3 (turfgrass fields and school farm)

Participants suggested renovating the multipurpose fields with a half-covered, 9-foot-tall PV canopy installed around the border of the field. The field will produce energy while being used for games and sports. On weekends, local food markets could be opened to provide an opportunity to sell produce grown at the school farm to local households. The school farm would be co-located with the PV canopy. Farm crops could include edible plants as well tactile plants and flowers to beautify the farm and provide interactive opportunities for visitors. At the eastern border of Site 3, right next to Site 1, an air quality forest was suggested (See Figure C-2). The forest would be designed as a multistory landscape with mixed plants and tree species. Some areas may be designed with PV shelter around places where tree shades do not reach. Underground stormwater retention was also suggested to reduce rainwater runoff issues due to increasing precipitation.

These ideas were synthesized into composite images (See Figure 3-5 and Figure 3-6). For an additional view, see Figure C-4.

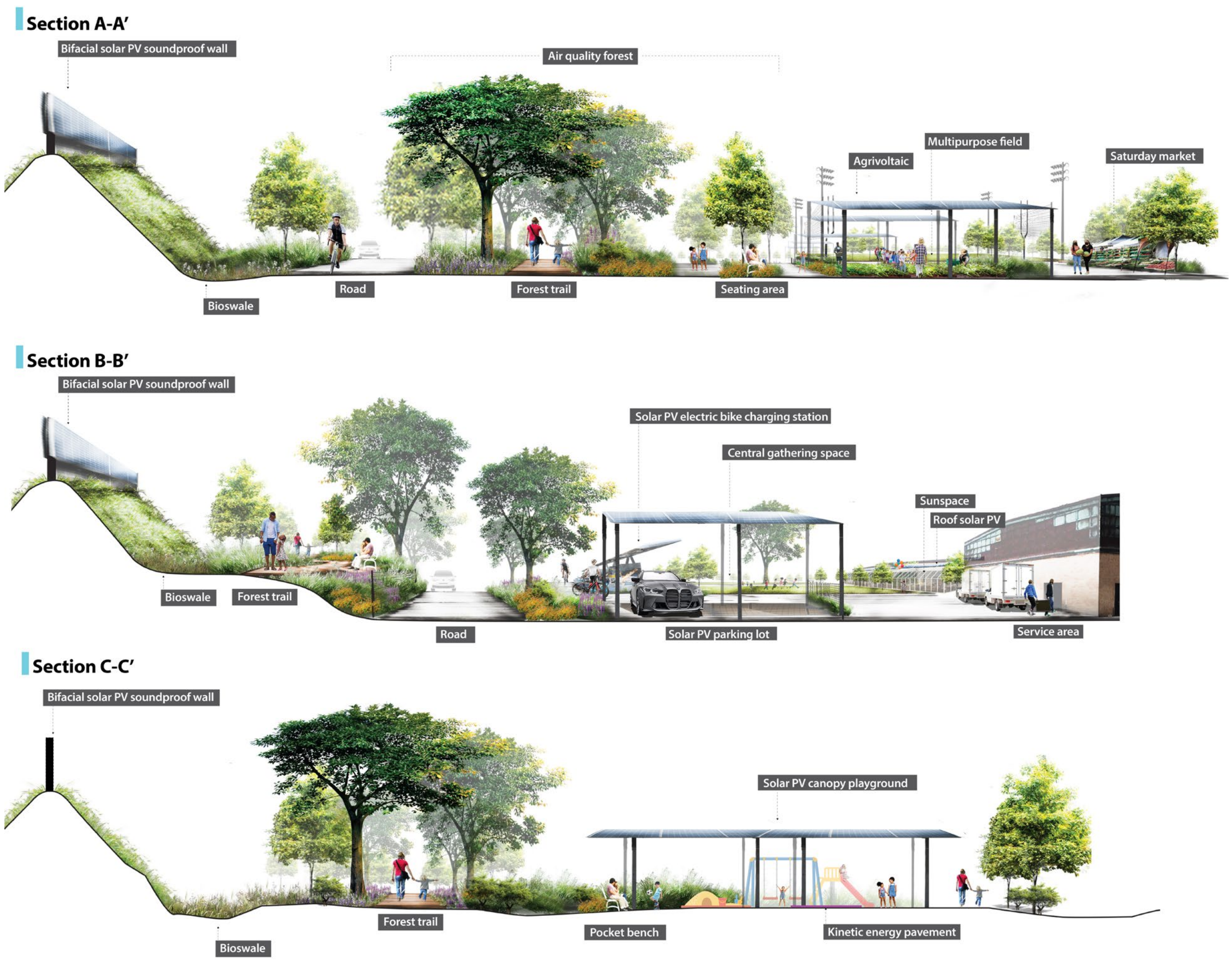


Figure 5 -- Landscape design concept for Oliver P. Lent Elementary School.

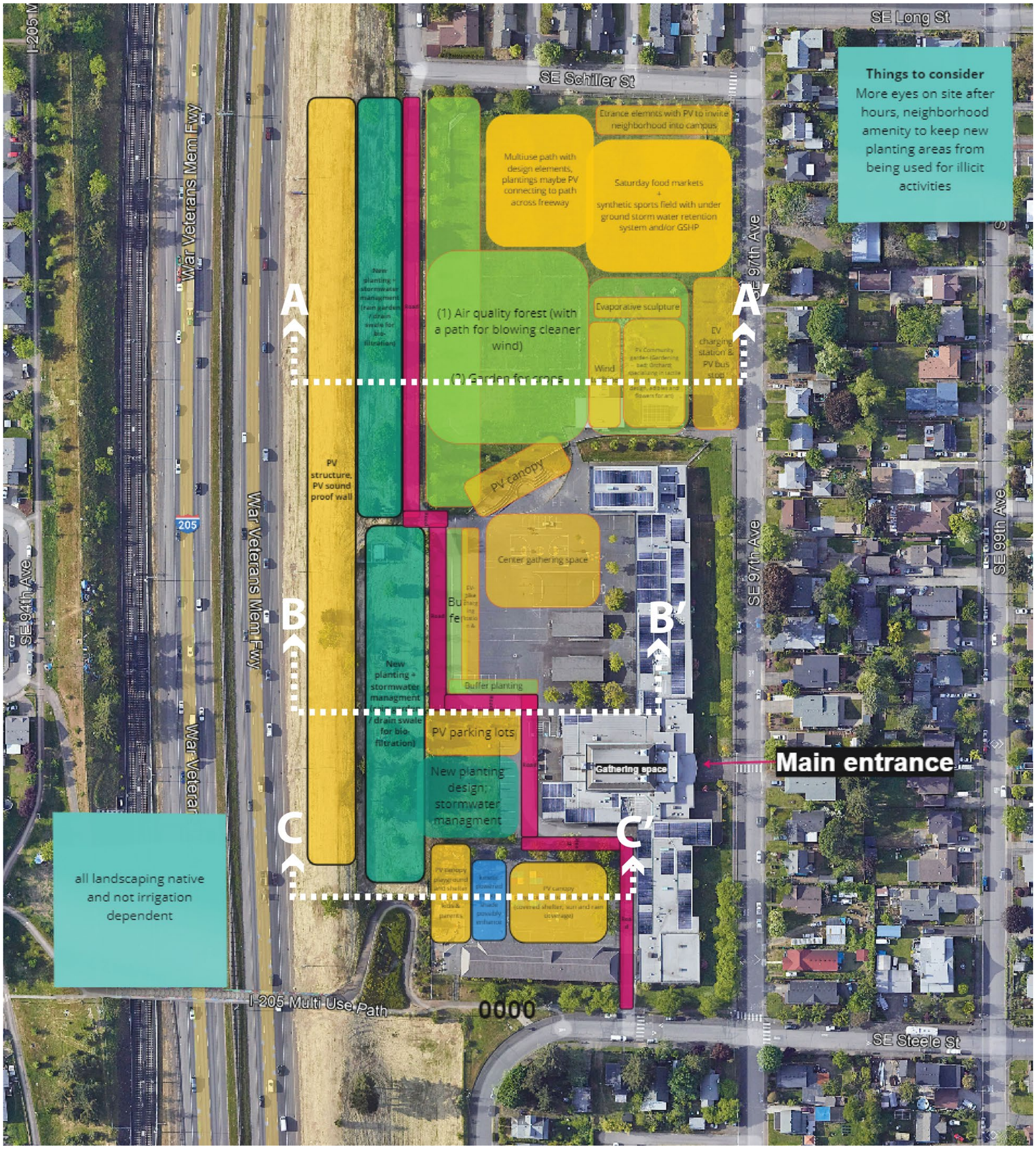


Figure 3-6 – Synthesis of concepts for Oliver P. Lent Elementary School.

3.2.1.2 Building group

Shading. In observing the schools' extensive east- and west-facing windows, participants expected window heat gain to be substantial. This heat was viewed as beneficial through much of the school year, in Portland's cool climate, but disadvantageous from mid-May through September, limiting the building's summer comfort and use. They therefore recommended a range of shading options, including (i) insulating, edge-sealed, and white or light-colored indoor shades; (ii) automatic or attentive manual operation for these shades to ensure that heat would be admitted when desired and excluded, when not; and (iii) operable timed awnings over windows, again to provide shading appropriate to the season, possibly with PV capability. On the western side of the school, recommendations also included transitional and outdoor shading structures; on the eastern side, these included tall deciduous trees to shade the roof.

Night ventilation. The typically cool nighttime air of Pacific Northwest summers was expected to provide an extensive passive cooling resource, participants said, and they noted the reliable north-northwest direction as well (National Centers for Environmental Information (NCEI) 2023). Further, they viewed the narrow east-west width of the building as a good match for this resource. To accomplish effective cross-ventilation, they recommended two primary measures: first, the addition of decorative metalwork on classroom windows to provide security for overnight ventilation when outside air is coolest, and second, the addition of transom windows to classroom doors and walls to provide airflow paths across the corridor. Participants did not favor the addition of air-conditioning, however, because of its cost, ongoing maintenance needs, and vulnerability to power outages (Sailor et al. 2019). They noted, however, that shading and natural ventilation would greatly reduce cooling loads even if air-conditioning were added in the future.

Rooftop PV. Participants noted that the current rooftop PV configuration, parallel to the roof surface, was likely to generate less electricity than the maximum possible. They therefore recommended tilting the panels according to regional recommendations, reducing radiant heat transfer from the panels to the roof and improving the panels' shading abilities. Additionally, depending on the roof's structural capacity, green roofs or rain gardens were suggested in places to create educational opportunities, reduce stormwater runoff, and create habitat for birds and insects.

Integrating these ideas, participants converged on two primary design concepts: Westside and East side as below.

West side

Along the west side, participants envisioned a leafy, sheltered, transitional indoor-outdoor space to buffer the classrooms from the noise and pollution of I-205 and from the heat and glare of the asphalt playground. Multiple options were discussed, as shown below.

Sunspaces. The most enclosed option was a series of sunspaces (a glazed area facing south that is located outside of the main building envelope) connected to the classrooms, creating microclimates that would provide daylight and improve seasonal awareness while excluding noise and pollution (See Figure 3-7 and Figure C-5). With the addition of easy-to-grow indoor plants, these spaces could also support education in photosynthesis, ecosystem services, and plant care, and they could be used as alcoves off of the main classroom for group work or quiet time. Simultaneously, these sunspaces could improve direct solar heating in the winter; support PV panels on sections of their roofs; and be cooled in summer through operable shading on the skylight roof sections and night ventilation. Further, these spaces could support education in microclimate design, renewable electricity generation, and passive space heating and cooling. In discussing trade-offs, participants noted that plants require care and can attract pests, and that any plans would need to be developed in full cooperation with the teaching and maintenance staff.

Back porch. The next option was the creation of a covered "back porch" to the school, accessible from the classrooms by exterior doors. The porch would be sheltered by a broad PV canopy, and benches or tables would provide outdoor workspace for messy projects, such as painting, pottery, etc. This porch would provide shade and a noise buffer to the west-facing classroom windows while creating valuable covered outdoor space. Additionally, the presence of PV panels within sight, and potentially within reach, was viewed as a valuable educational opportunity. The porch's roof was viewed as an opportunity for visible, tangible water collection, as well, connecting students with rainwater collection and treatment procedures. The trade-offs to this approach included the maintenance needed for cleaning; the potential for vandalism or unauthorized use; and the permanence of the shading provided to the west windows. At the same time, participants believed that thoughtful design, again in cooperation with teaching and maintenance staff, could avoid most of these problems. For example, translucent materials could be used for parts of the canopy cover, and work surfaces could be chosen according to maintenance needs. Security was viewed as a more general issue for the school grounds and not unique to the back-porch idea.

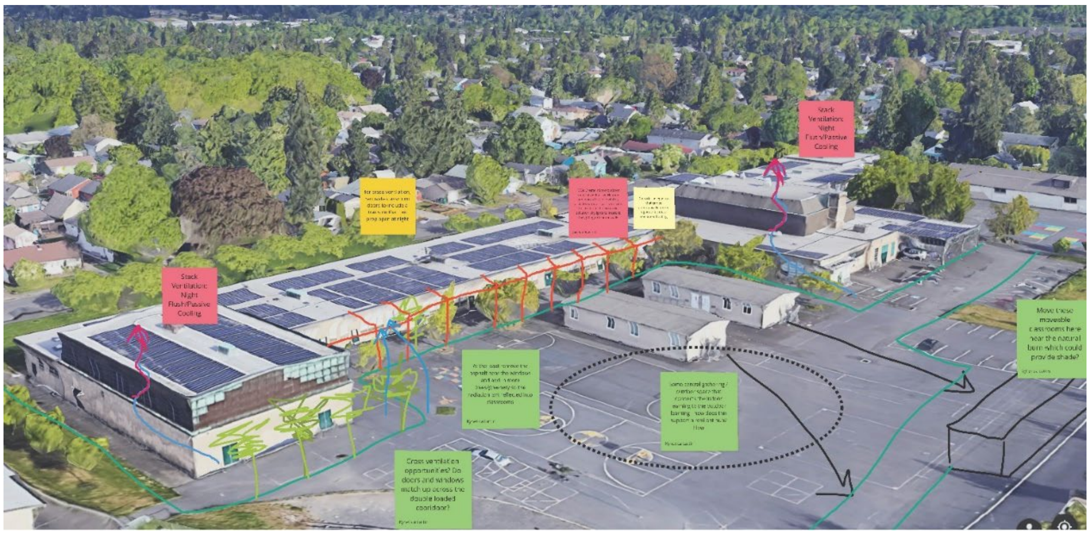


Figure 3-7 - Addition of sunspaces to the west-facing classrooms, providing opportunities for winter passive solar heating, summer shading, and an indoor-outdoor transitional space buffered from the noise and pollution of I-205.

PV shade structure or trellis. A related alternative was the use of a PV pavilion to provide fixed shading of the western classroom windows, possibly covering raised garden beds (See Figure C-6). Like the back-porch canopy, this pavilion would protect the classrooms from glare, allowing them to raise their blinds during the day. The utility of shaded, rain-sheltered garden beds, however, was debated, as these would require watering, though water collection from the pavilion would be possible. Still, some felt that shade-tolerant plants like rhododendrons could thrive in these conditions and provide an appealing green buffer between the classrooms and the playground. This discussion led to the simplest alternative, a trellis of deciduous vines along the west side to provide seasonal shading, possibly supporting intermittent PV panels. This option would again require maintenance, but it would provide passive cooling, a welcoming green buffer from glare, noise, and pollution, and an intermediate space between itself and the classrooms that could be used for play or projects.

East side

Pavilion. On the east side, participants saw the potential of a large pavilion to support the creation of a clear, welcoming, designated public gathering place for the community during recognized events (See Figure C-7). This pavilion would have the added benefit of sheltering students from rain as they arrived before school or waited for rides home, and as a result, the main school entry was viewed as the most promising location for this pavilion. Because this location has high solar exposure, it could be created from a combination of translucent materials to provide daylight, keeping the area underneath light and welcoming, and PV panels to provide electricity and partial shade. Participants also noted the potential for color and art to enliven this space, informed by the desires of neighborhood and school populations. Colorful wall tiling and floor mosaics, inspired by the local Spanish immersion school (See Figure C-8), were cited as precedents for such an effort (See Figure C-9).

Gardens and trees. Participants also viewed the addition of garden plots and trees on the east side as a design intervention that could support renewable energy goals effectively. Understanding how food is grown through direct experience, they said, was essential to students' understanding of global carbon and energy cycles, debates surrounding pesticide and fertilizer use, and the magnitude of energy used in the transportation and refrigeration of food. Participants recognized the problem of tending crops over the summer, and they recommended exploring partnerships with Community Supported Agriculture, Lents Green Ring, or other groups to accomplish this. For passive cooling, participants recommended tall deciduous trees with open structures, such as Oregon oak and big leaf maple, to shade the building's roof and hardscape in summer while admitting daylight and solar heat in winter. Shorter options to shade windows included Japanese cherry and Katsura. Additionally, participants felt that understanding climate and soil patterns, and their interactions with native trees and shrubs, was itself essential to education in ecology and the current mass extinction (Ceballos et al. 2015), which provide motivation for new commitments to renewable energy. To minimize irrigation needs on the site, participants recommended drought-tolerant species, many with edible leaves, bulbs, or fruit to provide food and habitat for wildlife (see Appendix C). Willows were also suggested, allowing students to make living woven willow walls and to harvest willow branches for crafts. Additionally, participants recommended lighting the trees at night through lights in trees themselves or abundant ground-level up-lighting, at low-to-moderate intensities and in warm colors, to provide both beauty and security. The Portland Winter Lights festival and the Willamette Light Brigade were cited as inspiring precedents (See Figure C-10).

Security. Because the school's east side is open to the neighborhood, participants noted the need for security. Trees and shrubs along this side and around the gathering area were viewed as desirable, but too much density near the ground could create hiding places for intruders. Permanent benches, likewise, were viewed as questionable: participants felt that schools have virtually zero tolerance for people on school grounds who are not conducting business associated with the school (or with a community event at the school), and that schools contrast strongly with parks, streets, and other public spaces in this regard. This was an important observation for designs that incorporate public amenities into schools and school grounds.

Integration with natural ventilation. Participants discussed the implications of the east- and west-side designs on natural ventilation at length, noting the need for internal airflow paths. Synthesizing the east-side arboretum, the west-side sunspaces or covered outdoor space, and interior airflow path-making, participants drew two sections to illustrate their thoughts (See Figure 3-8).

For additional background and design sketches for this site, see Appendix C.

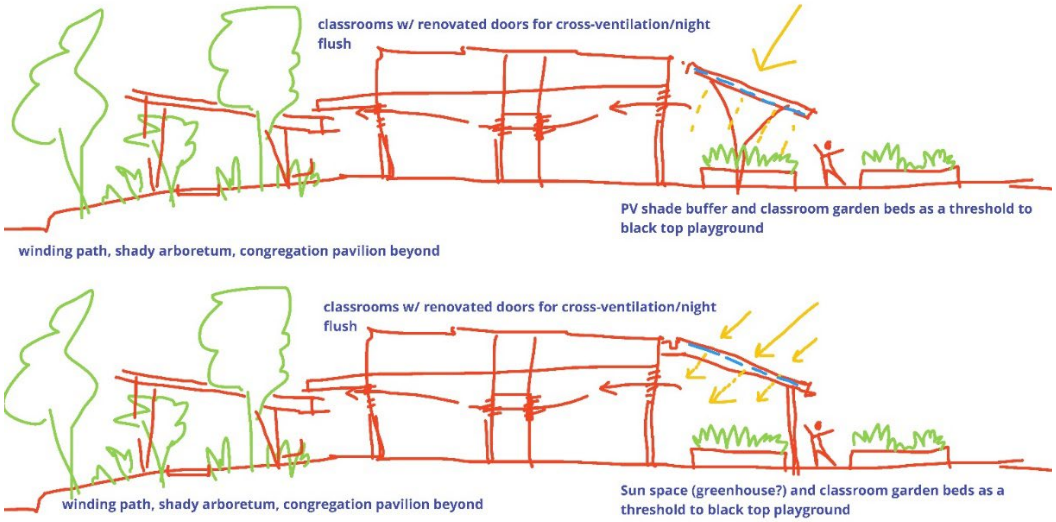


Figure 3-8 - East-west section illustrating west-side alternatives with the east-side arboretum and congregation pavilion. See Figure C-12 for a plan view.

3.2.2 Oliver P. Lent Elementary School: Discussion

The design approach for the elementary school highlights the significance of incorporating passive solar design strategies and local land uses to maximize synergies when implementing renewable energy solutions. With heatwaves becoming increasingly severe and frequent in the Pacific Northwest and beyond, this approach can be adapted to address comparable challenges in other urban areas.

Decentralization. Urban heat islands encompass entire cities, intensifying heatwaves and associated health risks. Sheltering residents from heat, however, can only be accomplished through decentralized means: shading of windows, rooftops, sidewalks, and streets; evapotranspiration from trees; and where the climate permits, extensive ventilation with cool night air. Such passive cooling strategies not only improve survivability but also reduce cooling loads, relieving grid stress and freeing renewable power for other uses. Workshop participants found numerous opportunities for passive cooling in and around the study building, complemented by opportunities for solar PV and wind turbines throughout the under-utilized study site: PV canopies could contribute to site shading, for example, especially over playgrounds, parking lots, and hardscaped gathering areas, while small wind turbines could intercept prevailing winds in several unobstructed areas.

Multifunctionality. In the exploration above, further opportunities for PV deployment emerged in the forms of play structure shelters and a noise-buffering wall along I-205, illustrating the strong connections participants found between the two themes: for greatest space economy and acceptance, distributed PV and wind power should be multifunctional to the extent possible, they advised. On the east side of the building, PV canopies sheltered a large welcoming entry pavilion in their designs, while on the west, PV panels were incorporated into the roofs of sunspaces and outdoor project spaces. Trees were viewed as multifunctional renewable energy technologies as well, providing not only shade (passive cooling) but habitat, educational opportunities in ecology and biodiversity, and beauty, particularly if well-lit by (solar- or wind-powered) night lights. Together, these explorations led to a larger-scale vision of the multifunctionality of the school itself, envisioned as a community resilience hub to provide cooling during heatwaves, power during power outages, and a place for gathering and events on the Lents Green Ring.

3.2.3 Klamath Falls: Design Concepts and Visualizations

A Canal

Participants produced four design concepts for the A Canal (See Figure 3-9). Participants explored section drawings for a representative cross section of the canal' lengths where it has the multi-modal path on the south embankment. The sections we designed would be translated into replicated modules that would abut each other to fully shade the water for all or portions of the canal. Participants chose to retain the path in all their designs and solve the four designs across some key tradeoffs. Further variations of these designs are possible.

Option 'A' (See Figure 3-9) synergizes with reducing flood risk by constructing a cutoff wall into the south embankment. Emergency flood incident access would therefore be much less frequent. It places the PV array close to the canal water level (at full flow) which would support more efficient energy production due to the cooling effects of the water. A more elaborate design might vary the height of the array with changes in water level. Option A provides maintenance access to the canal and the PV array by tilting it up from hinge assemblies affixed to the cutoff wall. A series of tower posts with path lights would be built all along the canal-PV system to house pulley cables for tilting up the modular PV arrays. These might be well designed to comprise a long, linear landmark feature along the canal that might compensate a bit for the loss of visible water as an aesthetic amenity for Klamath Falls. Each tower would have its own cable winch motor, or alternatively, a portable winch could be attached to the tower(s) where the PV array needs to be lifted. If needed, the existing security fence could be replaced with a plexiglass wall to reduce glare from the PV array into the eyes of early morning travelers on the path in the summer.

Option 'B' synergizes with reducing flood risk by constructing a cutoff wall into the south embankment. Emergency flood incident access would therefore be much less frequent. It places the PV array close to the canal water level (at full flow) which produces more efficient energy production due to the cooling effects of the water. Option B potentially solves the problem of variable water levels by avoiding the hinge design in Option A. It suspends the PV array from a structure across the canal that may be more expensive and uglier than that in Option A. This suspension system could allow the PV height to be adjusted to be just above the water more of the time at the likely cost of not fully shading the water when the canal is full. Guideposts into the embankment and not the chalk rock would stabilize the system during operations and in windy weather. The mounting of the structure on the north embankment would typically be in the subsoil above the chalk rock. The glare reducing security wall is again proposed.

Option 'C' synergizes with reducing flood risk by constructing a cutoff wall into the south embankment. Emergency flood incident access would therefore be much less frequent. The PV array is supported upon the roof of a structure well above the water so efficient electricity generation does not benefit from proximity to water. The PV roof is tilted to the south toward the sun path. A prime advantage of this design is that it provides year-around shelter from the sun, rain, and wind for users of the multi-modal path. Another advantage is that the PV arrays are stably installed, without challenging moving parts, easing PV maintenance access. Canal maintenance access would not require moving the arrays but would entail driving vehicles into the structure, which could require a higher roof than drawn. For maximum performance, Option C would require costly, continuous, at least partially translucent walls on both sides to block the wind and its evaporation inducing effects. This long, continuous shelter would become a major landmark feature in the Klamath Falls landscape and would need to be designed to be a beautiful asset. The glare-reducing security wall near the path would not be needed in Option C if the north wall of the shelter were designed to reduce glare onto the path. Glare impacts upon the surrounding city off the shelter walls and the PV roof array would need to be mitigated in a final design.

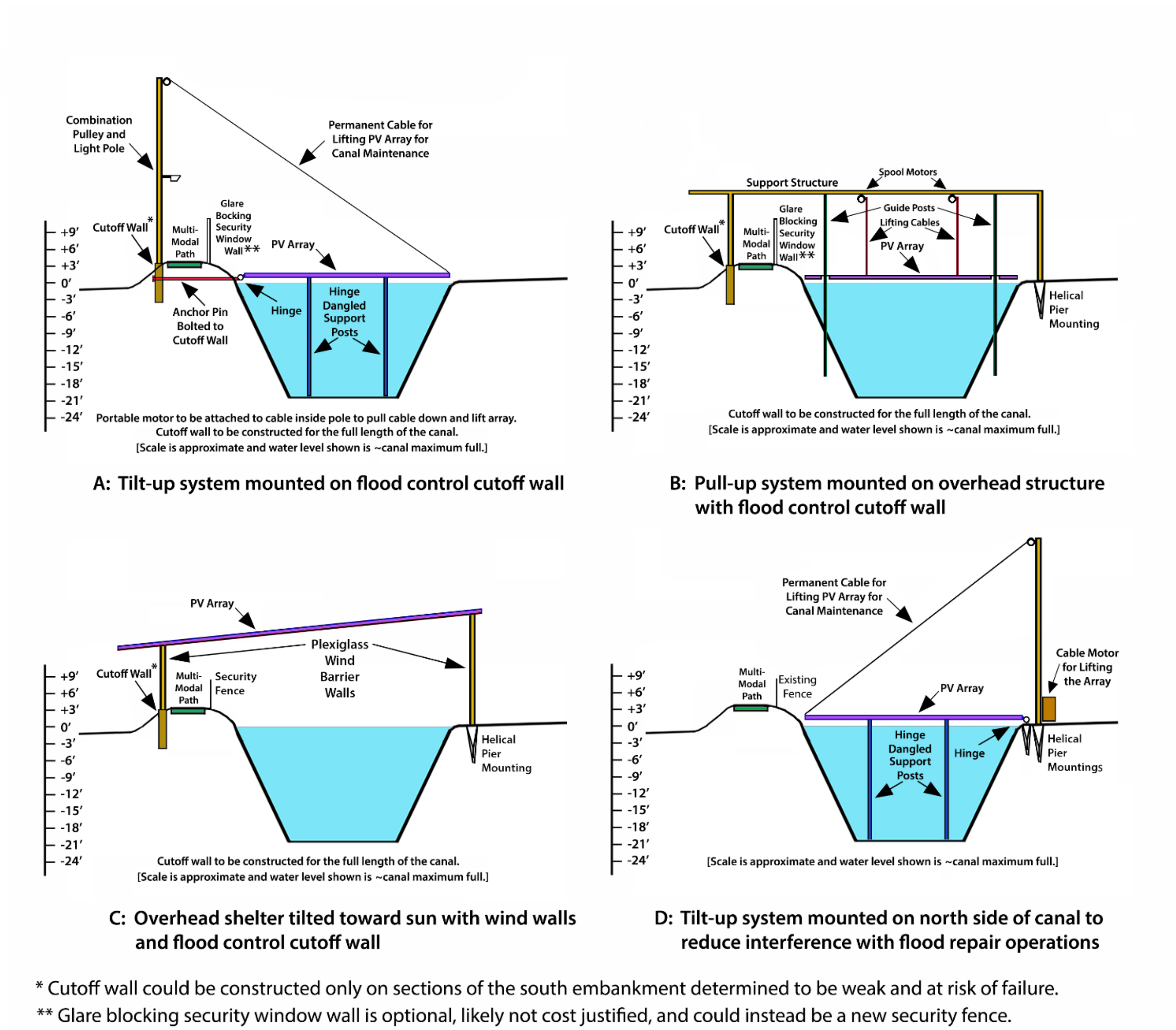


Figure 3-9 - Representative cross sections for modular component options for mounting solar arrays over K.I.D. 'A Canal'.

Option 'D' does not introduce a cutoff wall into the south embankment to reduce construction costs and therefore does not affect flood risks. It replicates Option A but with the tilt-up system mounted on the north embankment with the same advantages and tradeoffs. This design could enable emergency access to failures along the south embankment as they now occur but would require crews on the opposite bank to winch up required arrays to get them out of the way. This design would require KID crews, electrical operations crews, and construction crews to access the north embankment which is more problematic than the south side off the canal due to private property and structures near the canal in places.

C Canal

Participants came to one simple design option for the C Canal (See Figure 3-10). It has advantages in less costly scalable production of modules and simplicity of installation and maintenance. This canal has wide and level embankment tops with maintenance roads on the outer half of these. Abutting, modular PV arrays could simply be laid upon footings set into the embankment tops. These would have eye bolts at or surrounding each's center of gravity to enable a mobile crane to lift and set aside and replace for canal maintenance access. Each module would be supported by a substructure. Each would have a PV inverter and a readily removed and replaced electrical connection to an underground conduit under a maintenance road. The scale and detail of these modules would obviously have to be refined by engineers. The height of the PV array would be fixed so electric generation efficiency would vary as the height of water varies below the array. The water height may be more stable at major feeder canals, like the C Canal, than at canals further out the 'tree' of progressively smaller canals.

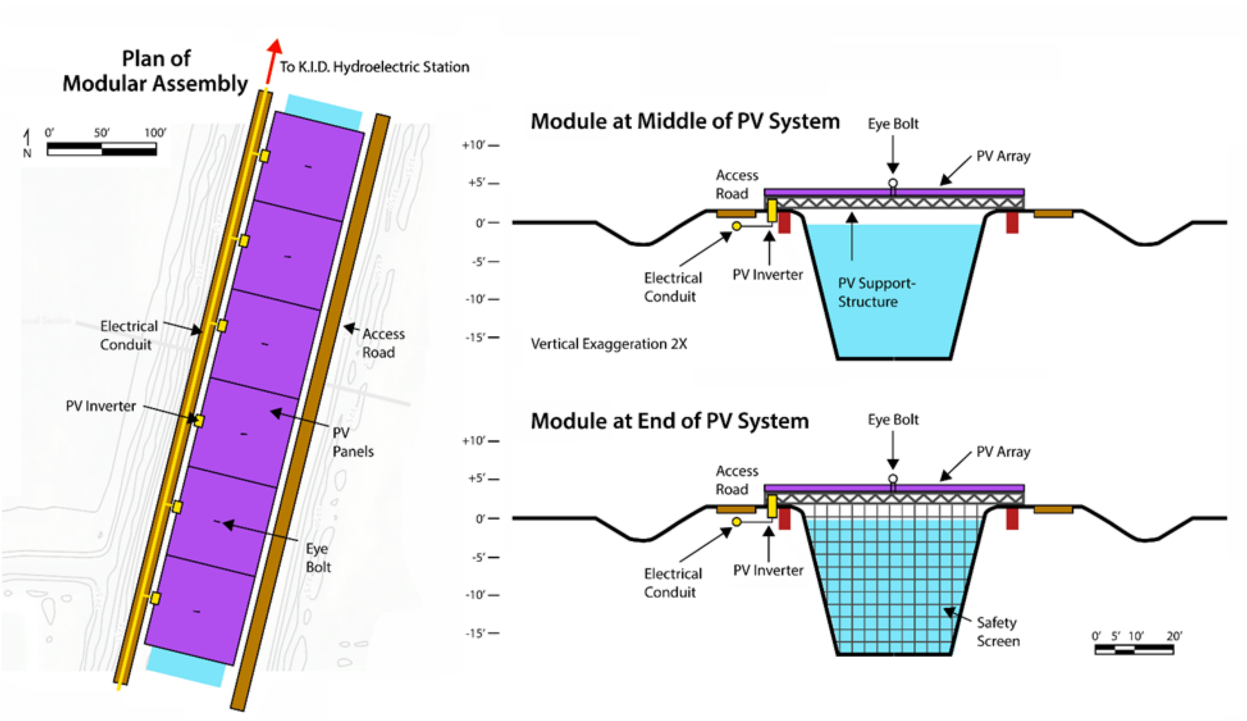


Figure 3-10 - Plan and cross section of typical modules for mounting solar arrays over K.I.D. 'C Canal'.

The C Canal design concept would probably have to be secure from public access for safety and prevention of damage to the PV arrays. There would probably be a need to prevent human or wildlife access to the space under the arrays. The proposed solution would be to affix a security screen to the end-point modules as illustrated in the bottom section.

3.2.4 Klamath Falls: Discussion

Generating Local Value: Agriculture is a major economic activity in the Klamath Basin. Delivering more, and more stable, water supplies to the farmers would add local economic value. The irrigation districts would benefit by greater income and lower canal maintenance costs due to reduced biotic activity in the water. The cost of electricity to the Klamath Irrigation

District could be significantly reduced over time by a length of PV over their A or C Canal, adding further local value to the farmers. If PV over canals in the Klamath Basin were scaled up considerably, they could generate a local power supply, transfer ownership, and distribution of new energy supplies to local farmers, communities, and irrigation districts. This electricity could be distributed at reduced cost to users who local authorities find to be at greater need. More electricity from locally owned and operated PV over canal projects would reduce this dependence on centralized decisions by Federal agencies. If irrigation districts could conserve more water due to PV over canals, this dependence on centralized authorities would be marginally reduced. Lastly, the stable water and energy supplies would help the community's economy to adapt to droughts and other challenges driven by climate change in a long term.

Natural Capital: The tail end of many of the Klamath Basin irrigation systems drain to wetlands and national wildlife refuges. Some of these are now either often dry or substantially reduced in extent. PV over canals should conserve water across these systems to enable more water to reach these habitats that support diverse wildlife and birds along the Pacific Flyway. The water quality that reaches these habitats is now adversely impacted by the algae and other biotic activity in the canals and the irrigation districts and farming communities are under pressure to make improvements. Large scale PV over canals could significantly reduce much of this biotic activity, and lower water temperatures (if placed over drainage canals to the wetlands), to benefit the ecosystem services provided to the wetlands.

The PV canal design exploration can be extended to other rural communities that face frequent and severe droughts.

3.2.5 Coast Salish Cultural and Natural Heritage Center: Design Concepts and Visualizations

Design concepts addressing resiliency and energy justice emphasized energy development and sensory experience particularly from the perceived perspective of Lummi values. These design explorations were considered separately and integrated. Design visualization with the site was limited, which may have been the result of the site being considered abstract and physically distant and unexperienced by the designers, noted that it will likely not be the actual site of the Heritage Center or because of the relatively short time to process the importance emphasized by Lummi stakeholders to need to build from the Lummi perspective on life. Compared to other breakout sessions, this group seemed to largely wrestle with the conceptual integration of energy and experience rather than detailed design of the site.

One of the design solutions was a rich integration of eleven diagrams including orca habitat, multi-generational thinking and tribal food supply, passive and geothermal heat systems, and tidal energy production, positioned around an existing satellite view of the site. The selection of diagrams were accompanied by the author's text about multi-generational thought via virtual reality, tidal and wind energy, and sensory experience including, "The sounds from nature, the scents of the plants/water, and the taste of local traditional food. Consider an immersive experience in the water from killer whale/salmon." This broadly holistic approach to design that considers participatory design emphasizes types, referencing existing diagrams and knowledge systems, rather than fundamental design either in new diagrams or in first spatial moves on the site.

Another design solution represented a more fundamental approach that emphasized the use of a background 3D Google Earth bird's eye view of the site with building placement and a sectional drawing from water to forest. The design presentation was centered around Site

Considerations strategies surrounded by the aforementioned 3D view, plan, photo of Coast Salish Institute longhouse as structure example, zoomed in photo of habitat bench for salmon and photo of PV panels with inquiry to location on the longhouse or elsewhere. The ideas were labeled over the 3D design drawing, “Distributed education/experience/empathy landscape” suggested an integration of stakeholder values, energy and the project as a tool to change people’s understanding through education.

For example, one design incorporated ideas of wind, tidal, and marine energy with traditional food production and multi-species concerns such as how energy production and food production impact orcas. Through this design, the participant emphasized multi-sensory experiences for human users and visitors to the site (See Figure 3-11). Another participant built on the concept of multi-sensory experiences with more specific design concepts, including an elevated viewing platform to allow for views across the land, the longhouse, and to the water (See Figure 3-12**)**. A viewing platform located offshore allows for water-based experiences of the site and a view of the longhouse from the water. These design elements encourage interactions within non-human animals such as birds, orcas, and fish, as well as the natural elements of air, water, and land.

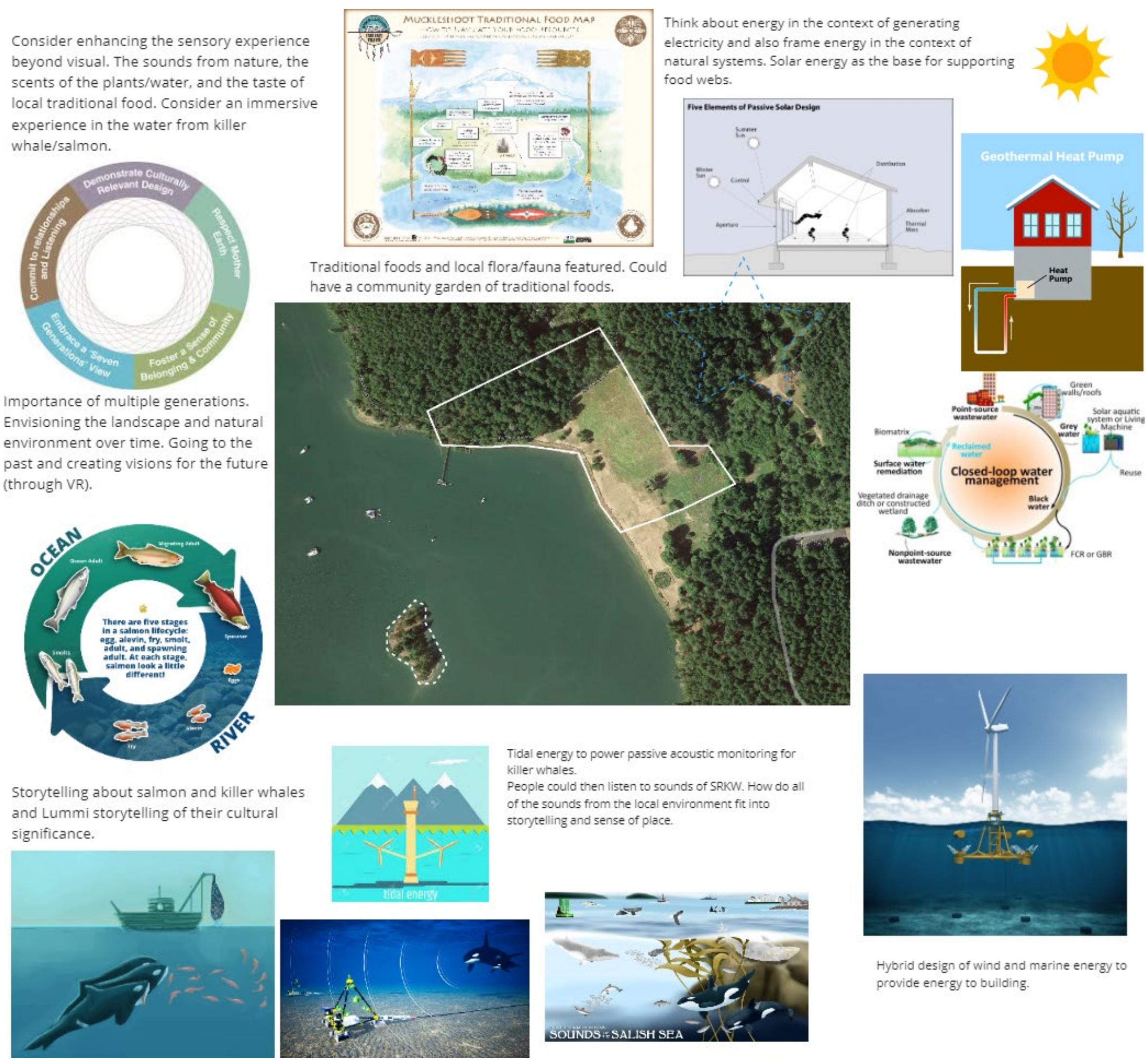
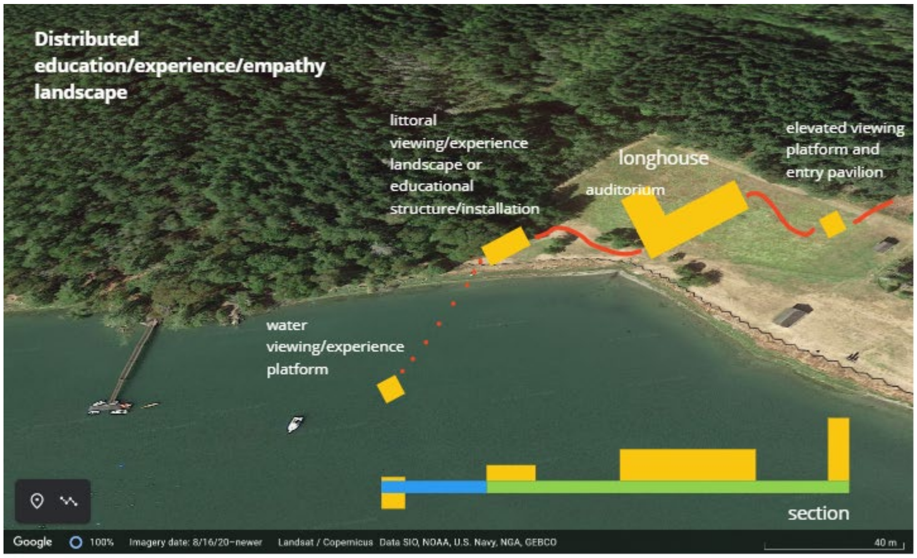


Figure 3-11 - Incorporation of wind, tidal, and marine electricity production with traditional food production and multi-species concerns.




PV panels on longhouse roof or elsewhere?


habitat bench (tidal shelves for salmon) along shoreline? [as in Olympic Sculpture Park, Seattle]

siting considerations:
-longhouse (L-shape) with doors at either end of main axis with potential auditorium on the small part of the L
-siting for communication over distance and strategic concealment
-sustainable solar and water integration
-want to site the building as part of a broader storytelling network / landscape that is more distributed, facilitates key views and interactions with the water to support empathy-based narratives


Coast Salish Institute longhouse as structure example

Justin Fowler

Figure 3-12 - Design concepts included an elevated viewing platform to allow for views across the land, the longhouse, and to the water to encourage interactions within non-human animals such as birds, orcas and fish, as well as the natural elements of air.

3.2.6 Coast Salish Cultural and Natural Heritage Center: Discussion

Issues of energy justice and renewable energy landscapes are closely tied to concerns of cultural sovereignty in many tribal communities across the United States. By involving local communities, Indigenous nations, national and state funding from the U.S., and private equity, this approach, which incorporates traditional tribal knowledge into the design process, can promote equitable and just coexistence with greater community resilience.

Energy Justice. Tribal energy justice must include recognition of tribal self-determination and support of cultural resurgence in impacted communities. Exercises to build empathy, such as this session's focus on listening and acknowledging, are one important method for recognizing tribal priorities in design processes. In addition to the need to develop empathy among tribal and non-tribal partners, energy justice requires incorporating tribal ancestral knowledge into design processes. This sort of approach requires meaningful partnership with tribal project leaders and designers, which in turn necessitates participatory design processes. Techniques for generating design ideas beyond the media skills required of professional designers are also important in an integrated design process that supports tribal energy justice.

Resilience: The discussion among participants in this group illuminated synergies between Indigenous values and approaches to nature and renewable energy goals. For instance, while Indigenous worldviews vary widely among various tribal communities and nations, there is broad understanding across tribal traditions of a world made of deep interconnectedness and interrelatedness. Renewable energy landscape design seeks to embed renewable energy development within specific contexts of place, people, and natural environment. The heritage center case study raised the example of interconnectedness between water resources for energy development, resident killer whales of the region surrounding the San Juan Islands, Pacific salmon, and the extensive systems of hydropower dams throughout the Columbia River Basin.

4.0 Addressing Landscape Challenges

As the workshop processes and outcomes indicate, landscape-level challenges related to energy infrastructure deployment and the mechanisms to address them are vast; as the build-out of technology continues, those challenges and mechanisms are likely to evolve. Synthesizing and abstracting from the co-creation process utilized in both workshops and the contributions from participants, the authors of this report developed principles to support holistic landscape and design processes in siting and deploying renewable energy infrastructure.

These principles are meant to foster increased siting opportunities for infrastructure in ways that meet multiple objectives, shifting away from incremental innovation to more transformative approaches in the energy transition. They are not intended to be prescriptive but rather to lay a conceptual foundation for expanding the role of design in energy infrastructure.

To that end, the following principles are proposed as guidelines:

1. *There is material value in viewing energy projects as landscape projects. Inter-scalar connections can be derived from a generalist landscape perspective in combination with a diverse group of technical experts.* Landscape architecture has strong roots in suitability mapping with overlays of various considerations stretching across environmental and social sciences. Their generalist perspective crosses disciplines and provides a broad design perspective for problem solving and communication that looks across scales and coordinates specializations to be distilled and shared with a variety of audiences. Conceptualizations with graphic presentations provide a discussion medium that can be shared and evaluated among consultants and community members to facilitate work toward acceptable compromises and consensus.

2. *Supporting local identity can be achieved by improving landscapes through renewable energy development "packages" that provide more than infrastructure solely intended for electricity production.* Renewable energy design should not solely be viewed and considered as a fence around solar panels, but rather those modules can be packaged with other landscape features. Ecological functions involving water harvesting, native plant materials, and other appropriate landscape improvements should become synonymous with renewable energy development to aid in a more socially acceptable approval process with synergized benefits for improving degraded or neglected sites.

3. *Deploying a variety of technologies, particularly at a finer scale, can diversify energy portfolios while supporting improved aesthetics and well-being of communities.* Monocultural land use tends to have poor overall performance and lacks aesthetic interest. This type of development is often met with resistance as the broad diversity of the landscapes is downgraded to a more literal definition of the space. For example, a variety of configurations for solar PV can be integrated into the urban, suburban, and periurban characters of places. However, the diversity in regions and landscapes offer other opportunities for renewable energy technologies that can capitalize on and reflect the characteristics of the place but be implemented to enhance or restore the already disturbed areas toward a net improvement across the landscape.

4. *Landscape performance metrics for renewable energy development must reach beyond energy optimization.* Renewable energy optimization must find compromises in energy performance in combination with other criteria that bring value to a community and landscape. Orientations and angles must harmonize with other site and contextual forms

for sometimes underappreciated aesthetic performance, which in turn has benefits that ease concerns and resistance. Approachability through education and understanding gives transparency to the benefits and trade-offs and can foster local innovation toward more robust renewable energy solutions.

5. *A participatory design process can serve as a powerful tool to promote energy justice by amplifying the voices of communities.* Renewable energy landscapes are closely intertwined with the issue of cultural sovereignty, particularly for tribal communities across the nation. By forging meaningful partnerships with tribal project leaders and designers, a co-design process that involves empathy-building through active listening and acknowledgement can help incorporate traditional tribal knowledge and wisdom into the design process, leading to a more just and equitable development of renewable energy.

6. *Avoidance is as important as multi-objective siting for renewable energy in a place-based approach.* Connecting generation technologies to energy and landscape conservation is critical to the sustainability of renewable resources. Passive landscape solutions, such as using trees to shade buildings and pavements, should be prioritized to reduce energy demands in conjunction with onsite generation technologies. These actions demonstrate a fuller understanding of a particular community or place beyond energy production: can energy producers take a more active role in conservation? Expanding demonstrated understanding of other local land uses and socio-ecological systems should include the identification of landscapes that must be avoided when considering renewable energy development. This may contribute to bringing peace of mind to community members and mitigate against hard lines of opposition in communications.

5.0 Conclusion: Moving from Theory to Practice

Increased alignment across disciplines will be necessary to support place-based and at-scale renewable energy deployment across the country. Categorizing the lessons learned from the workshops, the authors of this report outlined a series of considerations to advance the idea of designing renewable energy landscapes from theory into practice. These practical considerations are not derived from the theoretical principles in Section 4.0. Instead, the considerations complement the principles by focusing on tangible opportunities and challenges for landscape architects and design professionals to expand their role in energy infrastructure deployment. This includes:

1. *Planning for future collaboration and implementation with a broader set of stakeholders:* Community stakeholders, landscape architects, and energy professionals all said they left the workshops with a better understanding of one another's capabilities, excited to consider future collaboration for project implementation as well as research in this space. A shared perspective was developed over the course of the events: integrated renewable energy design that respects community needs and approaches infrastructure deployment in a holistic way can provide greater public good beyond maximizing energy output. Early engagement with designers on energy planning, education and transparency of technology requirements and associated data, and more engagement with researchers and manufacturers along the supply chain will help maximize community value.

2. *Understanding the challenge but facing knowledge and data gaps*: Designers understand the conceptual challenge of energy landscapes, but potential knowledge gaps appear to hinder greater synthesis and creativity beyond the popular and familiar solutions (i.e., solar energy and opportunities for multifunctionality through vertical layering). In particular, incomplete understanding of technologies and the opportunities and constraints that exist for deploying them limit discussion around their strategic implementation, particularly with less familiar and emerging technologies. Conversely, energy professionals recognize the challenges with siting that lay ahead but have not traditionally been exposed to design professionals who can help address them.

3. *Reconciling landscape-level and site-specific scales:* Better aligning the comprehensive approach and landscape-level thinking of landscape architects with energy decisions can produce enhanced place-based solutions. Carbon reduction/sequestration, life-cycle costs/benefits, urban heat island reduction, ecosystem function, and social equity are all part of landscape architects' everyday vocabulary. However, the positioning of site-scaled work and often being constrained as sub-consultants under tight budgets can limit landscape architect's overall influence in this space. Several landscape architect participants issued a call to action to one another to question the workshop pathways within the realm of their individual influence, regardless of scale, and to seek out community positions to work towards broader local improvements.

4. *Parallels and connections to water*: There seems to be strong parallels and opportunities to align design approaches between energy and water infrastructure. Landscape architects have particular strengths in stormwater management (i.e., green infrastructure) and water conservation (e.g., using native plant materials and irrigation efficiencies) and can apply those lines of thinking to energy systems. Workshop participants suggested that this could include avoiding undisturbed lands for the sake of hydrology, erosion, and aquifers; reducing evaporation with agrivoltaics, infrastructure

over canals, and floatovoltaics; avoiding steam-based turbines; and utilizing micro-hydro on existing water infrastructure and synergizing with efforts of water harvesting. At a larger scale, energy networks can parallel, and possibly align with, watershed networks and sub-watersheds to create a balance between top down and bottom-up influences.

5. *Deriving value from landscape architecture and design in the energy transition.* The design-focused format of the Pacific Northwest Workshop was new to most community stakeholder participants. At the end of the workshop, these participants shared that they see real potential for landscape architecture and design to help support communities in building their vision for the future. The topic of renewable energy is also new to many landscape architects (e.g., the most recent 5-year American Society of Landscape Architects' Climate Action Plan[1] does not explicitly mention renewable energy), particularly when thinking about at-scale deployment as participants were asked to do in the Southwest Workshop. Overall, the workshops were mutual eye-opening experiences that brought together often siloed disciplines to begin more integrative work in the short- and long-terms.

By continuing to bring together experts across disciplines and individuals from diverse sets of communities, the potential for supporting more meaningful infrastructure deployment becomes possible.

The workshop outcomes, principles, and practical considerations reflect the current state of innovation in designing renewable energy landscapes. Collective understanding, as established through the events, is largely focused on the practical—what is feasible in this moment—rather than pushing the boundaries on what might be possible. Achieving that next step requires that we first catch up to existing innovation in implementation and design since it is not yet commonplace. These workshops served as the first step in reimagining the potential of energy infrastructure across landscapes.

[1] For more information, see: https://www.asla.org/climateactionplan.aspx.

6.0 References

Ceballos, G., P. R. Ehrlich, A. D. Barnosky, A. García, R. M. Pringle, and T. M. Palmer. 2015. "Accelerated Modern Human-Induced Species Losses: Entering the Sixth Mass Extinction." *Science Advances* 1 (5): e1400253. https://doi.org/doi:10.1126/sciadv.1400253.

Conserve Energy Future. n.d. "Chaparral Biome: Location, Climate, Temperature, Soil, Plants and Animals." Accessed November 15, 2022. https://www.conserve-energy-future.com/chaparral-biome.php.

Dimond, K., W. Glockner, and K. Planinac. 2023. "Re in the Sw: Place Based and at-Scale Renewable Energy in the Southwest " Southwest Regional Virtual Workshop, 9 January 2023. https://www.pnnl.gov/sites/default/files/media/file/University%20of%20Arizona%20Design%20Brief.pdf.

High Plains Gardening. 2019. "Wind on the Plains." Accessed November 15, 2022. http://www.highplainsgardening.com/wind-plains.

Ko, Y., A. Rempel, B. Meier, I. L. Buson, P. Speranza, R. Ribe, and Y. Yu. 2023. "Designing Place-Based Renewable Energy Infrastructure: Exploring Opportunities and Challenges for the Pacific Northwest Region." U.S. Pacific Northwest Regional Workshop. https://www.pnnl.gov/sites/default/files/media/file/University%20of%20Oregon%20Design%20Brief.pdf.

Lozano-Carver, J. 2022. "Why the Texas Grid Causes the High Plains to Turn Off Its Wind Turbines." Accessed November 15, 2022. https://www.texastribune.org/2022/08/02/texas-high-plains-wind-energy/.

Mackun, P. J. 2019. "Fast Growth in the Desert Southwest Continues." Last Modified October 8, 2021. Accessed November 15, 2022. https://www.census.gov/library/stories/2019/02/fast-growth-in-desert-southwest-continues.html.

National Centers for Environmental Information (NCEI). 2023. "Past Weather: Portland Or." National Oceanic and Atmospheric Administration (NOAA). Accessed April 17, 2023. https://www.ncei.noaa.gov/access/past-weather/Portland%20OR.

NOAA Office for Coastal Management. 2018. "California Coastal Demographics." Accessed November 15, 2022. https://coast.noaa.gov/states/california.html.

O'Neil, R., D. Preziuso, K. Arkema, Y. Ko, N. Pevzner, K. Dimond, S. Gore, K. Morrice, C. Henderson, and D. Powell. 2022. *Renewable Energy Landscapes: Designing Place-Based Infrastructure for Scale.* Pacific Northwest National Laboratory. https://www.pnnl.gov/sites/default/files/media/file/Renewable%20Energy%20Landscapes%20White%20Paper%20-%20PNNL-32680_0.pdf.

Reker, S., J. Schneider, and C. Gerhards. 2022. "Integration of Vertical Solar Power Plants into a Future German Energy System." *Smart Energy* 7: 100083. https://doi.org/10.1016/j.segy.2022.100083.

Rempel, A. R., J. Danis, A. W. Rempel, M. Fowler, and S. Mishra. 2022. "Improving the Passive Survivability of Residential Buildings During Extreme Heat Events in the Pacific Northwest." *Applied Energy* 321: 119323. https://doi.org/10.1016/j.apenergy.2022.119323.

Sailor, D. J., A. Baniassadi, C. R. O'Lenick, and O. V. Wilhelmi. 2019. "The Growing Threat of Heat Disasters." *Environmental Research Letters* 14 (5): 054006. https://doi.org/10.1088/1748-9326/ab0bb9.

U.S. Geologic Survey. 2010. “Usgs High Plains Aquifer Wlms.” Last Modified February 4, 2014. https://ne.water.usgs.gov/ogw/hpwlms/physsett.html.

University of California Museum of Paleontology. 2007. “The Desert Biome.” Accessed November 15, 2022. https://ucmp.berkeley.edu/exhibits/biomes/deserts.php.

Appendix A Workshop Registrants

Table A-1 - Participant Backgrounds at the Southwest Workshop

State of Residency		
Arizona	42	45%
California	22	24%
Utah	7	8%
Nevada	4	4%
New Mexico	4	4%
Texas	4	4%
Other/No Response	10	11%

Profession/Field/Industry		
Landscape Architecture	49	53%
Architecture	18	19%
Sustainability	7	8%
Engineering	4	4%
Other/No Response	12	13%

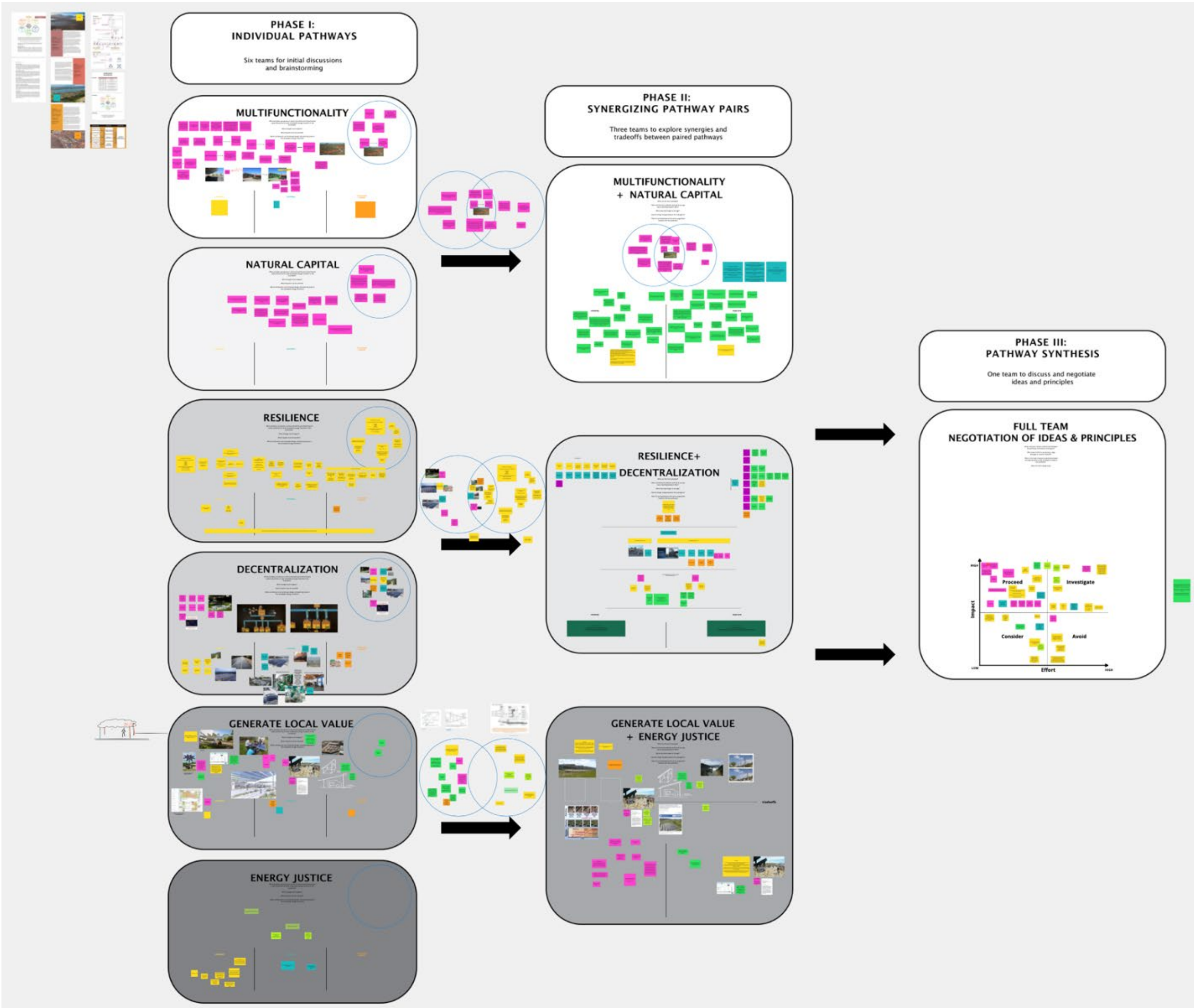
Indicated Pathway of Primary Interest		
Multifunctionality	30	32%
Resilience to Climate Disruption	27	29%
Generating Local Value	17	18%
Energy Justice	11	12%
Decentralization	9	10%
Natural Capital	3	3%

Table A-2 - Participant affiliation at the Pacific Northwest Workshop.

Affiliation	Participants
Akana	Jason Wells
ASLA	Samantha Patterson
Cameron McCarthy	Alexis Griffin, Colin McArthur
City of Eugene	Ted Shriro
City of Salem Planning Commission	Michael Slater
Community Renewable Energy Association	Mike McArthur
COurban	Katherine Scherrer
CSW | ST2 and Vallier Design Associates, Inc.	Marcia Vallier
Deep Blue Pacific Wind	Katie Morrice
Depave	Katya Reyna
Design Workshop	Aaron Lee Woolverton
dwg.	Daniel Woodroffe
ECO-System Solutions	Ian Appow
Esi	Norhan bayomi
Exeltech Consulting Inc.	Jasmine Aryana, Jon Chalfant
Farmers Conservation Alliance	Keith Kueny
GGLO	Marieke Lacasse, Nicholas Zurlini
Green Lents	Dasha Foerster
Greenworks	Dylan Anslow, Jigisha Modi, Rebecca Shepard
Hord Coplan Macht	Heather Tietz
Individual / Walker Macy	Alison Grover
Klamath Drainage District (KDD)	Scott White
Klamath Irrigation District	Gene Souza
Land Meets Water	Tristan Fields
Middlesex County Office of Planning	Nicholas Tufaro
MIT Environmental Solutions Initiative	Briana Meier, John E. Fernandez
ODOT	Oregon Dept of Transportation
Opsis Architecture	Kyhetica, Lattin
Oregon Country Fair	Sierra McComas
Otten and Associates	Lupin Hipp
Pacific Northwest National Laboratory	Danielle Preziuso, Jed Jorgensen
Parametrix	Jens Swenson

Affiliation	Participants
Rowell Brokaw Architects	Serena Lim
Seattle Public Schools	Kathy Johnson
Se'Si'Le	Kurt Russo, Jay Julius, John Vechey
Spinnaker Group LLC	Jonathan Burgess
Studio.e Architecture	Jocelyn Reynolds
TaiAo Landscape	Bhagyashri
U.S. Department of Energy, Water Power Technologies Office	Simon Gore
University of Oregon	Justin Fowler, McClean Gonzalez, Sara Loquist
University of Pennsylvania	Nicholas Pevzner
University of Regensburg	Liwen Li
University of Washington	Catherine De Almeida
VRLA	Vaughn Rinner
Weber Thompson	Shoshanah Haberman
-	Alison Reddy Abel

Appendix B Southwest Workshop Conceptboards



To view the details of the board, login as a guest at https://capla.conceptboard.com/board/f4bs-ta0m-bsz5-a65d-fx6x.

Figure B-1 – Snapshot of the full Southwest Workshop Conceptboard.

Appendix C Pacific Northwest Workshop: Background and Design Sketches for Oliver P. Lent Elementary School

Recommended landscape plants for the elementary school included white oak (acorns); nootka rose (rosehips), filbert (nuts), goldenrod (seeds), fireweed (seeds), flowering red currant (berries), snowberry (berries), madrone trees (berries), ponderosa pine (pine nuts), yampah (root), camas (bulb), serviceberry, trailing blackberry, bear berry, checkermallow (leaves and flowers), and tarweed (seeds).

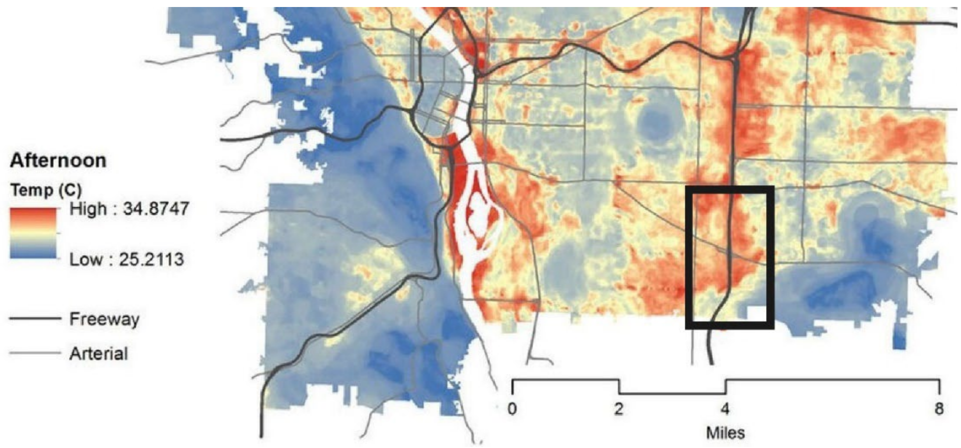


Figure C-1 - Portland urban heat island effects affecting the Lents neighborhood (black box). Adapted from (Antonopoulos et al. 2019) under Creative Commons license CC BY 4.0.

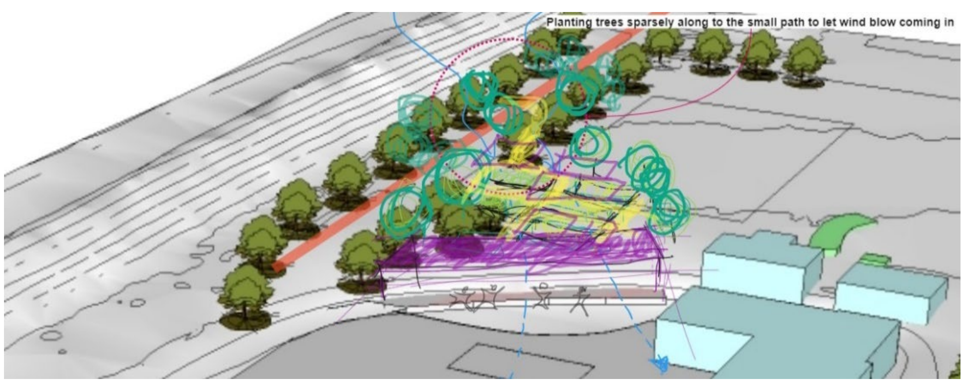


Figure C-2 - An example of an air quality forest. Trees are planted in a manner that aligns with the wind direction, allowing them to filter the air as it enters the site. The school amphitheater has been retrofitted with a PV pavilion to provide shade while generating renewable energy.

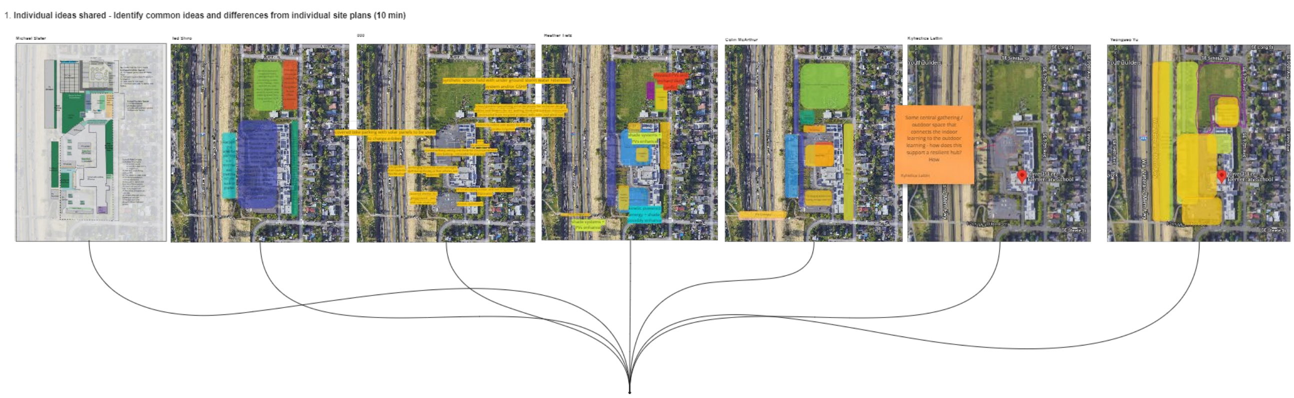


Figure C-3 - Design sketches across the elementary school.

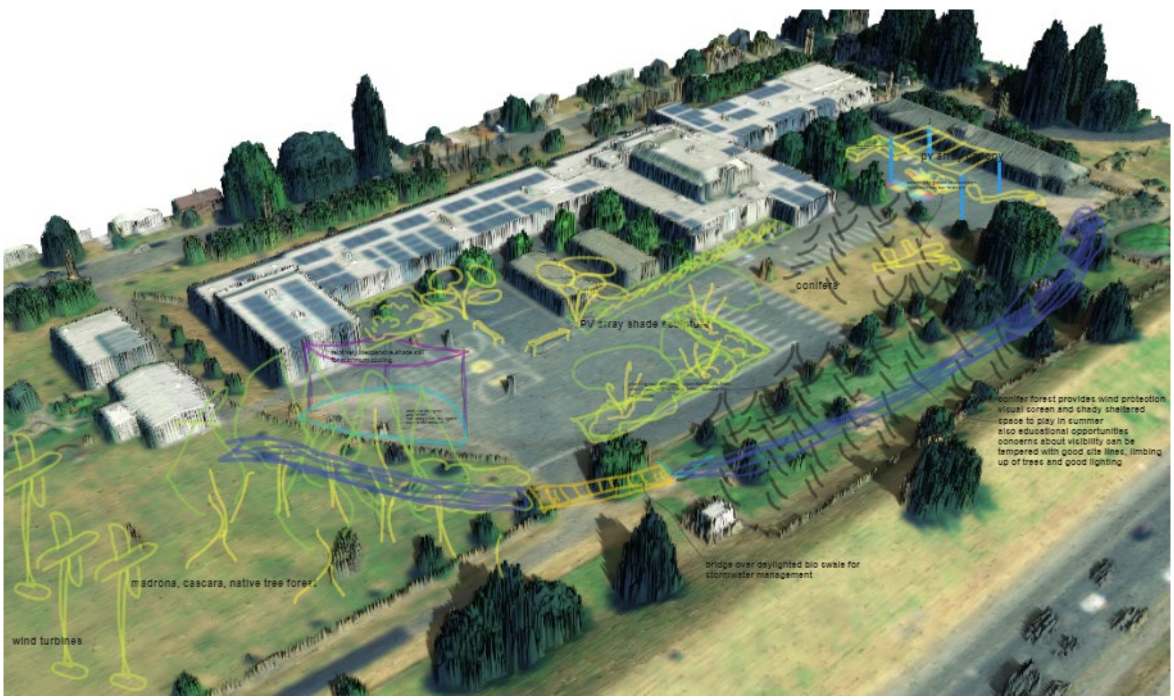


Figure C-4 - Integrated landscape master plan drawing.

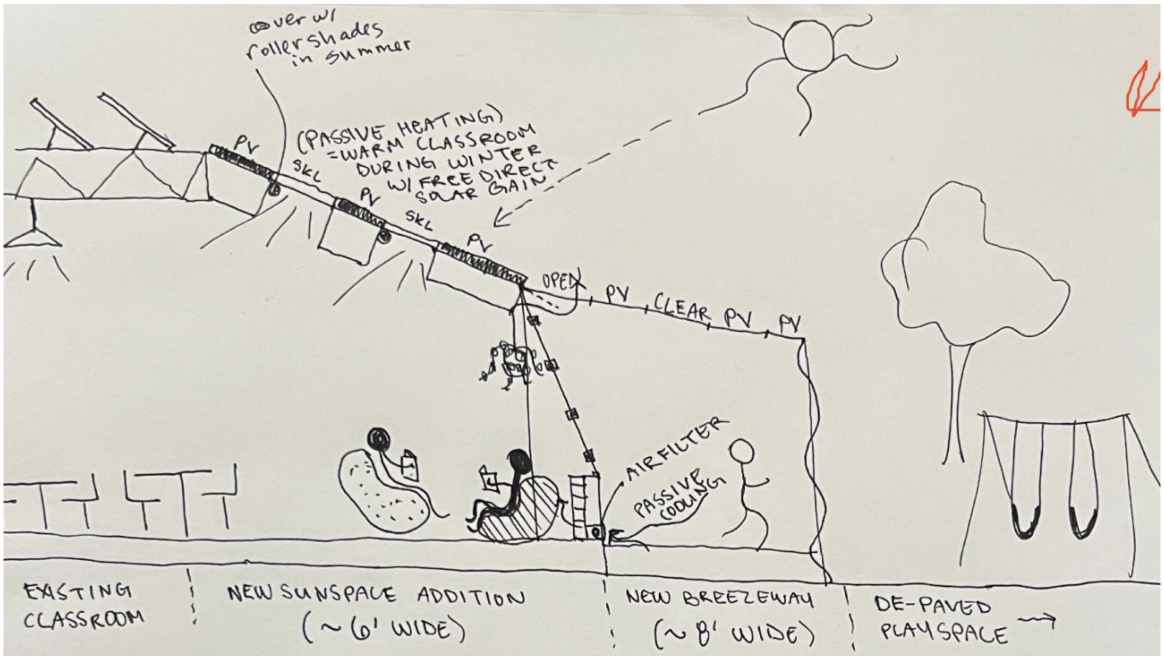


Figure C-5 - Sunspaces viewed in east-west section, showing the alternation of PV panels with skylights (SKL) to allow abundant daylight without creating excessive glare, combined with shading devices for summer use. Exterior to the sunspace is a new breezeway adjacent to the playground, de-paved of most asphalt.

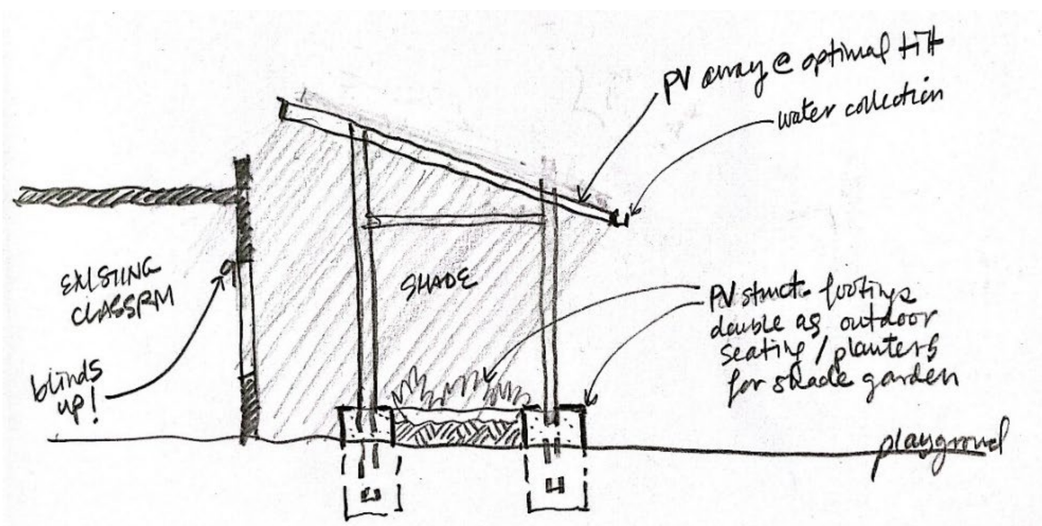


Figure C-6 - Free-standing photovoltaic structure with water collection, providing shade to garden beds and the west-facing classroom beyond.

Figure C-7 - Congregation pavilion, forming a clear, welcoming, designated space in which neighborhood and community members could gather during events (including heat emergencies) and from which they could enter the building. Participants hesitated to define the pavilion further without community input, given its potential cultural significance to the school and to the neighborhood.

Figure C-8 - Mosaic path, play sculpture, and educational signage explaining native plants envisioned to create a more welcoming, occupiable space for students.

Figure C-9 - Colorful mosaic tiling such as that used in the design of a Portland-area Spanish immersion school.

Figure C-10 - Tree lighting precedents, providing safety and beauty without high intensity and glare. Participants noted that many fewer lights would be effective, and that they could provide a use for some of the site's PV power that would delight the neighborhood.

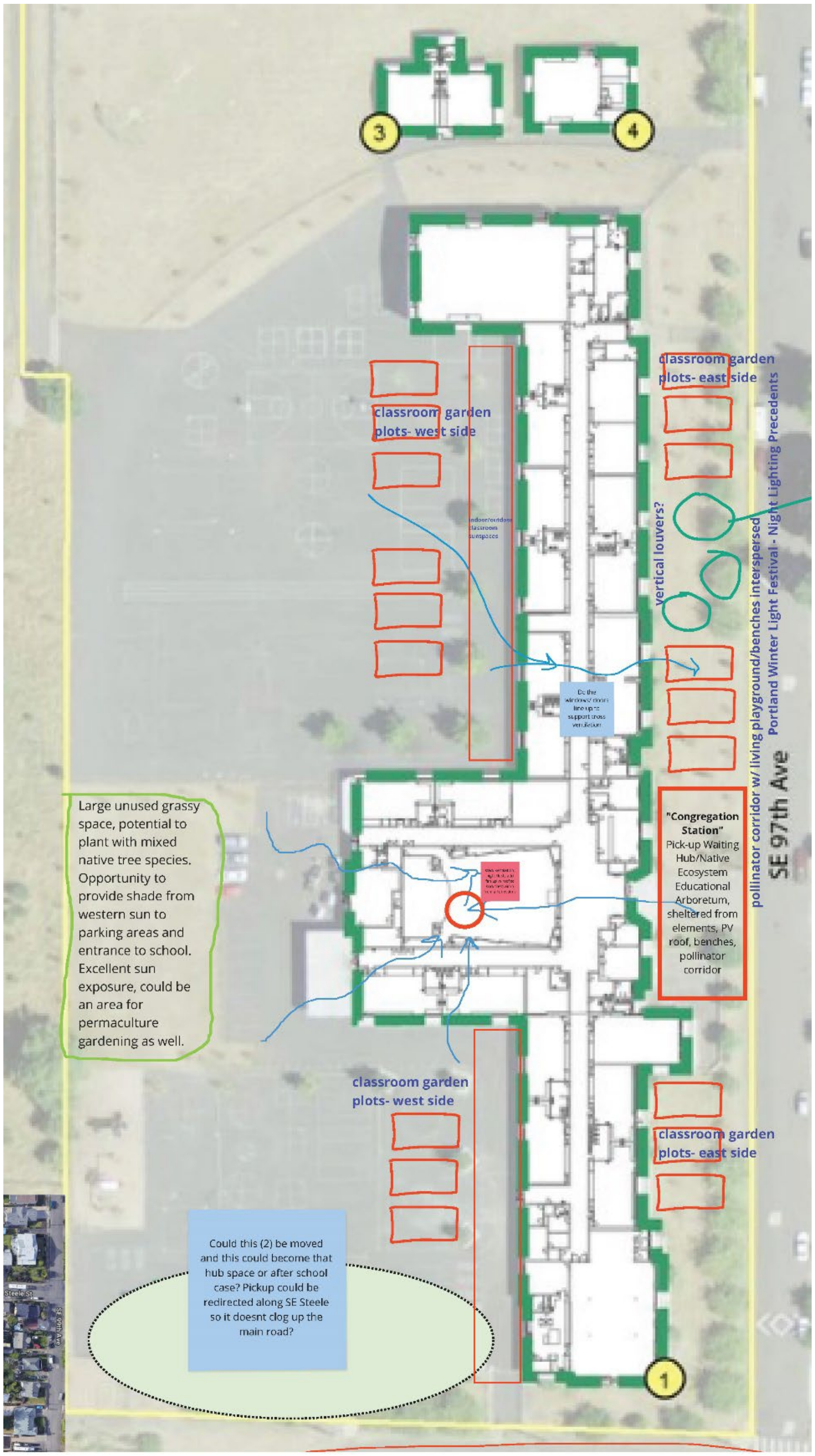


Figure C-11 - Composite plan, illustrating the congregation pavilion on the east side, accompanied by classroom garden plots and native plantings, as well as transitional indoor-outdoor spaces on the west side to provide covered outdoor space, shade, and protection from noise and pollution from I-205.

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