Designing Multi-Benefit Transmission Corridors Workshop

Post-Workshop Report

Northeast / Mid-Atlantic Region
University of Pennsylvania
January 2026

Nicholas Pevzner, Chesney Floyd,
and Shreya Mehta

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Cover photo: Nicholas Pevzner

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Executive Summary

Grid studies have demonstrated the urgent need to expand the nation's electrical transmission network, yet new transmission projects face significant headwinds — particularly around securing easements and overcoming negative public perceptions. Transmission corridors have major physical and visual presence in the landscape but rarely benefit from focused design consideration during planning. While designers have long been drawn to reimagining transmission systems, the technical constraints are not well understood outside the utility sector, and the full extent of opportunities for design engagement remains underexplored.

In August 2025, workshop organizers at the University of Pennsylvania convened a multidisciplinary workshop to expand the solution space for multi-benefit transmission corridors and explore the role of design thinking on this topic. The workshop brought together a multi-disciplinary group of landscape architects, utility operators, ecologists, energy analysts, and trail advocates to address a core question: how can we move beyond managing or mitigating the adverse impacts of transmission infrastructure toward actively leveraging transmission investment for community, ecological, and economic benefit?

Responding to prompts structured around "prototypical sites" (aerial maps of fictionalized locations containing a variety of features typical of the regional landscape) presented on large-format printouts, as well as 30 potential co-location configuration "modules" (hypothetical combinations of transmission corridors sharing space with another use or program) presented on illustrated module cards, workshop participants worked together to discuss the opportunities and tradeoffs of transmission routing across their given prototypical site, and evaluated the feasibility of the 30 modules while suggesting other module ideas and possible combinations. Workshop participants drew both on their own disciplinary foundations as well as the interdisciplinary group discussion to think about constraints and opportunities of transmission corridor design, suggest useful precedents, and share their motivations and concerns for successful co-located designs. Through group discussion, workshop participants generated insights and propositions for effective multi-benefit co-location of a variety of multifunctional arrangements, identifying potential synergies and strategies that can guide the design of future multi-benefit transmission projects.

This report summarizes the workshop methods and synthesizes these discussions and their insights for the design of multi-benefit transmission corridors.

Design Insights Across Scales

In response to the sites and modules, participants generated design insights at a variety of scales: from those relevant to small-scale site design along a transmission corridor to those affecting the regional-scale geography of the larger transmission system. These included:

- Design insights for recreational trails, with the potential to enhance variety and interest. Suggestions for trail design included prioritizing shade and thermal comfort, including a variety of experience, and connection to destinations. The corridor was considered as a continuous spine that could link to other trail systems, with investment concentrated in signature gateway elements, but recreational access benefits stemming from its linearity.

- Opportunities for wildlife connectivity. Participants recognized that transmission corridors could function as ecological connectors for pollinators and grassland species through careful vegetation management, while transmission-enabled interventions aimed at producing wildlife connectivity across barriers such as highways generated enthusiasm despite their complexity.
- Strategic undergrounding as a powerful tool for reducing forest fragmentation and creating synergistic benefits. While expensive, strategic undergrounding opportunities that combined undergrounding with protective berms or levees generated particular interest for their potential to generate with flood protection benefits in flood-prone areas.
- At the site scale, subtle grading was seen as a way to create seasonal wetlands that could reduce vegetation management needs, trail positioning as a way of maximizing shade and users' thermal comfort, and interpretive elements as a way of building public understanding of transmission and ecological systems.
- At the landscape scale, new corridors were seen as opportunities to connect communities to natural areas or to catalyze ecological restoration in heavily impacted landscapes.
- At the system scale, utilities' consistent relationships across varied ownership types and landowners that could enable implementation of multi-benefit arrangements along entire corridor systems. Partnerships between trail organizations and utilities were seen as a strong way to assemble easement agreements across multiple parcels, enabling larger transformations.

Key Findings

Successful multi-benefit design requires understanding of the technical constraints governing transmission infrastructure, which are not always clear to designers. Some key technical considerations were highlighted as important for designers to work within:

- Physical factors like tower/wire heights and right-of-way width are determined by transmission lines' voltage ratings and designers need to work within these constraints.
- Tower height is based on meeting conductor clearances but offers some flexibility of design in concert with utilities' cost considerations. New corridors offer more flexibility than existing ones, unless existing corridors are undergoing upgrading and tower replacement.
- The wire zone directly beneath conductors (i.e., wires) has stringent clearance and access requirements that prohibit tall vegetation and permanent structures, while the border zone offers more flexibility for vegetation, trails, and temporary amenities.
- Any intervention must maintain continuous access for utility maintenance vehicles.

Utility participants identified cost, maintenance access, and liability as primary constraints.

- For utilities, secondary uses work best when they meet public demand without adding significant cost.
- Programs and partnerships that reduce vegetation management burden have the opportunity to align utility operational needs with ecological or community benefits.
- Participants noted the potential for energy-intensive customers to share development costs through partnerships, and for the monetary investment associated with transmission improvements to support ecological or social connectivity goals through co-located design interventions.

The workshop revealed participating utility representatives' openness to considering arrangements previously assumed by designers to be off-limits.

- Programs such as sports fields, community gardens, grazing, tree farms under height limits, and solar installations outside the wire zone all received support when properly designed.
- Temporary structures for amenities were seen as acceptable when they did not obstruct maintenance access.
- Participants distinguished between modules implementable under existing utility-landowner agreements — such as integrated vegetation management, trails designed for dual use by maintenance vehicles, and grazing — versus those requiring special coordination or new business models.

Promising Directions

The workshop demonstrated that productive collaboration between designers and utilities is achievable when both understand each other's constraints and approaches. Participants identified a need for best practices resources compiling successful multi-use and multi-benefit case studies. Academic partners were seen as well-positioned to develop such resources.

While utilities' cost-focused mandate often diverges from designers' orientation toward community and ecological benefits, these misalignments fade if evaluation criteria expand beyond energy conveyance costs alone; emerging state policies requiring utilities to evaluate trail co-location are beginning to shift this dynamic. A catalog of permitted co-location programs could transform community engagement, enabling residents to envision and request specific amenities as part of transmission investment. With over 540,000 miles of transmission lines traversing the U.S. and significant expansion planned, the potential impact of a multi-benefit approach at national scale can lead to dramatic transformations of transmission corridors' public image and their contribution to community, ecological, and economic value. The workshop offered new ways of working through multi-benefit corridor designs, at a variety of scales, in ways that can be responsive to a variety of viewpoints, goals, and disciplinary concerns.

1. Introduction

1.1 The Multi-Benefit Approach

In response to grid congestion, increases in overall electricity demand, changing geographies of energy generation, disruptions by extreme weather events, and new sources of energy demand, grid studies have demonstrated the need and benefits of expanding the electrical transmission network across the United States (U.S. Department of Energy, 2024). Transmission expansion will include both the construction of new transmission corridors as well as the upgrading of transmission lines within existing corridors, and will be needed at local, regional and interregional scales. At the same time, new transmission projects face significant headwinds, particularly related to securing the necessary easements and overcoming negative perceptions about transmission infrastructure. However, a multi-benefit approach to transmission planning can generate recreational, ecological and economic opportunities within the transmission corridor, creating value for stakeholders and nearby residents, and shifting public perceptions about transmission (Pevzner et al., 2025b).

A multi-benefit approach to transmission corridors can shift the discussion from *managing or mitigating adverse impacts* of transmission lines to *leveraging transmission investment for the benefit of local communities, wildlife, and ecosystems*. Electrical transmission corridors are an important infrastructural typology that has a major physical and visual presence in the landscape, but don't often benefit from focused design consideration during their planning stage. While recognizing that the primary mandate of transmission corridors is the safe and reliable conveyance of electricity, a multi-benefit approach can look for opportunities to use the linear transmission right-of-way (ROW) to introduce additional co-located uses and activities that can generate a variety of benefits without sacrificing energy reliability. This co-location or multifunctionality challenge is at its core a design problem, but designers are not typically involved in the planning and siting of transmission corridors. The multi-benefit approach can benefit from the inclusion of design professionals and design thinking in order to develop workable and experientially desirable multi-benefit arrangements.

Building on previous arguments in favor of multifunctional energy infrastructure and designers' role in reimagining energy landscapes (Pevzner et al., 2021), a team led by Nicholas Pevzner, Assistant Professor of Landscape Architecture at the University of Pennsylvania's Weitzman School of Design organized a multidisciplinary workshop on this topic, called *Designing Multi-Benefit Transmission Corridors*. This workshop, sponsored by the U.S. Department of Energy's Grid Deployment Office (GDO) through the Pacific Northwest National Laboratory (PNNL) as part of the Connecting Transmission Corridors (ConCord) Initiative, sought to expand the solution space for multi-benefit transmission landscapes, using design tools and methods to test and evaluate a set of landscape approaches and potential arrangements for multi-benefit transmission corridors.

In order to expand the menu of potential design solutions for multi-benefit arrangements of transmission lines that not only minimize or mitigate the disruptions and harms that they may cause, but that could potentially provide benefits to ecosystems, to recreation, to communities' enjoyment of place, and to economic value, the *Designing Multi-Benefit Transmission Corridors* workshop brought together an interdisciplinary group of talented and motivated individuals to consider this challenge in the context of the Northeast/Mid-Atlantic region. The workshop took place at the University of Pennsylvania's Weitzman School of Design on the 15th of August, 2025. Responding to spatial and visual prompts from the workshop organizers, participants worked through participatory group discussions to test a series of landscape principles for the design of multi-benefit transmission corridors, to evaluate a suite of 30 different initial multifunctional arrangement prompts, and to articulate specific design opportunities. Asking how one might layer multiple functions, programs, amenities or benefits in the space of the transmission corridor, this workshop generated valuable insights and engagements, as well as tangible drawings, notes, and sketches of opportunities for going beyond conventional design standards and engineering practices, identifying key constraints and responding to them with design innovation. This report summarizes the methods and synthesizes the outcomes of the August 2025 *Designing Multi-Benefit Transmission Corridors* workshop.

Figure 1. One of the four concurrent group discussions at the *Designing Multi-Benefit Transmission Corridors* workshop at the University of Pennsylvania, each with a multidisciplinary group of participants discussing tradeoffs and opportunities. Credit: McHarg Center for Urbanism and Ecology, University of Pennsylvania.

1.2 Technical Considerations of Transmission Relevant to Design

Designers have long been drawn to imagining the redesign of various aspects of the transmission system, with varying degrees of credibility and engagement from utilities. Engagement by designers in the transmission topic have ranged from speculative provocations (as exemplified by the Dutch 2014 Green Architecture Competition award-winning proposal of the Ecological Energy Network by Lola Landscape Architects with Fabric Studio and Studio 1:1 (FABRICations, 2025), which imagined the space of transmission corridors as part of a new national park system), to actual implemented redesigns of pieces of the transmission system (for example the RIBA Pylon Design Competition (2014) organized jointly by the Royal Institute of British Architects and National Grid in the UK, which resulted in a built segment of transmission line with towers based on the winning design by Bystrup). Typically, however, the full extent of technical considerations and constraints of the transmission system are not clear to designers when they are operating in this space. Some constraints are set by engineering standards and performance requirements, but others are determined by individual utilities based on their risk tolerance, existing partnerships, and internal capacity. As a result, designers may unintentionally cross red lines that are nonstarters for a project's utility partners, halting potential design explorations and limiting the number of successful projects. Because of a lack of systematic engagement between designers and utilities, the full extent of opportunities for design engagement on transmission remains underexplored.

Figure 2. Examples of design engagement with transmission: Ecological Energy Network project by Lola Landscape Architects with Fabric Studio and Studio 1:1 (left); 2011 Pylon Design Competition winning design by architecture, design, and engineering firm Bystrup (right).

In order to engage the topic of transmission with greater confidence, and develop the various potential configurations of transmission co-location that would be explored in the *Designing Multi-Benefit Transmission Corridors* workshop, workshop organizers undertook research to ground themselves in the topic of transmission and its technical considerations. An expanded description of these technical considerations and constraints is available in Appendix E: Expanded Technical Considerations for Transmission Corridors.

Parameters like the height of towers and the width of corridors are determined based on engineering and safety requirements that consider numerous variables, such as the voltage rating of the line, what activities take place below the wires, as well as the sag and sway of wires under hot, icy, or windy conditions. Towers are designed to be tall enough to meet the minimum vertical clearance for wires at their lowest point under conditions of maximum sag. Corridor widths are designated with an eye to preventing vegetation from making contact with the wires if it were to fall, or the wires making contact with any vegetation or obstructions as they sag and sway. Thus the variables that determine ROW clearances include the arrangement of the wires on the tower, the tower heights, distances between towers, the movement of supporting structures under load, potential wire sway, and any added required clearances around the wires.

For co-location of transmission corridors alongside highways, a wide, unobstructed clear zone was assumed to be required between the edge of highway and the transmission towers to avoid potential vehicular collisions with towers, as well as to enable future highway lane expansion. For underground lines, the clear ROW width was assumed to be only 10 to 20 feet wide, as opposed to aboveground ROW corridors over 150 feet in width.

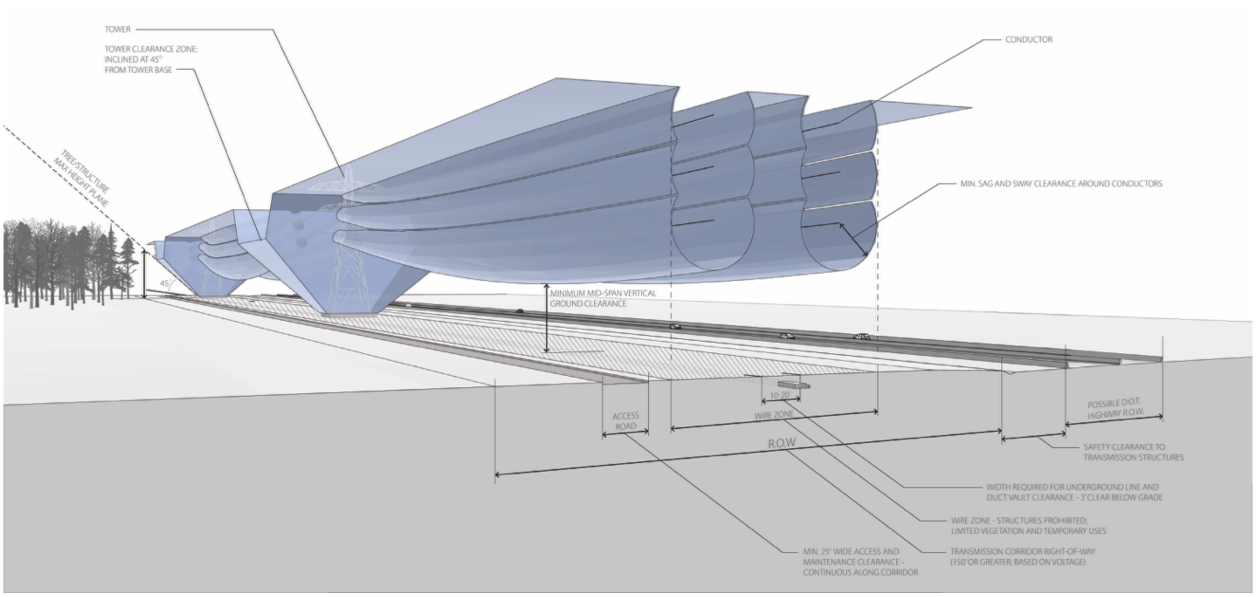


Figure 3. Graphic illustration of the various technical constraints and considerations that impact design in the transmission right-of-way. Minimum vertical clearance is determined by the height of the lowest wire at mid-span at maximum sag, while corridor width is determined by vegetation distance to towers and wires under maximum sway.

For designers, working in transmission corridors requires understanding the spatial constraints and parameters of electrical infrastructure. While there are other factors that play into the engineering of tower designs, ROW widths, and permissible uses, these foundations represented a starting point of technical knowledge for workshop organizers for crafting the workshop design challenge for participants, including the development of the “sites” and “modules” that would serve as the starting points of participants’ group discussions.

2. Workshop Structure

2.1 Multidisciplinary Roster of Participants

A key aim for the *Designing Multi-Benefit Transmission Corridors* workshop was the inclusion of a multidisciplinary cross-section of participants, so that group discussions would benefit from a cross-pollination of perspectives and experiences. Most critically, it was deemed important to include representation from electrical utilities that could speak to the practical constraints of designing and operating transmission infrastructure, as well as landscape designers that had previously demonstrated an interest and affinity for thinking about infrastructural spaces and multi-use trails. Additionally, since recreational trail co-location is an important aspect of multi-benefit transmission design, cycling advocates and trail organizations like the Rails to Trails Conservancy were deemed important to include, to speak to the experience of trail users.

Employing targeted outreach, workshop organizers convened a multi-disciplinary group of participants, whose backgrounds ranged from landscape architecture practitioners and academics, to energy analysts and regulators, to utility infrastructure and vegetation managers, to restoration ecologists, to trail and cycling advocates. Organizers were aided in this outreach by the Kleinman Center for Energy Policy at UPenn which suggested utility contacts from within the Northeast and Mid-Atlantic region, by the Bicycle Coalition of Greater Philadelphia which recommended a shortlist of local trail and cycling advocates, by the Landscape Architecture Foundation which put out a call to the landscape architecture community within the region, and the McHarg Center for Urbanism and Ecology at UPenn which reached out to select landscape architecture practitioners in Philadelphia.

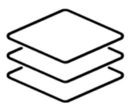
The workshop organized participants into four multi-disciplinary groups, one per table, with participants representing a range of different backgrounds seated around any given table. Importantly, each table had a mix that included some designers, some members with an energy or utility background, at least one trail advocate, as well as other participants with other backgrounds. For a full roster of participants with titles and affiliations, see Appendix A: Workshop Participants Roster.

2.2 Framing Presentations & Landscape Principles

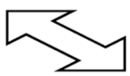
An initial set of presentations at the start of the workshop framed the topic for participants, laid out the four "landscape principles" for the design of multi-benefit transmission corridors (Multifunctionality, Connectivity, Legibility, and Participation), and offered a number of case study examples of transmission projects that engaged with these landscape principles in various ways. Remarks from a Grid Deployment Office and PNNL representative framed the importance of the transmission challenge, and a PNNL representative introduced current research on the topic as part of the *ConCord* initiative, as well as ways in which changes to the energy infrastructure planning process could include design and designers earlier in the process.

Remarks from utility infrastructure and vegetation managers gave examples of utilities' approaches to shared use within transmission corridors, emerging challenges such as wildfire risk, and leading examples of Integrated Vegetation Management (IVM) leading to more ecologically informed corridor maintenance. Remarks from landscape designers offered examples of design integration, both within energy projects generally and electrical transmission corridors specifically.

To help guide the next stage of the workshop discussion, workshop organizers offered four initial overarching principles that could guide the development of multi-benefit transmission corridors:



Multifunctionality: Achieving co-benefits by combining or co-locating multiple programs or land uses, including spatial, material, and programmatic multifunctionality.



Connectivity: Reducing the fragmentation of and facilitating the connections for people, neighborhoods, ecosystems, and/or animal movements, both along and across the corridor.

Legibility: Promoting of awareness and understanding of systems and how they operate, including of the transmission system and the natural and cultural systems that it traverses.

Participation: Enabling of active uses that give both visitors and nearby residents a sense of care and ownership in shaping the corridor, actively maintaining and stewarding it, or utilizing it for productive purposes.

For a full explanation of the four principles, see the *Workshop Brief* (Pevzner et al., 2025a), which was distributed to workshop participants at the start of the event. Workshop participants were asked to consider how the various design strategies and opportunities under discussion might support or advance these principles within the group's "site" and within the study region.

Following these opening remarks and presentations, participants were invited to engage in discussion around a sequence of prompts — the first responding to a hypothetical transmission scenario around a "prototypical site," and the second to a set of "modules" setting out a variety of potential transmission co-location possibilities, and an articulation of opportunities based on the groups' discussions.

2.3 Prototypical Sites

For the first prompt — "Site" — each table was presented with a large-format aerial view of a fictional site, composed of elements typical of the Northeast / Mid-Atlantic region, and participants were asked to use sticky notes on the aerial to call out the locations most important for them, based on their interests and concerns. The typical regional elements included fragments of urban or suburban development, industrial areas, large blocks of forest or agricultural land, pieces of large-scale transportation infrastructure such as highways, and elements of the existing energy grid including existing transmission lines, substations, and/or power plants.

Two different sites were generated for the workshop, and two tables received Site A while the other two tables received Site B. While the two sites differed in their specifics, they both had instances of neighborhoods fragmented by infrastructure, some large natural areas nearby, and large pieces of transportation infrastructure that could enable co-location for transmission corridors if participants chose to do so. The sites served as an icebreaker prompt to kick off the group discussion, getting participants talking about tradeoffs and opportunities of various routing options, without necessarily "solving" the challenges on their site. Having two instances of two sites struck a balance of comparison and replication, to gauge how participants' responses converged under similar conditions and how much they reacted to generic issues common to both sites versus specific relationships specific to each. The two sites are reproduced on the following pages.

A scenario for each prototypical site asked participants to imagine changes that would necessitate new or expanded transmission links, such as the new sources of energy supply or demand, that would necessitate expanding some transmission corridors and constructing some new ones. While the site aerials presented participants with a set of spatial relationships, the scenarios suggested some ways in which the sites would need to change, opening up new potentials and opportunities.

Scenario for Site A, as distributed to workshop participants

<table>
<tr>
<td>
Site A is located at the edge of a mid-size inland city. The landscape is characterized by rapid transition from residential neighborhoods to agriculture, interstate and local highway rights-of-way and interchanges, and converging high-voltage transmission corridors.
In this scenario, an existing high-voltage transmission corridor carrying two 220 kV circuits crosses the site from the northeast to the southwest (heavy white dashed line). As part of required grid upgrades, this existing corridor requires an increase in capacity to 500kV. An additional new 500kV corridor needs to link new energy generation sources located northwest of this site with destinations to the southeast (yellow arrows). Various possibilities exist for routing these new segments: through existing forest fragments, co-located with a portion of the existing highway, or following a new route.
The highway and transmission infrastructure currently fragments several patches of high-quality forest habitat.
</td>
<td>
Highways and transmission corridors also currently separate two neighborhoods from one another. Each of these areas include existing recreational paths and park areas.
Special considerations for this site include:

Opportunities for the transmission corridor as a transition between residential and agricultural land uses in the southeast portion of the site
Opportunities to mitigate habitat fragmentation
Potential to link existing hiking and bike trails
Potential to establish connections between disparate residential neighborhoods
Potential to co-locate transmission with highway infrastructure - both opportunities and constraints
High-visibility moments where current transmission corridor passes through a residential neighborhood (in the southwest portion of the site)

</td>
</tr>
</table>

Scenario for Site B, as distributed to workshop participants

Site B is located at the old industrial waterfront of a growing city. This area is characterized by significant industrial infrastructure, including an active power plant and rail lines. As industrial uses relocate to other areas, residential neighborhoods are infilling along the waterfront, and large areas of sensitive wetland habitat offer potential locations for new recreational destinations.

In this scenario, a pair of existing high-voltage transmission corridors each carrying two 220 kV circuits approach the power plant from the southwest (heavy dashed white line). One corridor follows an existing railway (inland route) and the other moves through the wetlands, along a highway right-of-way, and then into agricultural areas (coastal route). A new high voltage underwater power cable will be linking to new offshore energy generation sources, bringing electricity onshore at the former power plant site (heavy dashed line from the east). As part of grid upgrades, one of the two existing transmission corridors requires an increase in capacity to 500kV. Additionally, a new 500kV corridor needs to link the new source of offshore electricity to sites to the north, either following a coastal highway route or moving inland (yellow arrows).

The highway and transmission infrastructure currently separates the coastal estuary from the upland riverine corridors that feed into it. As the city develops, the waterfront is becoming an increasingly desirable destination for both residential and recreational land uses.

Special considerations for this site include:

- Opportunities to create corridor crossings to increase access to the waterfront
- Potential to link existing hiking and bike trails
- Potential to co-locate transmission with highway infrastructure - both opportunities and constraints
- Potential to establish connections between disparate residential neighborhoods
- Opportunity to reduce impact on sensitive wetland and estuary habitats
- Opportunity to reduce fragmentation of forest/riverine corridors

Based on the spatial patterns they found on their table's site, participants discussed the tradeoffs of transmission corridor routing, such as between denser vs. less densely populated areas, whether it's optimal to route the corridor along large pieces of transportation infrastructure vs. avoid them, through more disturbed vs. more untouched natural areas, and through publicly owned vs. private lands. Participants representing utilities noted the relative ease of working with larger public landowners rather than many smaller private ones, which made state agencies such as DOTs which own the land along highways, and railroads that own rail ROWs, attractive partners for siting transmission corridors; designers noted the challenge that co-located uses in corridors along highways posed for user experience. A corridor that needed to cross a highway presented a greater coordination challenge, but offered a chance to piggyback other connectivity benefits atop this alignment. Discussion focused on what to do with landscape features such as large transportation infrastructures and natural areas — whether to gravitate towards them or avoid them — and what some of the tradeoffs might entail. Alternative routes and design ideas were raised and discussed.

The following pages contain a reproduction of the Site A constructed aerial image as distributed to two of the tables, followed by a reproduction of the Site B constructed aerial image.

Figure 4. Site A. Constructed aerial image of Site A as distributed to participants at two tables.

Figure 5. Site B. Constructed aerial image of Site B as distributed to participants at two tables.

2.4 Modules

The second prompt — "Modules" — asked participants to consider 30 potential configurations of transmission co-location that organizers on a set of "module cards," and to sort these modules into those they supported, those they opposed, and those that warranted more discussion. Modules included public recreation infrastructure such as various types of trails co-located within the transmission ROW; collective community programs such as farmers markets, sports fields, and gathering spaces; economically productive programs within the transmission ROW such as tree farms, orchards, composting facilities, animal grazing, and other forms of agriculture; and various kinds of crossings across the transmission corridor for people, animals, or forest vegetation. Each module card featured an illustration of the resulting spatial arrangement, listed a number of considerations that might be relevant for that particular arrangement, and called out specific features relevant to that arrangement. Space was provided on each module card for participants to write their notes or reactions, and participants were urged to mark up their cards throughout the workshop day.

The 30 initial modules distributed to participants served the purpose of providing examples of co-location already commonplace within transmission ROWs, suggest some more provocative arrangements in order to elicit participants' reactions and feedback as far as tradeoffs and constraints from their disciplinary point of view, jump-start the group discussion of constraints and opportunities, and expand the menu of potential programs that participants were considering.

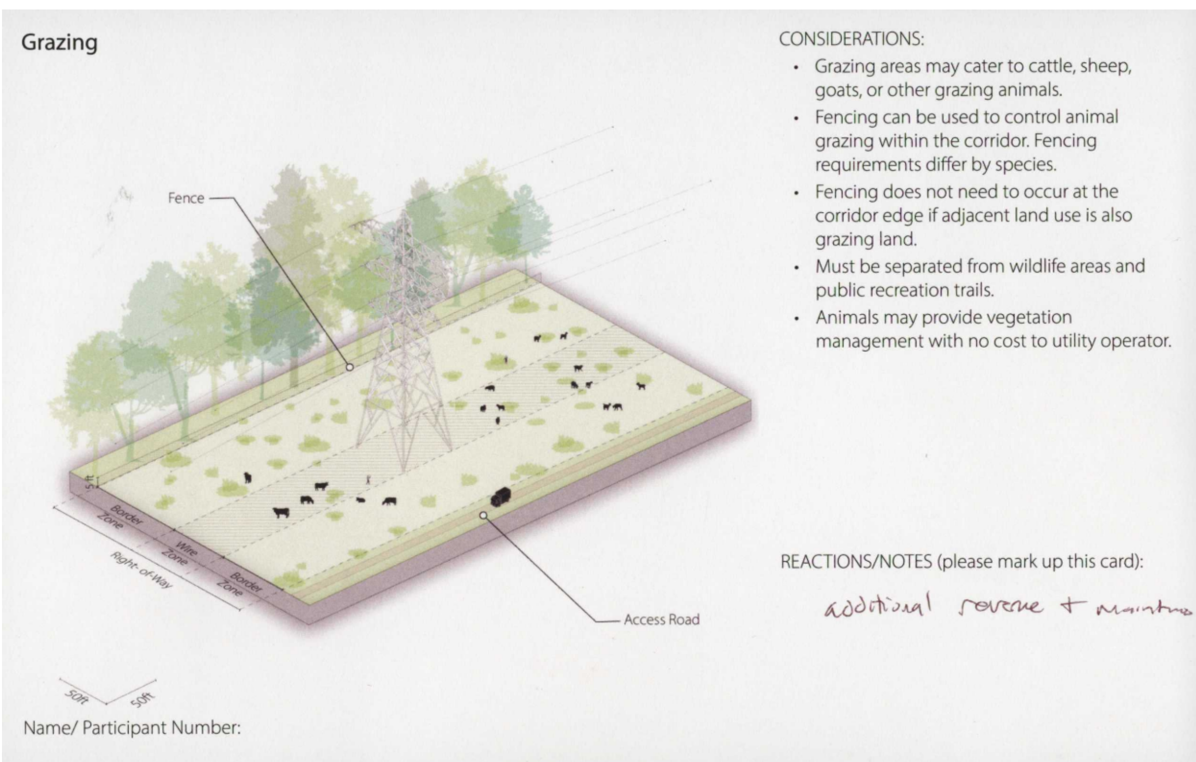


Figure 6. Example of a module card. Each workshop participant received a deck of 30 initial module cards, along with a few blank cards that participants were encouraged to sketch additional ideas on.

Participants sorted the modules into their favorites, most problematic, and those worthy of further discussion, and sketched out ideas for other modules that may not have been represented in the initial stack of module cards on a set of blank cards included at the end of the deck.

2.5 Report-back and Collective Discussion

For the final portion of the workshop, participants distilled major key points from their tables' discussions, which were shared out to the entire group. Finally, a closing discussion that included all workshop members together considered the common themes across all four tables, and reflected on potential ways forward towards greater interdisciplinary collaboration on this topic, ways of improving the sharing of successful case studies within the group and wider set of professions represented at the workshop, and thoughts on promising approaches for the development of more multi-benefit transmission corridors.

3. Outcomes

3.1 Discussion of Sites

Reacting to the first prompt, participants marked up their table's assigned site, discussed possible alternative arrangements for the new transmission corridor on their site, and different constraints or opportunities that various parts of the prototypical site posed for the expansion of the transmission system. This prompt served to initiate discussion, and to draw out participants' concerns, experiences, and knowledge that might be relevant to the multi-benefit transmission challenge, along with an introduction to themselves, their background, and their perspective for their tablemates. Together, participants identified opportunities for adding value or mitigating impacts, for doubling up on infrastructure in multifunctional arrangements, identified areas to target for intervention or to avoid, suggested strategies for achieving multi-benefit outcomes, and talked through various tradeoffs of these different arrangements, while starting to think about specific design opportunities.

Conversations did not arrive at a single consensus position, but rather focused on consideration of tradeoffs based on what the goals of a given transmission corridor alignment might be. As participants discussed possible alternative arrangements for new and expanded transmission corridors in their groups around their table's prototypical site, they highlighted which site elements, locations, or spatial relationships were important to consider, based on their point of view, interests, and issues of concern. They also organically offered up examples and case studies to illustrate conditions and inform the discussion, helping the group better consider the tradeoffs.

The following pages contain diagrams summarizing and synthesizing the reactions and discussions of participants at multiple tables about Site A and Site B.

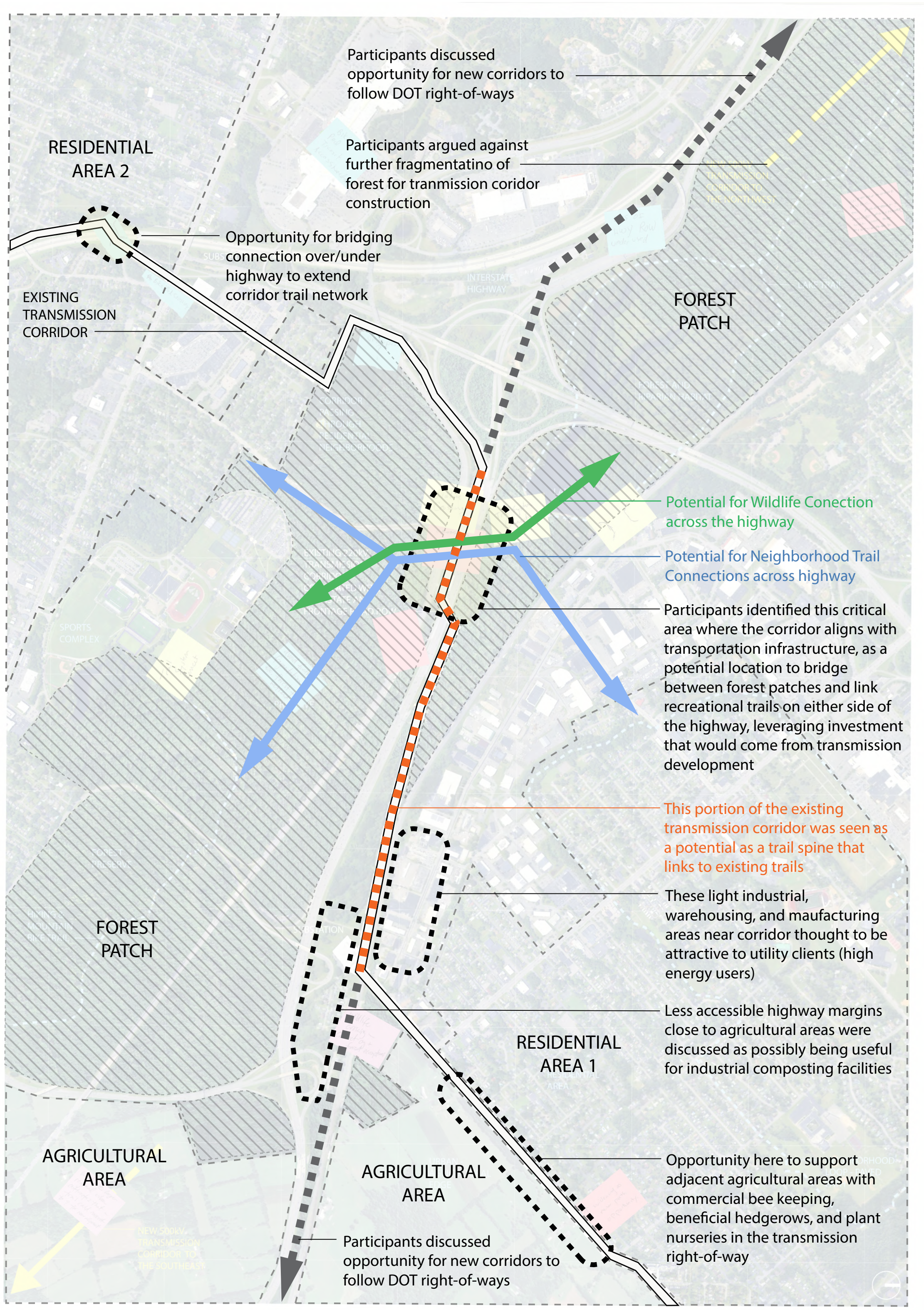


Figure 7. Summary diagram of Site A participants' reactions. This diagram summarizes points of conversation at various locations on Site A, for the two groups of participants that considered this site.

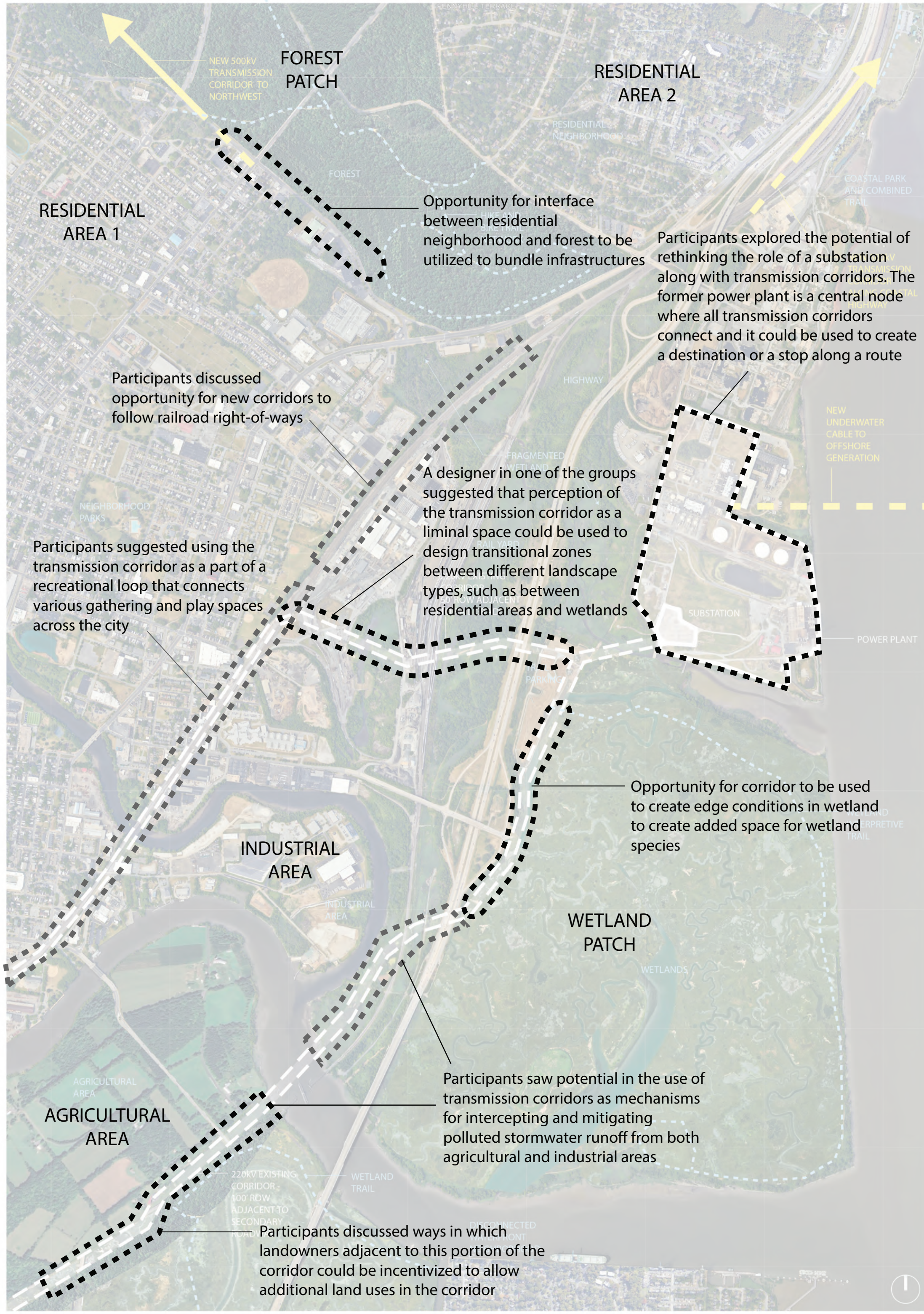


Figure 8. Summary diagram of Site B participants' reactions. This diagram summarizes points of conversation at various locations on Site B, for the two groups of participants that considered this site.

3.2 Discussions by Topic

With the introduction of the second prompt — the modules — group discussion turned from considering the sites on their own, to also considering a suite of potential co-located uses and programs, 30 of which were distributed to participants in the form of "module" cards to jump-start consideration. Participants supplemented additional uses and programs by sketching their own cards on blank additional cards provided to everyone. Participants were asked which modules they agreed with, which they saw concerns with, and asked to discuss their concerns or additional opportunities, as well as what contexts a given module might be appropriate in. Here we organize major points of discussion around the various modules by topic, ranging from considerations of different ownership types, to issues of trail design within the corridor, ecologically and economically beneficial uses, consideration of undergrounding and novel tower designs, ideas for improved public perception, and utilities' perceived constraints.

The discussions included participants' support or concern with various module types. For a table summarizing participants' reactions to all 30 modules, classified by participants' background, see Appendix C: Module Reactions. (This table was generated by ranking all modules that generated any kind of written response or reaction into generally supportive comments (coded green), comments that indicated possible support or some support but with caveats (coded orange), and comments that indicated strong concerns or opposition (coded red), organized by participant).

Ownership: The fragmented nature of land ownership in the region was seen as a major challenge for implementing public access along significant and continuous stretches of transmission corridors, whether that public access was in the form of trails or collective programs. Numerous participants noted that in trail development, much like transmission, working with large landowners is very helpful for getting trails in place, especially if they own large contiguous parcels; trail advocates and cyclists noted that longer regional trails in Pennsylvania and New Jersey typically follow abandoned rail ROWs that are made available to them in full under the Rails to Trails Act. For trails that lack a former railroad, an easement to ensure public access would need to be negotiated separately with every different property owner along the corridor. Whether because of landowner refusal or because of natural or infrastructural barriers to movement, a trail might very well not be able to connect continuously along the entire transmission corridor.

Trails: Despite this contiguity challenge, the opportunity of transmission corridors to expand existing trail networks was widely discussed at every table. Participants saw the extensiveness of the transmission corridor infrastructure, and the fact that it reaches from urban areas into surrounding rural, agricultural, and natural areas, as an important opportunity for human connectivity. At the same time, because transmission corridors frequently pass roads, highways, water bodies, and steep topography, they present challenges for contiguous trail making. Alignments of dual-use transmission corridors with trails would need to be carefully designed to minimize the number of costly crossing points. A landscape architect proposed that if such a continuous alignment could be achieved, the corridor could act as a "spine" to which other trail systems could be linked, giving the multifunctional corridor a central role in enhancing connectivity.

Another participant from a landscape architecture office offered lessons for trail routing from a large trail project that developed a toolkit approach to trail development — from a “path of least resistance” route that took advantage of ease of permitting, to a more expensive and difficult to permit route that offered more interesting experiences if easement acquisition was successful. Designers and cycling advocates pointed out that this strategy is typical of trail projects that consist mostly of low-cost linear trail improvements and then concentrate on one or two “signature” elements that provide access and a focal point in the larger system and act as destinations.

Cycling and trail advocates strongly encouraged designers to think carefully about quality of placemaking in the provision of long trail systems within infrastructural spaces. They noted the monotonous and unused hike and bike trails that have been built in some areas of New Jersey along old rail grades. In terms of the design of trails, there should be consideration of having variety in trail conditions, and finding locations for amenities such as scenic rest areas, hydration stations and bathrooms. Ensuring the provision of shade along the trail was another centeral consideration for cycling and trail advocates. Similarly, thermal comfort and safety was an important consideration for utilities as well in deciding whether trail use by the public within transmission ROWs would be allowable, with one participant noted measuring dangerous temperatures well over 100 degrees F along unshaded asphalt paths within their service territory.

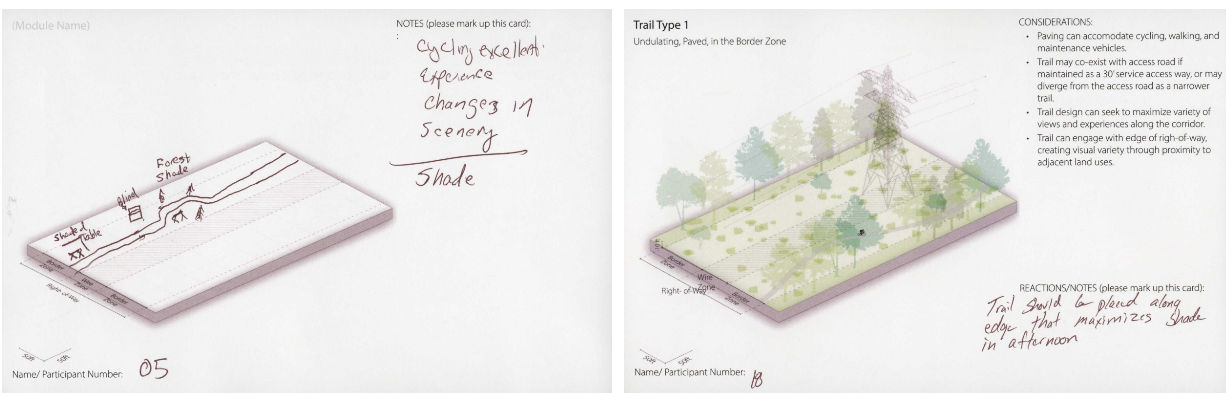


Figure 9. Participant comments noting the importance of shade for thermal comfort and safety.

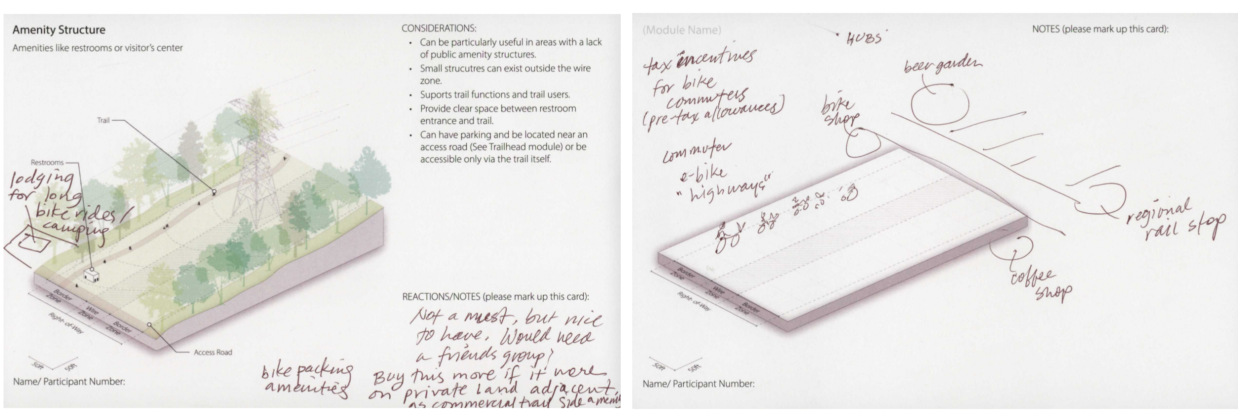


Figure 10. Ideas for enhanced cycling trail experience.

Some participants suggested other enhancements to the cycling experience, such as dedicated e-bike commuter lanes, and routing that took advantage of complimentary adjacent programs or development of dedicated support programs on adjoining parcels, like bike shops, restrooms, cafes, beer gardens, multimodal opportunities such as regional rail stops, and lodging or camping for longer multi-day bike rides. One participant offered the example of the Radschnellweg ("fast bike path") in the Ruhr region of Germany, which connects eight cities over 60 miles with dedicated bicycle lanes as an example of a trail precedent that enjoys major public support. The Radschnellweg features bridges and tunnels over/under roadways to separate bikes from cars at crossing points, offers passing lanes, and includes provisions for e-bikes.

For trails along highways and other transportation rights-of-way, designers suggested that controlling noise and making genuinely attractive corridor designs would be critical to encouraging public use and transforming public perception. Treating the infrastructural corridor *as a place* represents one major dimension of a needed culture shift both in terms of public perception, but also in terms of how utilities see their own facilities.

Utilities' Constraints: For participants representing electrical utilities, some of the primary concerns were ensuring maintenance access to the entirety of the corridor for maintenance, inspection, and repair. This meant avoiding all permanent obstructions that would get in the way of maintenance vehicles. Any kind of permanent structure in the ROW was likely a red flag for the utility representatives, but temporary or movable structures were possible as long as they were in the border zone and not the wire zone directly below the conductors. Utilities were also keen to avoid public uses directly in the wire zone, if at all possible, although sports fields were mentioned as an exception that has been allowed in the past if communities requested them, since maintenance vehicles could esily drive over sports fields if needed. On the whole public space opportunities generated qualified support from participants, including from utility participants, as long as they added benefits for communities and did not include permanent structures within the ROW. Amenity structures such as restrooms were generally welcomed by designers and trail advocates, and tolerated by utility participants, as long as they were mobile or temporary, and placed outside the wire zone. Shade structures could not interfere with access by utility maintenance crews, but were otherwise welcomed within the ROW for thermal comfort reasons. Community gardens or allotments were seen as providing valuable space for gardening to urban residents, with potential reputational benefits for utilities, without too much liability or reputational risk, although the wire zone directly below the wires needed to be kept clear and provisions made to ensure continuous access by utility maintenance vehicles.

Economically productive programs such as orchards or tree farms were allowable under struct maintenance provisions — trees no higher than 12' was mentioned as a typical condition, with the utility reserving the right to come in and cut any vegetation that exceeds maximum height limits. That said, the critical question in all these scenarios was the maintenance of necessary minimum distances between users and overhead wires, with taller towers enabling taller programs below. There was some concern about any program that necessitated mechanical equipment, such as orchards or industrial composting faciltities, with safety fears of mechanized equipment making contact with overhead wires by accident or operator error. To enable such co-location, equipment operators might need to have special safety training or the vertical clearances could be increased by having higher wires. Commercial composting was also resisted by utility participants because of the potential of reputational risk from smell. Grazing, agriculture (small-scale or large-scale), and beekeeping, meanwhile, received strong support.

The biggest constraint for utilities was cost, since any added costs would be borne by ratepayers, and in some cases regulators demanded lowest-cost provision of energy. Thus, secondary uses within the corridor could work for utilities if there was public demand and direct requests from communities, some reputational benefit, and not much additional cost, compared with business as usual. From this perspective, programs in which maintenance would be taken on by a third party, such as a municipal parks & recreation department (for sports fields, gathering spaces, or trails, potentially) or a mission-oriented nonprofit like a conservation organization (for pollinator meadows or wetlands, for example), could form the base of productive partnerships with utilities.

Ecology: From an ecological point of view, forest fragmentation was a clear concern for many participants, especially those with an ecology background. Due to the relative ease of developing transmission corridors through less populated areas with fewer landowners, forests were seen as potentially being impacted more intensively by transmission corridor routing than urban or agricultural areas, with large forested blocks more often “losing” relative to other, more densely used land uses, despite forests’ high ecological value.

Participants noted that transmission corridors provide ample opportunity to establish grasslands, one of the least available habitats in the Northeast and a beneficial buffer for capturing and filtering stormwater runoff from both agricultural and industrial areas. Establishment of pollinator habitat and wetlands in the corridor ROW were widely supported across all participant backgrounds.

While improved connectivity for grassland-loving or early successional species was seen as straightforward due to the relative ease of maintaining grassland or meadow habitat along the corridor, participants also saw opportunities for the transmission corridor to provide even greater connectivity for wildlife if it could link habitat patches already fragmented by major pieces of existing transportation infrastructure. Improved connectivity over existing barriers such as highways, railroads, or water bodies would entail the construction of specialized crossing structures for wildlife. Such specialized crossing structures along the corridor (represented by the “Overpass Type 1: Elevated wildlife crossing for non-human species” module) enjoyed widespread enthusiasm from a cross-section of participants, but some noted the expense, complexity, and permitting difficulties of getting such crossing structures built. Achieving construction of crossings would only become more complex if they also had to support electrical transmission infrastructure, they noted. Despite the cost and complexity, some participants saw the potential of the investment that came with transmission projects as helping to enable such wildlife connectivity infrastructure, which is otherwise difficult to fund. An ecologist noted that investment in transmission corridor improvements could be leveraged to provide strategic habitat bridging over the highway, connecting two large forest fragments and making a major improvement to forest habitat in the area. When some designers questioned if it was a good idea to combine recreational human uses with wildlife crossings, an ecologist responded that due to the difficulty in finding capital investments for ecological restoration, the presence of new human uses and recreation could similarly bring new attention and investment for wildlife corridors. Crossings for wildlife enjoyed more support from utility participants compared to crossings for people, due to safety and liability concerns of having people in the wire zone. Many noted the necessity to consider the place-specific context of where such crossings would be effective for wildlife connectivity, making this module highly site-dependent and responsive to specifics of habitat and species of concern.

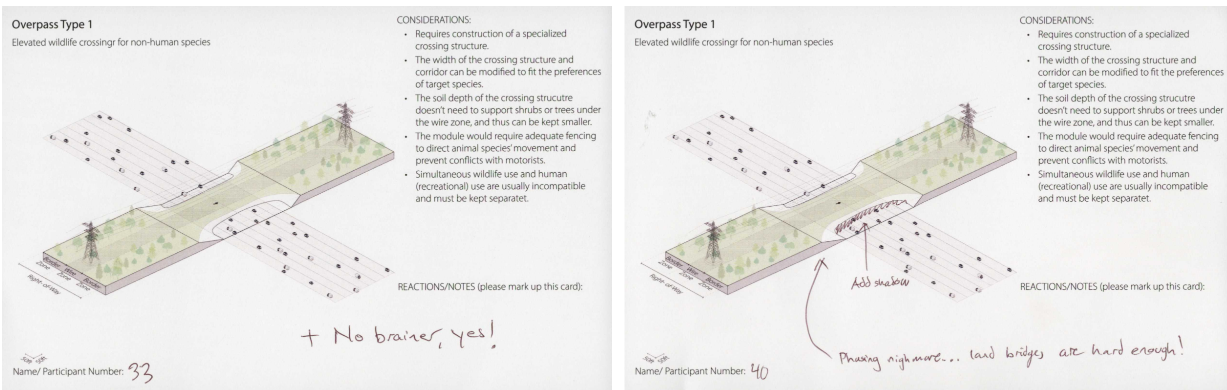


Figure 11. Contrasting participant reactions to the wildlife overpass idea.

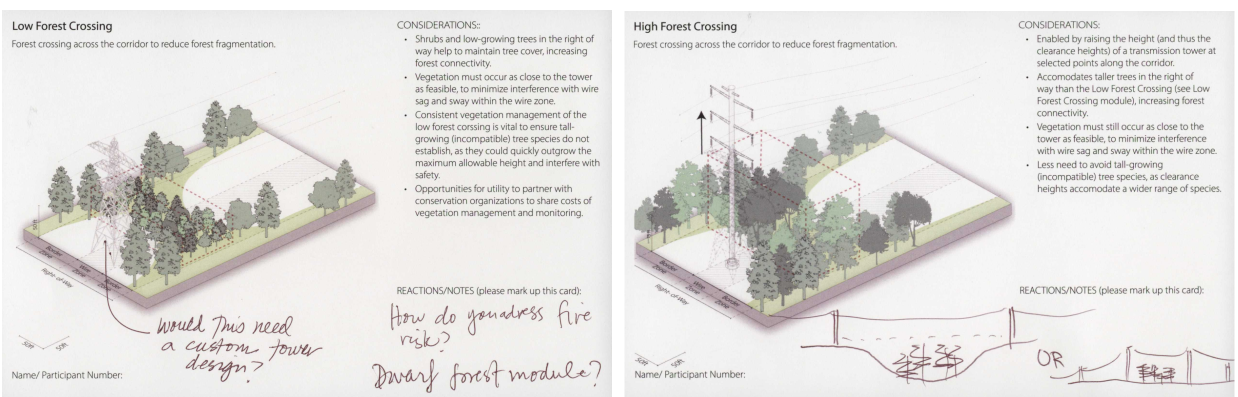


Figure 12. Participants' reactions to forested crossings across the ROW.

For ecological connectivity *across* the transmission corridor, vegetation management considerations were considered key. Workshop organizers had suggested three "forest crossing" modules that preserved trees within the ROW: the "Low Forest Crossing" module imagined shrubs and small trees within the ROW next to a tower where the conductor vertical clearance is highest; a "High Forest Crossing" module that had normal-height trees but next to a special taller tower; and a "Ravine Crossing" module that takes advantage of natural drops in topography to allow trees in the wire zone. While utilities already allow full-height trees and other vegetation to exist within the ROW in ravines and other steep drops in topography as long as clearances allow, such moments are highly site-dependent and uncommon in the Northeast/Mid-Atlantic region. More in line with standard IMV practices, utility participants suggested such "forest crossings" may be most possible with opportunistic use of topographic drops, along with low-growing trees that constitute a "dwarf forest" that doesn't necessitate special taller towers. Even these designs, however, would need to account for utility maintenance access to the wire zone and ways to counteract wildfire risk.

Numerous participants identified great potential for the corridor to capture and store water, increasing stormwater infiltration and reducing runoff. Designers noted that small variations in topography of just 6 to 12 inches could enable the establishment of vernal pools and shallow wetlands, with one participant noting that the establishment of aquatic or marsh-type ecosystems would have the added benefit of virtually eliminating the need for vegetation management, since they would displace taller-growing vegetation. Birding was also seen as a major potential use, and a designer suggested a new trail arrangement that could improve the bird watching experience by concealing bird watchers on trails that stayed at the wooded edges, just outside the cleared area of the ROW, and avoided disturbing wildlife within the corridor — though this would entail a slightly wider corridor acquisition that was able to capture a sliver of forest within its easement limits.

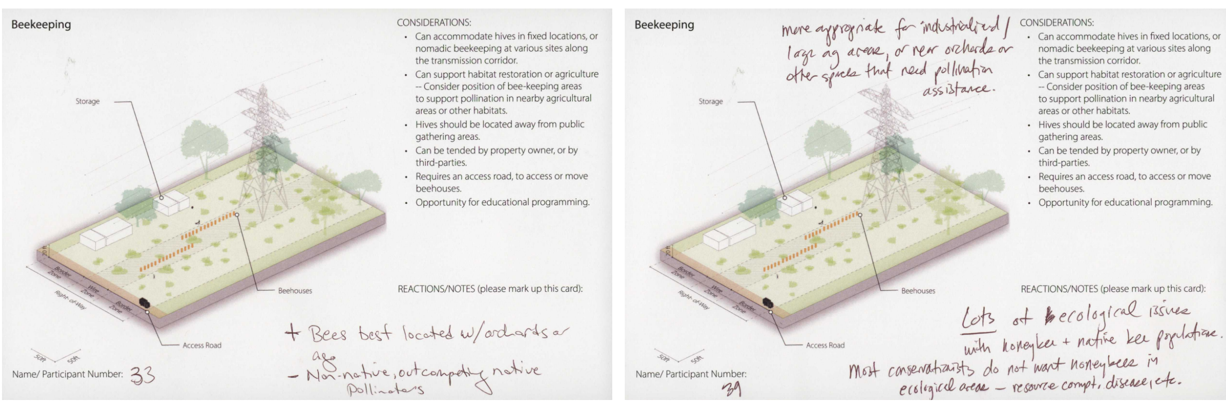


Figure 13. Participants noting ecological concerns with beekeeping as opposed to pollinator habitat.

While many participants supported agriculturally productive arrangements such as beekeeping within the transmission ROW, which is currently practiced by multiple utilities, some participants noted ecological concerns with beekeeping if not properly sited. As compared to the uncontroversial and widely supported practice of creating native pollinator habitat, beekeeping for agricultural pollination was considered an industrial practice that should be sited as such. Beekeeping was seen as suitable near large-scale agriculture contexts, which could benefit from its pollination services, but problematic when situated near native pollinator habitat, due to issues with non-native European honeybees outcompeting native pollinator populations.

Economic Benefits: Several participants asked how corridors can generate real value, instead of just mitigating transmission's adverse effects. Workshop organizers had proposed a suite of uses and programs that generate income, either for operators or landowners, such as grazing, agricultural cultivation, plant nurseries, orchards, industrial composing, and tree farms.

While designers were enthusiastic about industrial composting as a productive ROW use, utilities expressed concern over composting operations, citing potential reputational risk due to smell. Agriculture and grazing in particular were uncontrovercial and enjoyed widespread support across the board. Participants proposed additional economic arrangements, such as the cultivation of grasses, short-rotation woody crops, and other fast-growing crops for biofuels or fiber production. Use of the corridor for supporting small-scale logging was brought up, with the ROW's border zone potentially supporting temporary laydown areas for logs and maintenance roads supporting log truck access. Hunting was a particularly polarizing use, with many participants skeptical of its ability to share space with other public uses safely, as well as potential damage to transmission infrastructure, although utilities acknowledged that this use often already takes place, informally. Berry and mushrooms foraging was mentioned as another use that already occurs, without issues.

Use of the corridor for solar energy production was widely supported at multiple tables, even though local solar generation would be disconnected from the specific transmission line overhead. Some participants noted the reputational benefits to transmission utilities that hosting solar energy production within the ROW might offer, and the reduction in land use pressure on agricultural land nearby. Some participants pointed to the added benefits that elevated solar PV canopies along

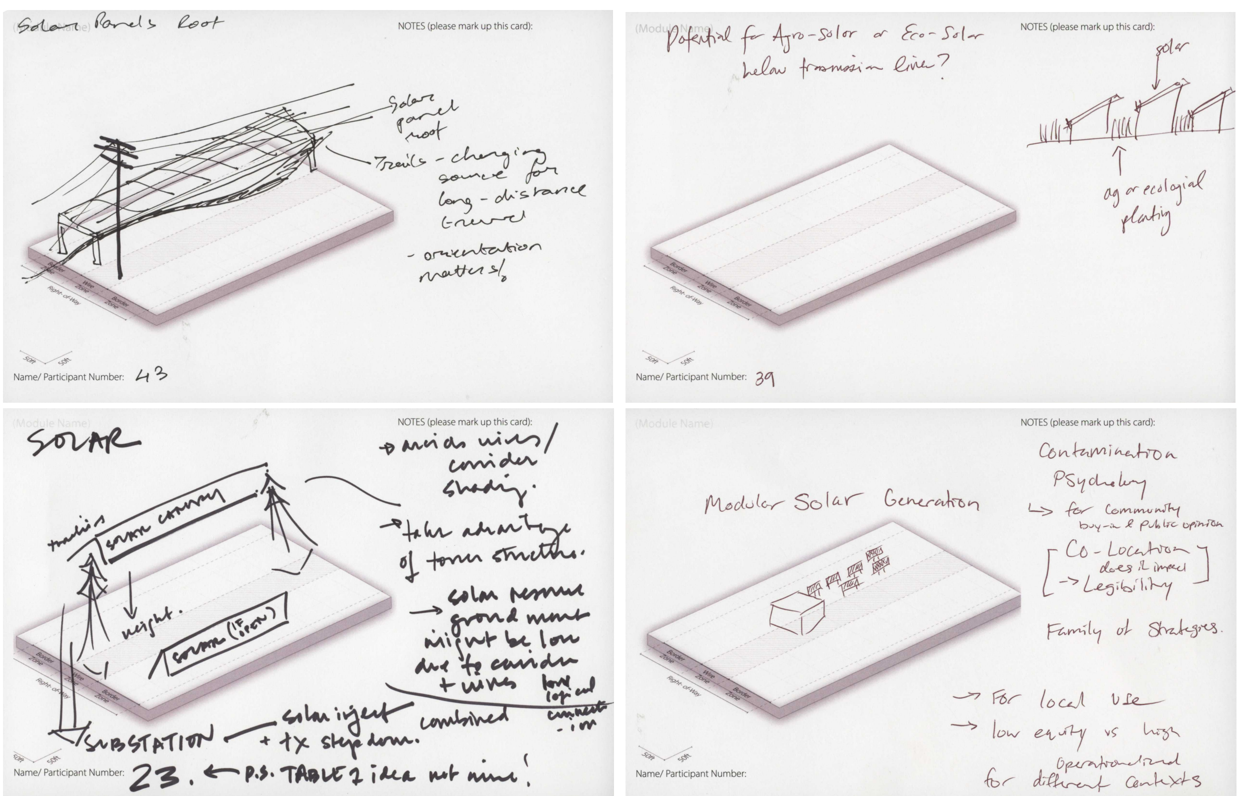


Figure 14. Participant proposals for solar in the ROW.

trails and parking lots within the ROW could have if designed to double as shade structures. Utility voices noted the need to maintain adequate separation distances from solar PV racking to overhead wires, and the need to ensure maintenance access along the ROW, but were generally amenable to such arrangements as long as solar was kept in the border zone and not directly below the wires. Solar panels could furthermore be combined with agricultural production (agrivoltaic) or ecological planting (ecovoltaic), and energy produced could feed into adjacent neighborhoods or power off-grid amenity structures within the ROW.

Policy analysts and utility operators also identified other new uses and technologies that could benefit from co-location with transmission corridors. Data centers and manufacturing hubs were identified as potential high-energy-demand utility customers that may move into areas close to urban centers served by existing transmission corridors, taking advantage of brownfield sites in post-industrial corridors, and which could bear a higher proportion of the cost of transmission corridor development through partnerships with local utilities, for example paying for the creation of multi-benefit arrangements at no added cost to residential ratepayers.

Perception and Public Use: Participants thought about how to make the arival of a transmission corridor be readily recognizable as a local benefit. Speaking to the legibility principle, a few participants suggested the value of short-term, quick-to-initiate programs that could quickly demonstrate value (for example Chrismas tree farms or sports fields), even before construction of the actual transmission would take place. Some of the proposed programs were focused on creating public space for community gathering and civic functions within the transmission ROW, more focused on collective social cohesion benefits rather than a clear economic benefit.

Provision of public space like sports fields and other kinds of open space within a transmission corridor were seen as being especially valuable near more densely urbanized areas, where open space is less available, or near economically disadvantaged neighborhoods which would benefit from the investment in public space that could accompany transmission development. However, public gathering spaces for large groups of people below the wires was not universally welcomed, given utility concerns over safety and liability. Any uses that involved parking raised the possibility of nuisance shocks due to induced current accumulating in vechicles parked below the wires.

New Proposed Underground Arrangements: While not represented in the initial set of modules participants received from workshop organizers, undergrounding of transmission lines came up at numerous tables of its own accord. Designers were interested in better understanding the constraints associated with undergrounding — including the added cost — while imagining the potential value that undergrounding offered for unlocking otherwise difficult-to-achieve arrangements. From an ecological point of view, undergrounding could avoid the large gaps in forest cover along corridor ROWs, with narrower required clear widths potentially even allowing for canopy closure above the transmission line, an important considerations for forest health. This was seen as a major benefit that could be applied strategically for re-connecting fragmented forest habitat areas or prevent further fragmentation, through targeted short instances of undergrounding.

Multiple participants from landscape design and ecology backgrounds expressed interest in undergrounding transmission lines within berms or sound walls, rather than trenching. As they noted, berms convey the added benefit of flood protection, which can lead to doubling up of benefits from new transmission lines when co-located with bike trails and flood protection in flood-prone areas such as riverine landscapes. Portions of the East Coast Greenway run through such areas, and could benefit from such arrangements.

Undergrounding also resonated with utility concerns for being better able to weather extreme weather events and disasters, including wildfire. For designers, the ability of transmission investment to in fact *contribute* to resilience against extreme weather events, such as floods, was a key opportunity — for example by including floodwater management within a corridor through grading, or by constructing berms or levees as part of the act of undergrounding, as noted above. While sourcing fill material for berms or levees would entail an additional expense, if such in-berm undergrounding was done in combination with a flood mitigation project that was already funded, the transmission line undergrounding could piggyback on this flood mitigation infrastructure construction at little additional expense.

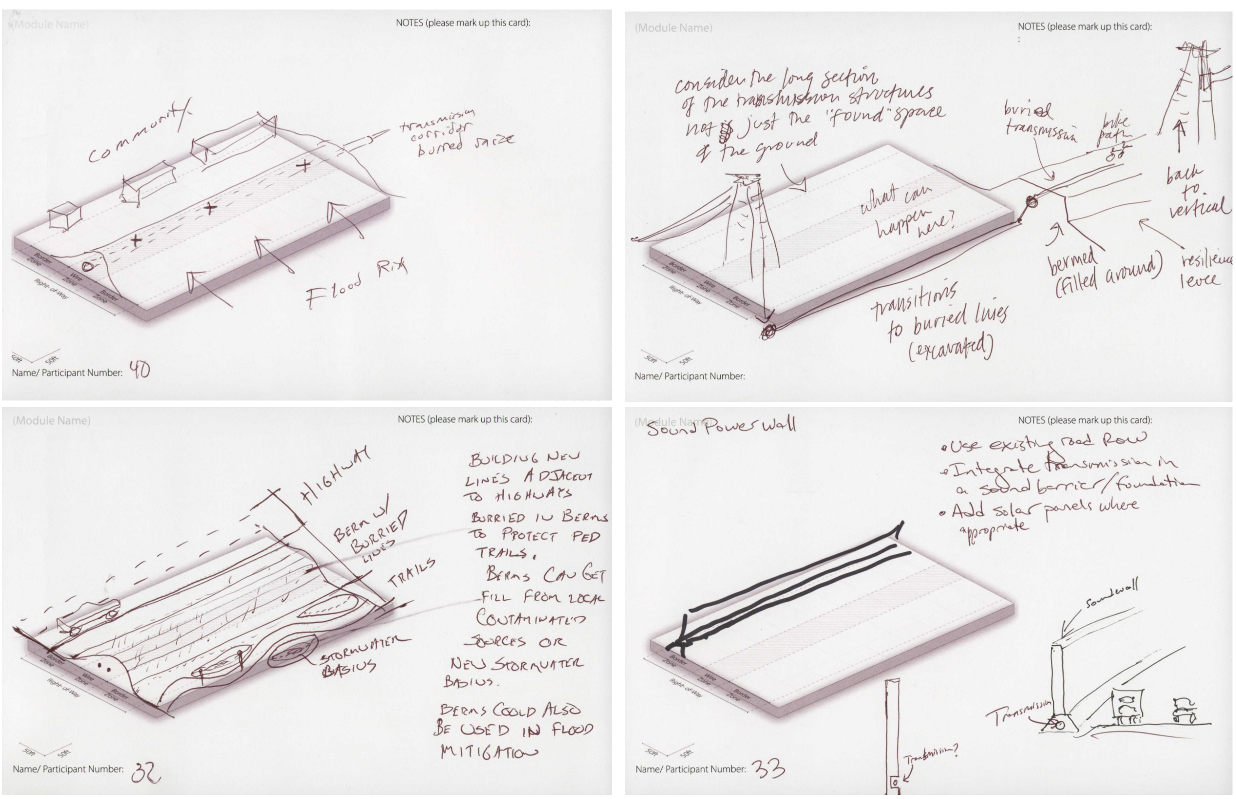


Figure 15. Proposals of undergrounding with co-benefits. Suggestions from multiple participants for multifunctional arrangements such as undergrounding in berms that provide additional benefits (flood control, sound protection, elevated bikeway), or transmission lines integrated in constructed sound barriers.

From a human experience point of view, designers concerned with improving the experience of trail users on highway-adjacent trails explored various options of integrating transmission with sound barriers along the roadway. For transmission corridors being routed adjacent to highways and sharing the highway ROW, integrating transmission wires in a berm or structured sound barrier could create sound separation, improving trail users' experience and enabling people to spend time on the trail next to the highway more safely and comfortably.

New Proposed Tower Designs: Participants also discussed the potential for non-standard designs for transmission towers. Some groups were interested in making the tower less intimidating and more welcoming, while others were thinking about opportunities for public access to towers, how to enable additional uses for towers aside from just holding up the wires, or in order to better enable non-standard uses below.

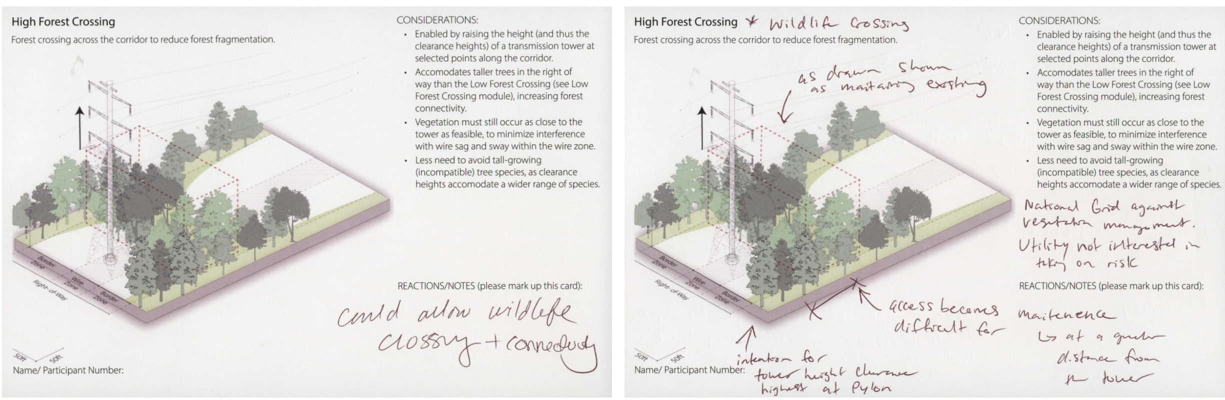


Figure 16. Participants considering the feasibility of special towers to enable taller vegetation below.

Elevated non-standard towers that could enable taller vegetation within the ROW were discussed as offering wildlife connectivity benefits, but at the expense of maintenance and risk concerns for the utility. Utility participants suggested that added cost of special towers was a concern, but that such arrangements might be possible on a one-off basis with proper engineering and that the underlying topography could help enable taller vegetation without the need for specialized towers.

Other participants expressed interest in specialized towers that could enable trail users to gain access to parts of the tower in order to benefit from the elevated prospect that such an overlook could provide, akin to hikers' enthusiasm for fire towers as scenic destinations. While understanding the constraints to such arrangements from the utility's side, they nonetheless argued for the added value that some version of public access could offer to trail users and the trail experience, and for the perceived savings that co-location of additional uses would bring to such large infrastructural elements that clearly utilize a large amount of steel. One participant wondered about the potential of glue-lam wooden towers, and the reduced carbon footprint of using wood instead of steel, offering the example of experimental wooden wind turbine towers by Vestas in Sweden.

Some participants suggested that in key locations, towers could be replaced by other more complex structures, for example supporting solar panels, providing access for visitors to experience the corridor from different vantage points, or housing other uses such as battery storage for microgrids, greenhouses for crop production, or other low-occupancy programs. Imagining alternative ownership and regulatory structures that could enable such arrangements, utility operators and policy analysts wondered if the utility would still "own" the tower, or just its energy conveyance, and how risks, liabilities and potential economic benefits could be shared among many stakeholders essentially sharing a single structure.

Table 1. Multi-use Tower Design Tradeoffs

Public benefit	Engineering Requirement	Regulatory Considerations	Precedents
- Use of tower as overlook, to gain elevaion for better views (similar to attraction of old fire towers on mountiantops as public recreation destination) - Public's satisfaction of seeing resource-intensive steel tower structure serving a dual purpose	-Need to ensure adequate distance between members of the public on the tower structure and the conductor wires -Need to provide protection of members of the public on the tower structure from microshocks due to AC induction or electrocution from lighting stikes	-Potential conflict with utility's primary mandate, may require approval from regulators -Added expense of bespoke tower design may require approval from regulators -Non-electricity functions may possibly necessite splitting of ownership or non-standard contractual arrangement	-Transmission towers often host cell tower functions -Bespoke tower design competitions to improve public perception have been held in past (RIBA Pylon Design Competition in UK with National Grid) -Transmission consent agreements already exist that enable additional uses along ROW

Expanding this discussion beyond towers only, designers argued that the various modules might be divided into two types — those that can be implemented systematically, as part of existing agreements between utilities and land-owners (such as trails, beekeeping arrangements, or alternative vegetation management practices) and those that would require special approval, coordination, changes in risk assessment or even new business models to support them, but that could come as targeted requests from communities. When taken into consideration alongside the earlier proposals for transmission infrastructure becoming integrated into sound barriers, floodwater management, and the combination with trails and transportation infrastructure, these suggestions for hybrid and non-standard arrangements pointed to possible futures in which select portions of transmission corridors might offer multi-modal functions with fully integrated linear infrastructures as opposed to just "infill" uses and benefits under typical transmission lines.

3.3 Discussion of Landscape Principles

The four landscape principles introduced in the beginning of the workshop helped frame the groups' discussions and pointed towards ways of evaluating the various opportunities for multi-benefit arrangements, and generated different degrees of engagement.

Multifunctionality: This principle, which suggests that co-benefits can be achieved and landscape function improved when multiple programs or land uses are combined and co-located, was inherent in all 30 of the modules distributed to participants, and formed the starting point for many of the discussions throughout the workshop. The question was not *if* multifunctionality should be pursued, but *how*, *where*, *what kind*, and what would need to change to enable these multifunctional combinations.

The main potential co-benefit opportunity that emerged in many discussions was the potential for reduced cost and improved logistics of vegetation management within the ROW through co-location. Establishment of wetlands and low-growing shrub/low-growing forest for habitat benefits did this by limiting what trees could grow there, as did intensive cultivation by third parties that prevented tree establishment (e.g. agriculture, orchard, plant nursery, tree farm, community garden, grazing). So did changes to the underlying ground that prevented tree growth (e.g. sports fields, anything paved). Another key opportunity for economical co-benefit had to do with utility access roads, and trail types for public tails that could support dual use by utility maintenance vehicles when needed. But avoiding conflict was just as important for successful multifunctionality — for example ensuring that no-go areas under the wires and tower were maintained despite the addition of public uses, and avoiding any uses that blocked or prevented access by utility maintenance crews, for example by avoiding any permanent structures or obstructions within the wire zone.

Connectivity: This principle was embraced by participants from all backgrounds, whether that connectivity was social, ecological, or recreational. Numerous participants were interested in the potential of using transmission corridors to increase the social connectivity for communities divided by existing transportation infrastructure, and the ecological connectivity for fragmented ecosystems. Recreational trails as social connectors received widespread support, including from utility representatives, as long as they steered clear of the wire zone and transmission towers. One of the designer participants suggested that the transmission corridors should aim to create a recreational loop that connects play and gathering spaces across a city. While the idea of connectivity was clearly understood and supported, the details mattered in evaluating whether connectivity would be successful: especially for ecosystems, the details of which habitats and species were being connected would be critical to consider. Grassland connectivity (along the corridor) was much more easily imagined than forest connectivity, given that vegetation management in the corridor already tends towards a grassland condition, and could be deployed continuously. For forest connectivity (across the corridor), a few of the module ideas for "forest crossings" and wildlife overpasses enjoyed support especially from participants with an ecology background, but a more skeptical reception from those with a utility background.

Legibility: Transmission lines are often not legible to the public — neither where they go and what they connect across, nor their safety (for some users, fears persist), or what utilities need for them to work safely and reliably. For designers trying to design with transmission systems, safety standards and utilities' constraints are not commonly known. Participants spoke about opportunities for education and demystification of transmission for users through engagement with trail organizations, with ecology and conservations organizations, and with municipal parks and recreation departments. The idea of nested scales came up in connection to the legibility principle: the fact that trail users within a transmission ROW, for example, are experiencing a particular place and landscape, but that it was connected by the transmission corridor to a much larger territory, and that there was an opportunity to instill this larger geographic relationship into the identity and design of particular trails and public moments along the corridor.

Participation: While many of the examples in the modules imagined various kinds of formalized active and collective use of the corridor space by the public, this idea received more enthusiasm from the design community than the utility cohort, given concerns about liability and large groups of people gathering below the wires (although examples of sports fields or community mountain bike parks within transmission ROWs exist). The active management and stewarding of vegetation in the corridor by third parties, aside from the utilities themselves, was more easily imagined when the participation came from more discrete uses such as agriculture and grazing, or public trails overseen by municipalities and trail organizations. But the idea that communities could approach utilities and propose new active uses for the ROW space as starting points for a discussion, while currently unusual, was seen as a potentially productive model.

Place and Context: While not included in the initial four landscape principles, participants noted the importance of place and context in the design of transmission corridor landscapes — the idea that a given transmission corridor design needs to be place-based and responsive to its context. Different sites have different specific conditions, different geomorphology, different nearby communities and community priorities, and so the design of these multi-benefit transmission landscapes needs to be evaluated and adjusted based on their suitability for a given context, rather than always following a universal set of rules.

3.4 Planning and Design Insights

Drawing from the discussions at multiple tables, we can synthesize some aggregated planning and design insights to inform strategies and opportunities for multi-benefit transmission corridor design at a variety of scales.

At the System-wide Scale

The utility's common unifying relationship across the multitude of different owners that a corridor traverses can be used to plan widespread implementation of certain modules in order to achieve impact at scale. For example, a utility can use integrated vegetation management for a pollinator species of concern along its entire corridor, such that system-wide habitat improvements are achieved across many different parcels and ownerships. For public access infrastructure such as cycling trails, trails organizations can work in partnership with utilities to do systematic outreach to the various landowners, in order to assemble agreements for a trail easement overlay throughout the transmission corridor.

Responding to the legibility principle, trail designers can make use of legibility interventions at the scale of the overall system, such as continuous interpretive signage along a powerline trail, to convey the full geography of connectivity that the transmission corridor traverses, including educating visitors about the geography of a utility's service area, its ecosystems and management practices, and the role of that particular transmission corridor has within the larger grid.

At the Landscape / Routing Scale

New transmission corridors that feature integrated trails can be routed so that they connect communities to one another with cycling and pedestrian routes, to larger long-distance cycling networks, to attractive destinations at the end of the trail, and to rewarding experiences along the way. Corridors near residential areas can be routed towards nearby natural areas to bring trail users to natural amenities, with the corridor itself routed so as to take advantage of and provide pleasant natural experiences.

Conversely, new corridors with integrated trails can be routed to go through already-heavily impacted areas, such as former industrial areas or large underutilized shopping malls, and focus on ecological restoration along the corridor. Working up from highly impaired ecosystems, such siting could produce the most dramatic improvement in ecological function, and make such benefits legible to trail users through legibility interventions that show before-and-after comparisons of given places to clearly communicate the degree of improvement and transformation.

Corridors can be routed so that co-located trails within the corridor can benefit from a diverse variety of landscape experiences, including variation in the natural or agricultural landscapes that form the corridor's context, as well as a variety of interactions with programs in adjoining parcels that trail users can experience as they move along the corridor. Corridor routing should try to avoid monofunctionality of trail user experience.

New transmission corridors running parallel to flood-prone river/stream landscapes should consider undergrounding within berms, levees, or other flood control infrastructure in order to offer dual benefits — both the aesthetic and ecological benefits of undergrounding and the flood mitigation benefits to adjacent communities. The continuous elevated berm or levee can also support public trails along the top, providing even more public benefit, along with utility maintenance access.

New transmission corridors being routed though unfragmented forested landscapes should consider undergrounding, or strategic moments of connectivity to reduce the effects of fragmentation and help maintain the conditions of interior forest habitat — or avoid routing through unfragmented forest in the first place. In already fragmented forests, whether from existing transportation infrastructure or existing transmission corridors, fragmentation can be reduced by introducing strategic moments of connectivity, for example by creating wildlife overpasses across existing transportation infrastructure barriers as part of the transmission investment, by localized undergrounding, or by implementing “forest crossings” at key moments to maintain landscape-level connectivity.

At the Localized Site Design Scale

“Forest crossings” can be achieved through careful design of the corridor at moments of desired forest connectivity. These design moves can include strategic short segments of undergrounding, as this would allow for forest canopy closure and improved forest habitat connectivity across the corridor. Alternately, “forest crossings” can be produced by establishing a low-growing shrubland or “dwarf forest” plant community at strategic moments of desired connectivity, by making use of sudden drops in elevation such as ravines and stream valleys (which can enable trees to grow taller below the wires), or by making select towers significantly taller than the rest (which means added cost, but which would enable taller vegetation near these towers thanks to their added height and thus wires’ distance from ground). To truly support forest connectivity, “forest crossings” should be wide enough to allow a significant band of “interior forest” to continue from one side of the corridor to the other, free from edge effects.

Instead of leveling the corridor to remove topographic variation, corridor design can use grading and topography to create subtle variation, producing localized wet areas for water collection, such as intermittent wetlands and vernal pools. Targeted creation of these wet areas can make those parts of the corridor inhospitable to trees and taller vegetation, reducing the need for tree cutting for vegetation management, for example in the wire zone. A paved dual-use trail/access road through wetland areas can support both utility maintenance vehicles as well as public access for trail use. Alternately, public trails can run exclusively within the border zone, with a separate access road for maintenance vehicles within the wire zone.

The design of trails within transmission ROWs should consider which parts of the corridor offer shade during peak afternoon sun angle, and maximize available shade for users’ thermal comfort. For the sun angles in the Northeast/Mid-Atlantic region, in north-south corridor segments, this would privilege having the trail hug the western edge of the corridor; in east-west segments, the trail would hug the southern edge. For new corridors, the easement can include a somewhat wider corridor than just the minimum clear zone that vegetation management would necessitate, so that there is a possibility of keeping trees and taller vegetation at the edge of the ROW within which trails could run.

Additional localized detailed design of trail gateways close to neighborhoods or parking areas that act as entry points to the trail can take advantage of already-existing supporting programs adjacent to the transmission ROW (for example by connecting to existing restaurants, cafes, breweries, etc. next to the ROW). Design of the ROW can also implement temporary/movable structures for functions such as restrooms, food stands, overlooks, shaded seating areas, etc. within the ROW border zone (as long as continuous utility maintenance access along the wire zone is unobstructed). Shade structures within the border zone can incorporate solar energy generation if solar access is adequate. Design of interpretive moments can add to users’ legibility of interesting ecological, historical, or transmission system-related moments.

4. Conclusion

Diversity of Perspectives

The *Designing Multi-Benefit Transmission Corridors* workshop represented an intensive focused day of discussion and collaboration. Workshop participants across the board welcomed the opportunity to get out of their familiar disciplinary echo chambers to spend time with and learn from fellow participants from other backgrounds. Many noted the dearth of such multidisciplinary forums in their typical professional experience, and expressed interest in continuing the conversations across disciplines initiated at the workshop. The workshop greatly benefitted from the open-mindedness and collaborative spirit of the discussions, and the willingness of participants to educate their fellow participants on perspectives and examples from their own profession's point of view.

The workshop demonstrated the value of multidisciplinary conversations in quickly generating a variety of potential solutions to a given corridor routing or corridor design question. Designers were able to quickly contextualize potential benefits of a given corridor arrangement or program module idea for a variety of possible stakeholders such as trail users, nearby communities, or ecosystems and their plant and animal populations. Utility representatives, meanwhile, were immediately able to suggest which strategies might be possible given technical limitations, cost constraints, and considerations of liability, reputational risk, or public good will. Trail advocates were able to provide numerous examples that spoke to trail users' potential experience, while participants with ecological knowledge were able to speak on behalf of ecosystem health and the ecological implications of disturbances or land use changes, expanding the conversation beyond purely social or economic benefits.

Spatial Tradeoffs

The workshop prompts did not always produce a single direction or strategy, instead resulting in considerations of tradeoffs. Should the most difficult and disturbed parts of the site, such as existing highway infrastructure and industrial areas, be avoided because they are more difficult to work with from a technical or regulatory perspective, or do such sites offer the most potential value of possible ecological improvement and least fear of further disturbance? Should a corridor cut through the forest to reduce impacts to a neighborhood, or stay close to the neighborhood to spare the forest? Could staying close to a neighborhood offer the most potential for contributing public amenities like sports fields, community gardens, playgrounds, and natural open space to underserved communities? Should more intact natural areas such as large forest or wetland blocks be avoided by transmission routing in order to avoid causing harm, or would such routes offer the most enjoyment and value for trail users along a corridor? The answer to any of these questions would depend on the priorities and value judgements of any number of stakeholders, which might be mutually opposed. Workshop participants were able to discuss and consider such tradeoffs, without needing to specifically choose a single direction or outcome.

The discussions also exposed the limit of such discussions on hypothetical or imagined sites, since actual site conditions and actual communities might have specific needs, preferences, and limitations that cannot be assessed in the abstract. The specific details of ecosystems (specific plant communities, ecosystem conditions, presence or absence of specific species of concern) would be important to consider when developing transmission corridor designs, and might change whether certain costly ecological interventions were deemed to add value in a given context — the workshop's prototypical sites did not provide such fine-grained detail. Similarly, specific communities' perceptions and opinions about both the transmission infrastructure and possible social or economic programs would alter which arrangements were deemed to add value. In the absence of actual stakeholders, the discussion of potential complex dual use arrangements and specific co-locations remained a conceptual discussion. Nonetheless, participants were able to identify certain cause-effect relationships and combinations of uses which in the proper context were generally seen as adding value, producing multiple benefits, and being desirable.

Misalignments

Utility participants emphasized the need to deliver lowest-cost energy as their primary mandate from their regulators, while designers suggested non-traditional arrangements that could conceivably provide other values and co-benefits. Despite the many examples of expanded value demonstrated throughout the workshop as resulting from design thinking, design is still often seen by utilities and regulators as an added and unnecessary expense.

Whereas utility participants expressed motivations of cost consciousness, enhanced public image, and reduced reputational risk, designers tended to be motivated by creation of community and ecological benefits, including improved environmental performance and enhanced public experiences, without being too concerned about the division of responsibility or liability within the corridor. Many of the non-traditional arrangements explored in the workshop would only make sense if the evaluation criteria were expanded beyond the pure cost of building or maintaining transmission lines for energy conveyance alone, and if such expanded assessments of value were incorporated into the way transmission corridor projects were permitted and regulated.

While they enjoyed engaging with one another at the workshop, designers and utilities did not have much history of working together professionally, which could stem from misalignments in the different way these fields seek out work or services: design firms and ecological restoration consulting companies typically go after projects via Requests For Proposal or RFPs, whereas utilities would likely seek to procure design services via a Master Services Agreement or MSA.

Public policy analysts spoke about another challenge for multi-benefit use in corridors: multiple benefits may imply many stakeholders, as well as the need to balance between the needs of utilities, landowners, users, and nearby communities and ecosystems. A multi-benefit scenario that succeeds in providing benefits to all of these groups may have diffuse authority and decision-making, while designers and utility representatives argued that in their experience, successful multi-benefit projects require an entity capable of acting as a convener of disparate stakeholders, facilitating communication among them and mobilizing them towards a shared goal.

Promising Directions

A growing number of successful multi-benefit case studies suggest that while still uncommon, such arrangements are becoming more widespread. More awareness of these case studies, both among communities and utilities, can change public perception of transmission corridors, and increase both the demand for such mutually beneficial arrangements on the part of communities, and the willingness to entertain them on the part of utilities. Utility representatives noted utilities' tendency to be risk-averse, work only with trusted partners, and avoid undue publicity that could result in unwanted attention. They noted a pressing need for "best practices guides" or case study libraries that compiled precedents of successful multi-benefit case studies — such a case study compilation would be of benefit to utilities, who find it easier to try something new if it has already been piloted successfully by another utility, as well as to designers, who are often unsure of what is possible within utility ROWs. Both groups articulated a value in universities' involvement in building a more formal national catalog of case studies, sorted by common regional variables, noting academic partners' role as well-regarded neutral third parties who could provide scientific knowledge, research, and reputational cover for utilities to propose non-traditional multi-benefit arrangements.

The multiplicity of so many potential multi-benefit opportunities discussed at the workshop, as demonstrated by the 30 programmatic modules developed for this workshop plus the additional ideas proposed by participants, represented an opening in and of itself, both for changing public perceptions of transmission corridors, and for the process by which utilities think about developing such corridors. While the variety of modules was intended by workshop organizers as a provocation, in order to spark discussion and draw out both opportunities and potential conflicts from the various participant's professional perspectives, the idea of having a catalog of permitted co-locatable uses and programs was seen as a potentially valuable tool for community engagement, which could enable communities to have an expanded sense of what multi-benefit arrangements might be possible. The catalog of potential co-location programs and uses could benefit from further study, to capture the full range of potential ideas that utilities and regulators would be willing to entertain.

Policy changes at the state level that are pushing transmission planners to evaluate public trail co-location as a routine step — such as Colorado's recently signed Powerline Trails Bill (HB22-1104) and the Multi-use Trails Bill being considered in New York — are already changing the starting point of multi-benefit discussions. The addition of a design perspective to help deliver better user experiences, add ecological functionality, and capitalize on spatial and programmatic opportunities can be a clear next step. Beyond trails, an expanded catalog of multi-benefit arrangements could enable a participatory process in which communities envision multiple possible co-benefit outcomes as potential amenities that can be requested alongside a transmission project, rather than utilities approaching communities with a single potential co-benefit proposal when developing a transmission project. This inversion has the potential to transform the transmission development dynamic, opening much more bi-directional conversations and creating added opportunities for design innovation.

Finally, while this workshop succeeded in bringing together a wide cross-section of disciplinary expertise and motivated participants, it was constrained by participant's geography, availability, and invitation. More such workshops, with other participants or in other locations, can expand upon the lessons learned here and incorporate an even wider array of viewpoints, to test and reinforce the suite of approaches for designing multi-benefit transmission corridors. The potential impact of the multi-benefit approach, if replicated at the scale of the national transmission system, could be dramatic. Currently, over 540,000 miles of transmission lines occupying millions of acres exist in the United States (PNNL, 2025a), connecting a geography that touches a diversity of communities and ecosystems. At the same time, integrating multi-benefit transmission corridors with their surroundings requires holistic place-making, responsive to local conditions and stakeholder concerns, which this workshop necessarily generalized for the sake of wider discussion. While this workshop asked about sites and conditions common to the Northeast and Mid-Atlantic region, these conditions may be different in other regions, necessitating different or unique solutions, and suggesting space for other opportunities.

Figure 17. Closing synthesis discussion. Participants at the workshop sharing key insights and closing thoughts in multidisciplinary conversation. Credit: McHarg Center for Urbanism and Ecology, University of Pennsylvania

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6. Appendix

Appendix A: Workshop Participants Roster

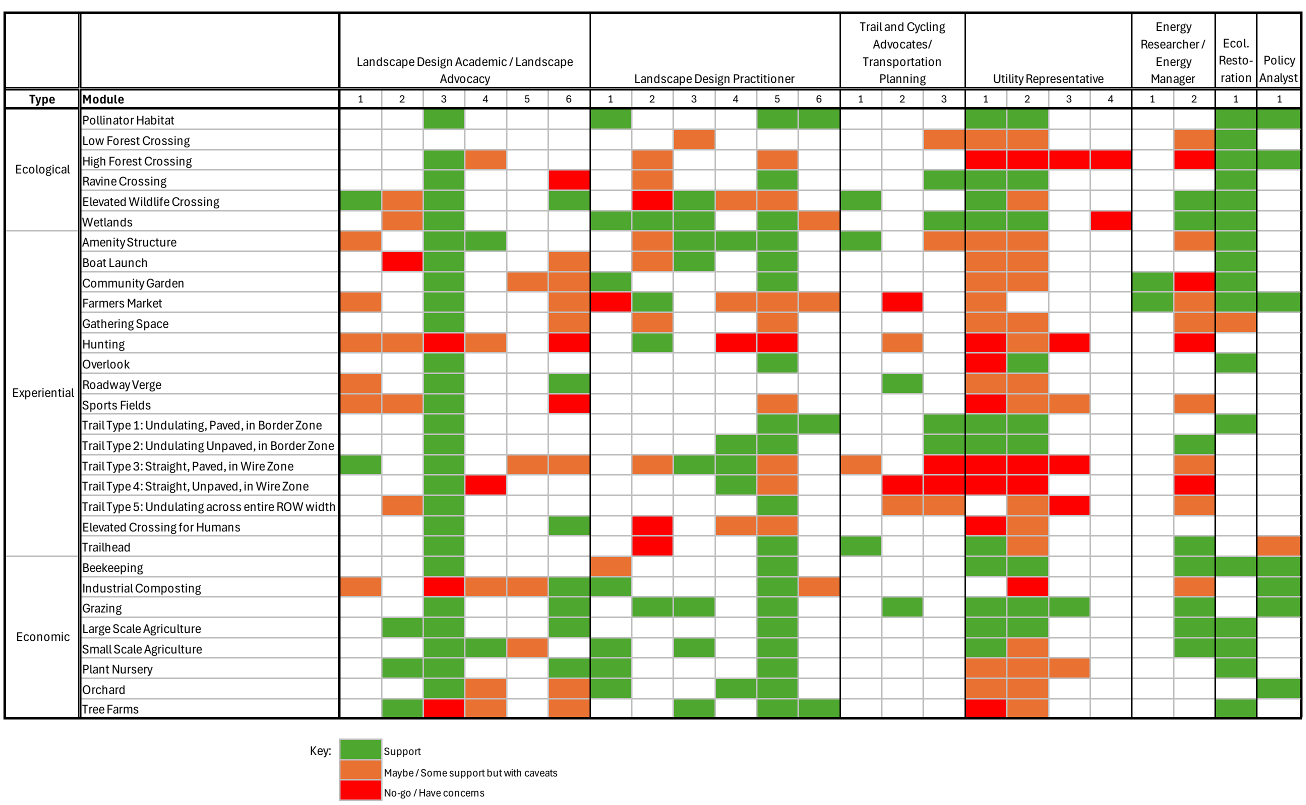
- Robin Berry - Director, Critical Infrastructure Risk Management, National Grid
- John Boyle - Research Director, Bicycle Coalition of Greater Philadelphia
- Eric Brown - Manager, Electric T&D Vegetation Management, Sacramento Municipal Utility District
- Sanya Carley - Faculty Director, Kleinman Center for Energy Policy at the University of Pennsylvania
- Danielle Choi, RLA - Associate Professor, Harvard Graduate School of Design
- Claire Fellman, RLA, ASLA - Associate Principal, Reed Hilderbrand
- Nate Heavers - Associate Professor, Temple Unversity
- Erik-Logan Hughes - Acting Program Manager, Grid Deployment Office
- Carolyn Kousky - Associate VP for Economics & Policy, Environmental Defense Fund; Founder, Insurance for Good
- Matt Ludwig - Principal Transportation Planner & Engineer, NV5
- Michael Miller, RLA, ASLA - Partner, OLIN
- Krithika Mohan, PLA, ASLA - Designer II, Toole Design
- Ellen Neises, RLA - Associate Professor of Practice, University of Pennsylvania; Executive Director, PennPraxis
- Rebecca O'Neil - Advisor, Pacific Northwest National Laboratory
- Rebecca Popowsky, RLA, LEED AP, SITES AP - Director, McHarg Center for Urbanism and Ecology at the University of Pennsylvania
- Danielle Preziuso - Socio-Technical Systems Engineer, Pacific Northwest National Laboratory
- Tom Sexton - Northeast Director, Rails to Trails Conservancy
- Aaron Stone - Associate, Field Operations
- Christopher Streb, LEED AP - Learning & Innovation Leader, Biohabitats
- James Tonrey - Analyst, Regulatory Policy & Strategy, National Grid
- Jordan Van Order - Fixed Utility Valuation Engineer, Bureau of Technical Utility Services, Pennsylvania Public Utility Commission
- Heather Whitlow - Senior Director of Programs & Communication, Landscape Architecture Foundation
- Gena Wirth, RLA, FASLA - Design Principal & Partner, SCAPE
- Nate Wooten, RLA, ASLA, RA - Associate, OLIN
- Le Xu, RLA, LEED AP - Innovation Director, Salt Design Studio
- Jean Yang - Assistant Professor, SUNY ESF
- Yeongseo Yu - Post-doc, Pacific Northwest National Laboratory

Appendix B: Workshop Agenda

The workshop was held August 15, 2025 in Meyerson Hall, in the Stuart Weitzman School of Design, University of Pennsylvania, at 210 South 34th Street, Philadelphia, PA 19104. The schedule was as follows:

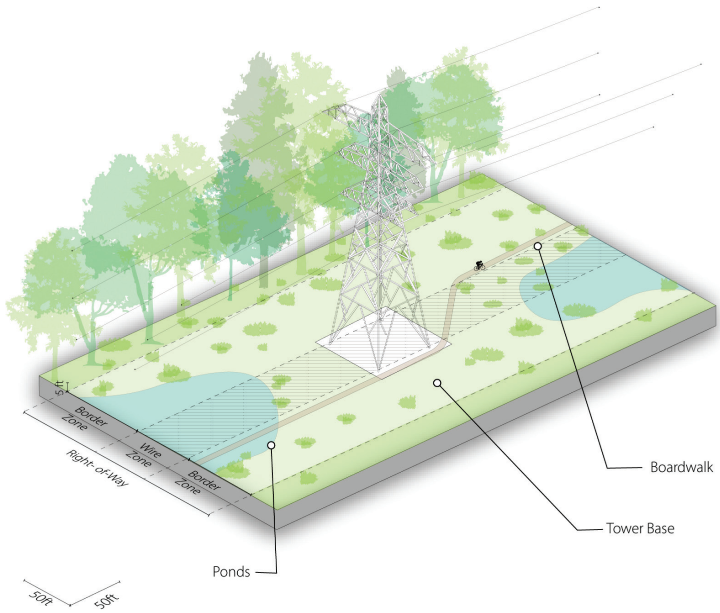
10:00 am - 10:30 am	**Welcome, Introduction & PNNL/DOE Kickoff**
10:30 am - 11:00 am	**Overview of Principles, Strategies, Opportunities**
11:00 am - 12:30 pm	**Group Working Breakout Sessions**
12:30 pm - 1:30 pm	**Lunch**
1:30 pm - 3:00 pm	**Working Session 2 & Key Points Summaries**
3:00 pm - 4:00 pm	**Discussion and Synthesis**
4:30 pm - 5:00 pm	**Final thoughts & Closing**

Appendix C: Module Reactions



Appendix D: Full deck of module cards distributed at start of workshop

Wetlands/ Ponds



CONSIDERATIONS:

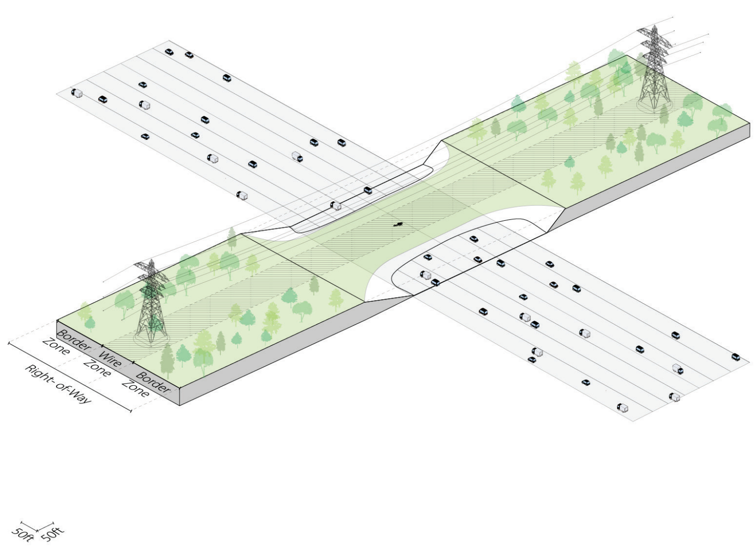
- In urbanized areas, this module can support improved stormwater management.
- Low-lying wetlands and mudflats are unaffected by wire clearances.
- Aquatic ecosystems not interrupted below water level allowing movement of birds, fish and other animals.
- Access across wet ground is challenging; requires routing along areas of high ground or on elevated/bridge sstructure.
- Special attention is required to determine maintenance access with this module.
- Opportunity for educational programming
- Ecosystem function and recreation may overlap

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Overpass Type 1

Elevated wildlife crossingr for non-human species



CONSIDERATIONS:

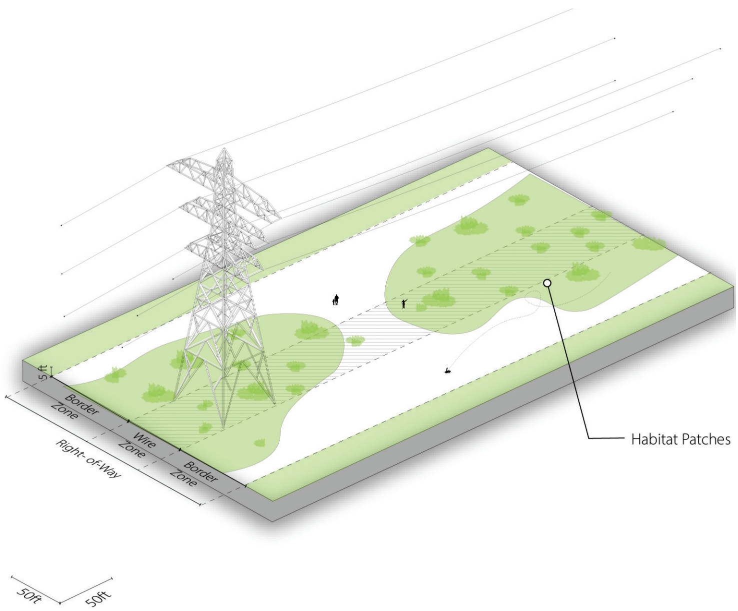
- Requires construction of a specialized crossing structure.
- The width of the crossing structure and corridor can be modified to fit the preferences of target species.
- The soil depth of the crossing strucutre doesn't need to support shrubs or trees under the wire zone, and thus can be kept smaller.
- The module would require adequate fencing to direct animal species' movement and prevent conflicts with motorists.
- Simultaneous wildlife use and human (recreational) use are usually incompatible and must be kept separatet.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Pollinator Habitat

grassland and shrub habitat for pollinator species



Name/ Participant Number:

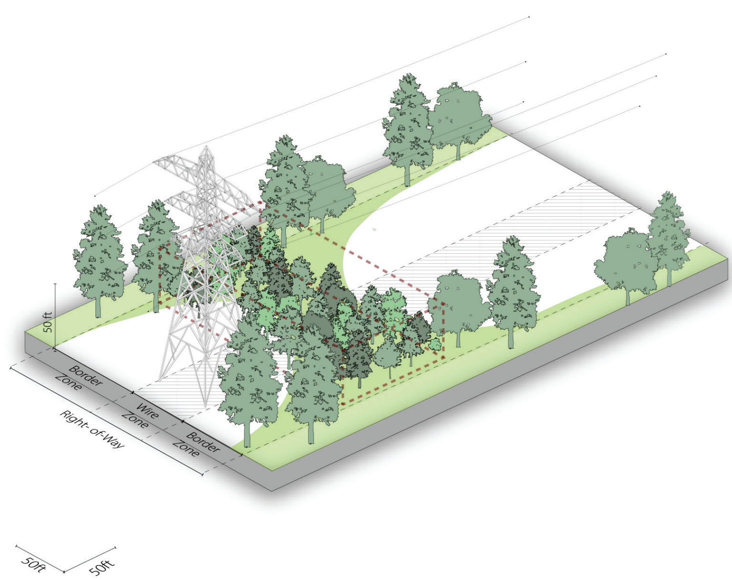
CONSIDERATIONS:

- Transmission rights of way can function as habitat for wildlife, especially grassland and meadow species which rely upon early successional ecosystems.
- Flowering species provide habitats suitable for pollinators.
- Pollinator-friendly species typically remain below 15' in height, allowing them to be placed anywhere throughout the corridor.
- Long contiguous corridors provide for free movement of pollinator species.
- Meadow/grassland requires maintenance every 1-3 years to prevent shrub encroachment.
- Possibility of invasive plants is high in open, sunny ecosystems with repeated disturbance.
- Opportunities exist for educational programming.

REACTIONS/NOTES (please mark up this card):

Low Forest Crossing

Forest crossing across the corridor to reduce forest fragmentation.



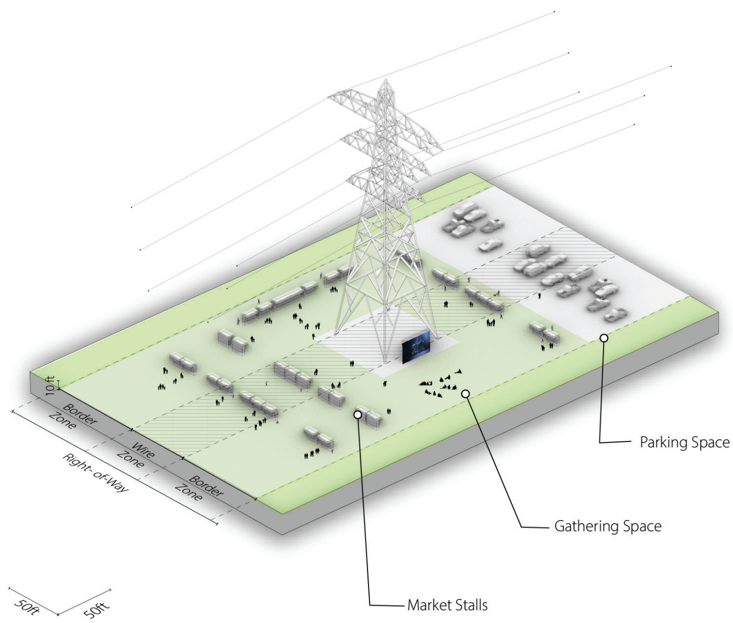
Name/ Participant Number:

CONSIDERATIONS::

- Shrubs and low-growing trees in the right of way help to maintain tree cover, increasing forest connectivity.
- Vegetation must occur as close to the tower as feasible, to minimize interference with wire sag and sway within the wire zone.
- Consistent vegetation management of the low forest corssing is vital to ensure tall-growing (incompatible) tree species do not establish, as they could quickly outgrow the maximum allowable height and interfere with safety.
- Opportunities for utility to partner with conservation organizations to share costs of vegetation management and monitoring.

REACTIONS/NOTES (please mark up this card):

Farmers Market



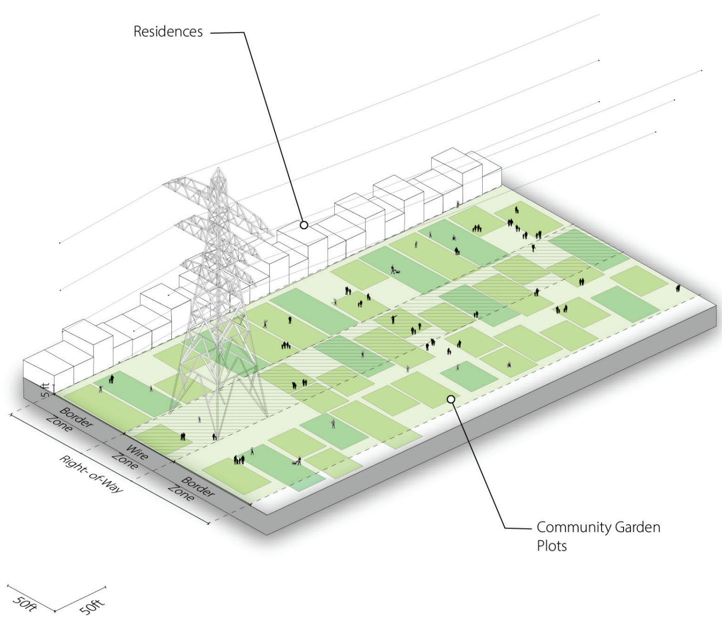
Name/ Participant Number:

CONSIDERATIONS:

- Requires an access road, from where goods and people can be transported to and from the space.
- Benefits from proximity to population center, neighborhoods, and/or communities.
- Temporary (non-permanent) structures such as market stalls and portable toilets permitted below transmission lines.
- Provides open space for community gathering and economic activity.
- Market space may be multi-functional with several activities occurring at different times or simultaneously.

REACTIONS/NOTES (please mark up this card):

Community Gardens



Name/ Participant Number:

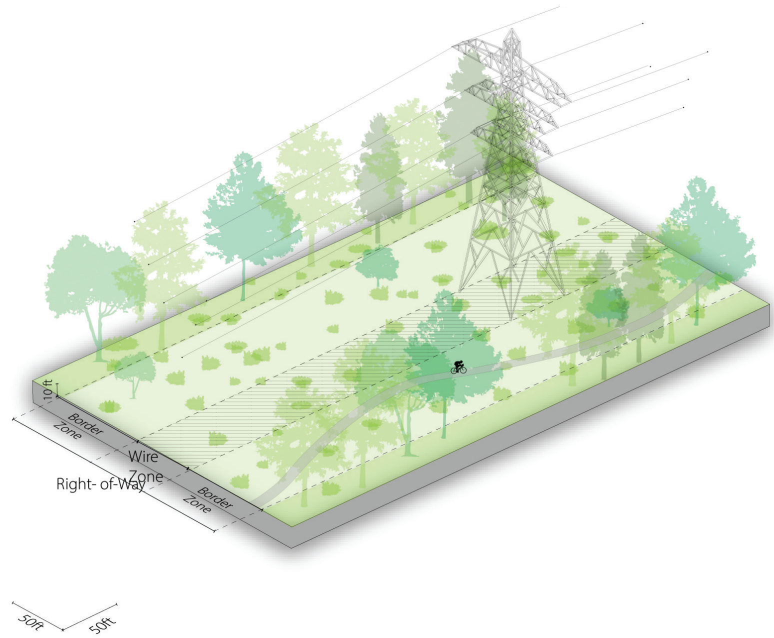
CONSIDERATIONS:

- Can create important gathering and cultivation spaces in dense urban neighborhoods.
- Irrigation water source required.
- Can incorporate green waste processing, composting, material stockpiling and some plant nursery functions.
- Fencing required. Access can be controlled to members or open to public.
- Ownership of this space would determine the method of leasing the plots to community members.

REACTIONS/NOTES (please mark up this card):

Trail Type 1

Undulating, Paved, in the Border Zone



CONSIDERATIONS:

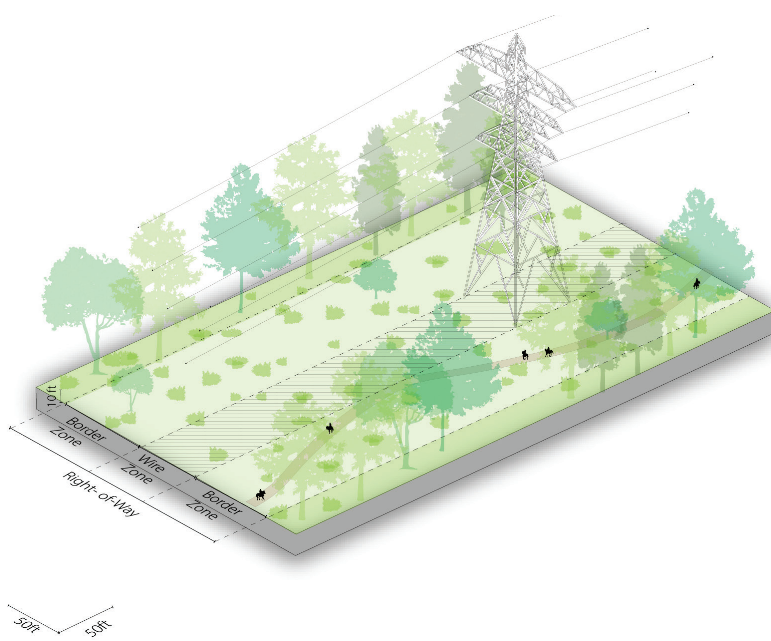
- Paving can accomodate cycling, walking, and maintenance vehicles.
- Trail may co-exist with access road if maintained as a 30' service access way, or may diverge from the access road as a narrower trail.
- Trail design can seek to maximize variety of views and experiences along the corridor.
- Trail can engage with edge of righ-of-way, creating visual variety through proximity to adjacent land uses.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Trail Type 2

Undulating, Unpaved, in the Border Zone



CONSIDERATIONS:

- Unpaved trail can accomodate hiking, mountain biking, horses, ATVs, and other off-road users.
- Trail may co-exist with access road if maintained as a 30' service access way, or may diverge from the access road as a narrower trail.
- Horses should not occupy the same trail as mountain bikes, but can share space with hikers and maintenance vehicles.
- Trail design can seek to maximize variety of views and experiences along the corridor.
- Trail can engage with edge of righ-of-way, creating visual variety through proximity to adjacent land uses.

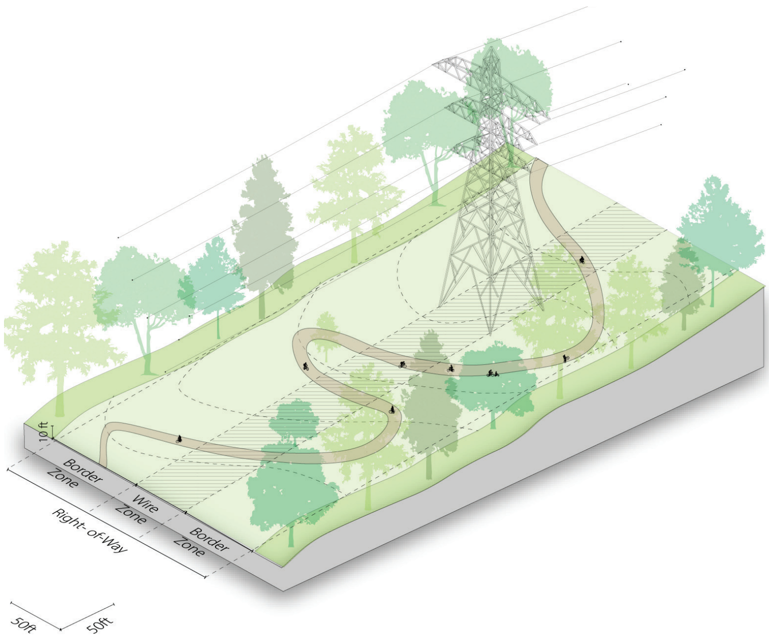
REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Full deck of module cards distributed at start of workshop (1/4)

Trail Type 5

Undulating, Paved or unpaved, Across entire ROW width



Name/ Participant Number:

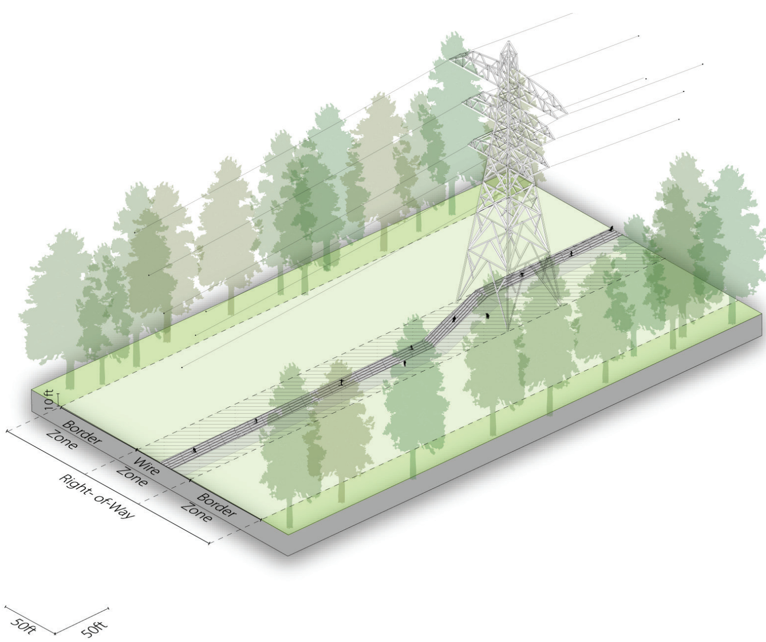
CONSIDERATIONS:

- This module accomodates rough and/or significantly sloped terrain.
- Trail route can take advantage of existing topographic variation. Switchbacks allow access across steep grades.
- Trail can have a paved or unpaved surface, making it more suitable to particular users (mountain bikers, horses -- See Trail Type 2).
- Trail may co-exist with access road if maintained as a 30' service access way, or may diverge from the access road as a narrower trail.
- Trail design can seek to maximize variety of views and experiences along & across the corridor.

REACTIONS/NOTES (please mark up this card):

Trail Type 4

Straight, Unpaved, in the Wire Zone



Name/ Participant Number:

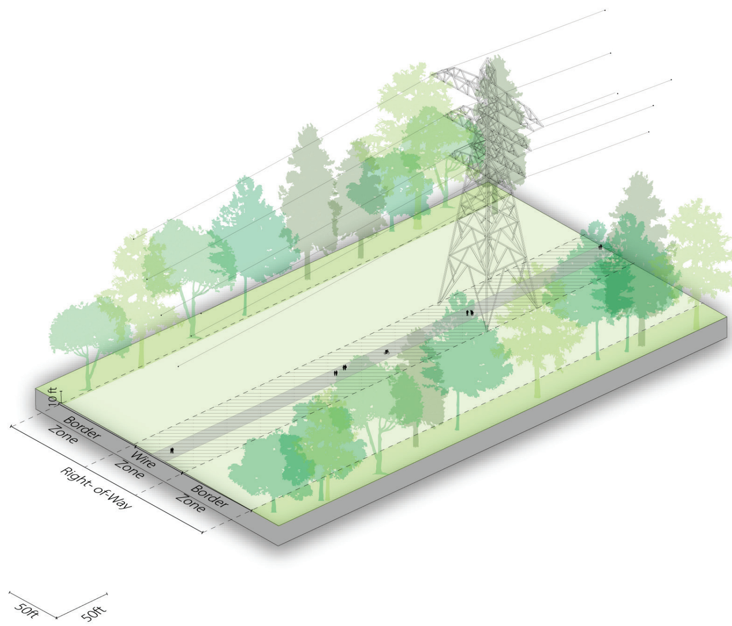
CONSIDERATIONS:

- This trail type necessitates a level or very gentle topography along the right of way.
- Straightness of trail creates a dramatic linear experience (forced perspective).
- Alignment with towers creates opportunities for up-close engagement.
- Unpaved surface can accomodate hiking, mountain biking, horses, ATVs, and other off-road users--or cross-country skiing or snomobiles in winter.
- Enables easy access to vegetation management within the wire zone.
- Consider where the trail may diverge from the maintained 30' service accessway.

REACTIONS/NOTES (please mark up this card):

Trail Type 3

Straight, Paved, in the Wire Zone



Name/ Participant Number:

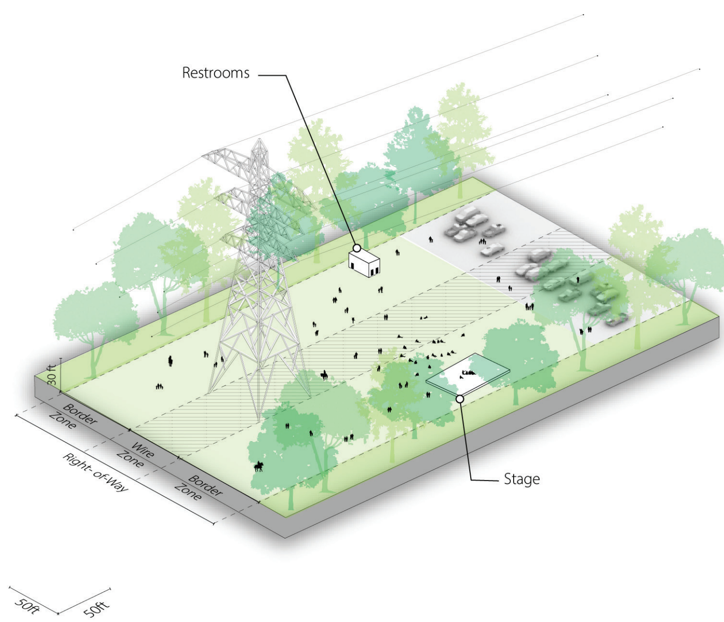
CONSIDERATIONS:

- This trail type necessitates a level or very gentle topography along the right of way.
- Straightness of trail creates a dramatic linear experience (forced perspective).
- Alignment with towers creates opportunities for up-close engagement.
- Paving can accomodate cycling, walking, and maintenance vehicles.
- Enables easy access to vegetation management within the wire zone.
- Consider where the trail may diverge from the maintained 30' service accessway.

REACTIONS/NOTES (please mark up this card):

Gathering Space

performance and gathering space along the corridor.



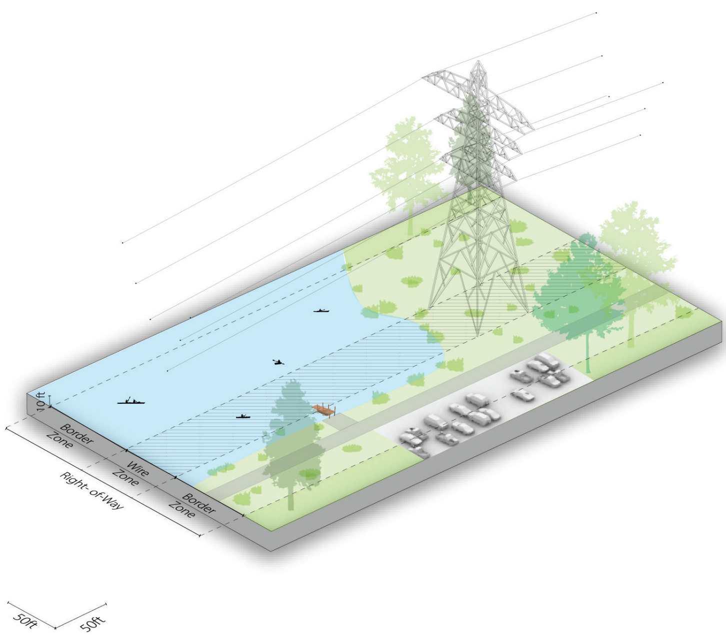
Name/ Participant Number:

CONSIDERATIONS:

- Primary public assembly spaces occur outside the wire zone.
- Parking space required to accommodate a large number of visitors.
- Consider impact of light and amplified sound to surroundings.
- Provides an activity node within the linear corridor space.
- Small support strucutres (such as restrooms and stages) outside the wire zone.
- Compatible with trail systems and recreational uses.

REACTIONS/NOTES (please mark up this card):

Boat Launch



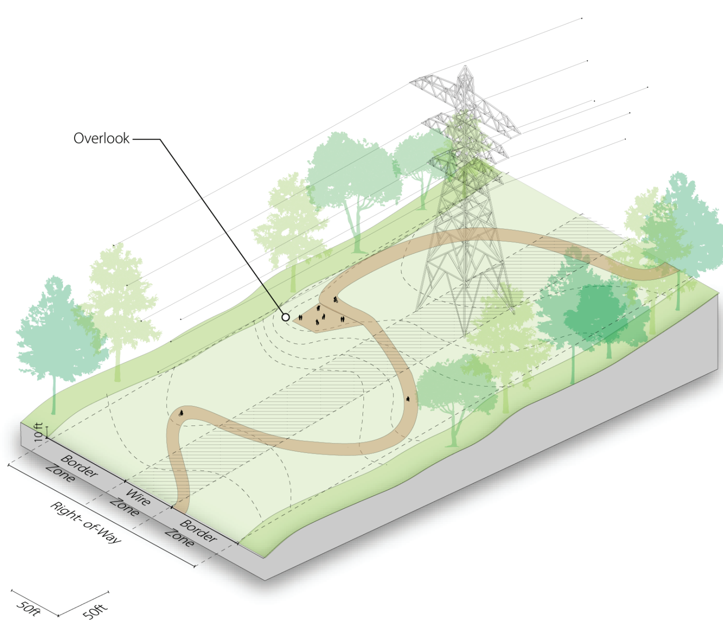
Name/ Participant Number:

CONSIDERATIONS:

- Provides an access point within a larger network of trail- or water-based recreation
- .Proximity to a water body is required.
- Boat launch can take advantage of access road.
- Adequate parking may require coordination with adjacent land owners.
- Ecosystem function and recreation function may overlap.

REACTIONS/NOTES (please mark up this card):

Overlook



Name/ Participant Number:

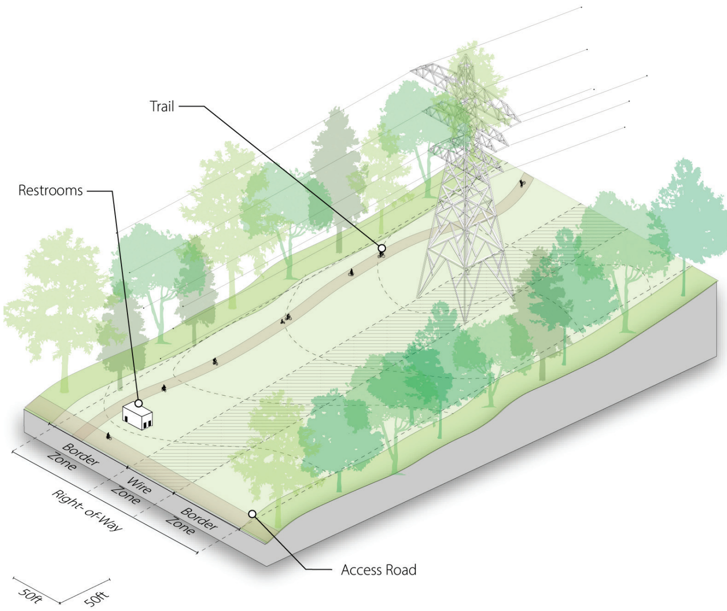
CONSIDERATIONS:

- Most effective when combined with a vantage point provided by change in topography or a long open view.
- Position to orient the view towards significant landscape features
- Can also accommodate other amenity structures, like restrooms and visitors centers.
- Opportunity for educational programming
- Opportunity for educational programming -- supports legibility of landscape features, local ecosystems, or the transmission corridor itself.

REACTIONS/NOTES (please mark up this card):

Amenity Structure

Amenities like restrooms or visitor's center



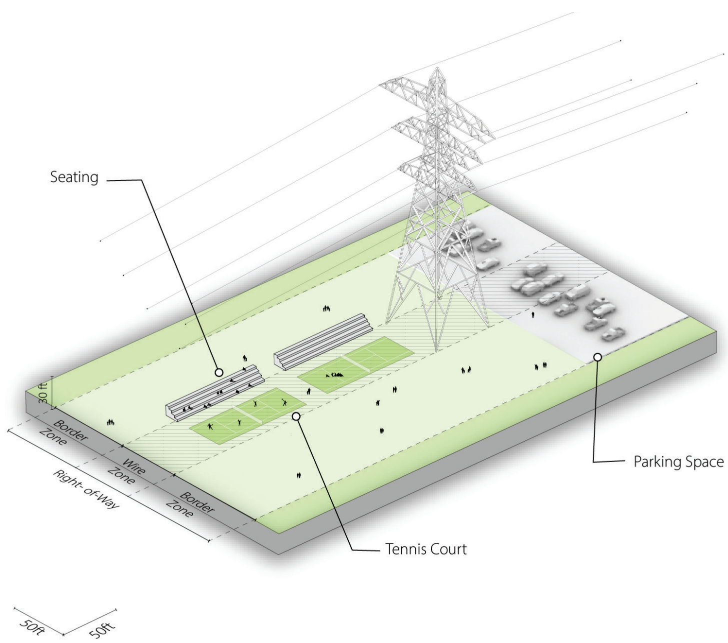
Name/ Participant Number:

CONSIDERATIONS:

- Can be particularly useful in areas with a lack of public amenity structures.
- Small strucutres can exist outside the wire zone.
- Suports trail functions and trail users.
- Provide clear space between restroom entrance and trail.
- Can have parking and be located near an access road (See Trailhead module) or be accessible only via the trail itself.

REACTIONS/NOTES (please mark up this card):

Sports Fields



Name/ Participant Number:

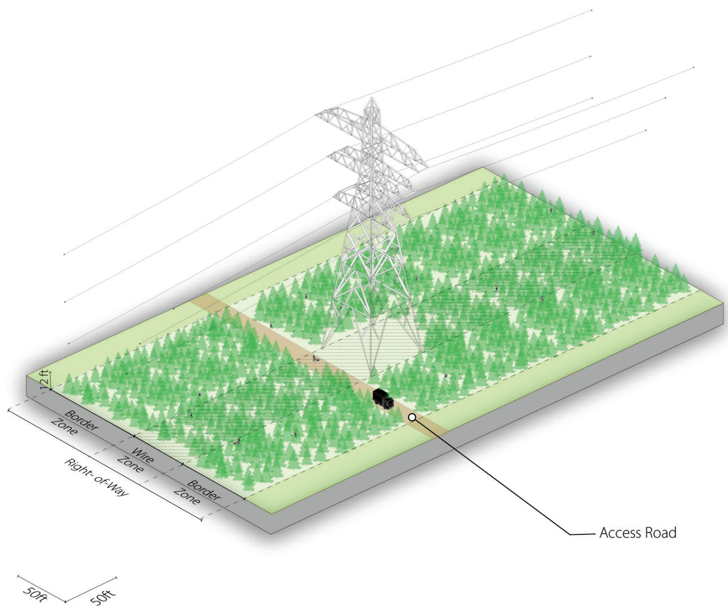
CONSIDERATIONS:

- Benefits from proximity to residential areas -- sports events establish the corridor as a public gathering space.
- Low clearance of most track and field sports and many ball-sports allows flexible layout within the right of way.
- Requires road access and parking.
- Ability to take over longer or shorter lengths of the tranmission corridor allows for smaller and larger sports complexes based on the size of the user base and community needs.

REACTIONS/NOTES (please mark up this card):

Tree Farm

Commercial tree farms



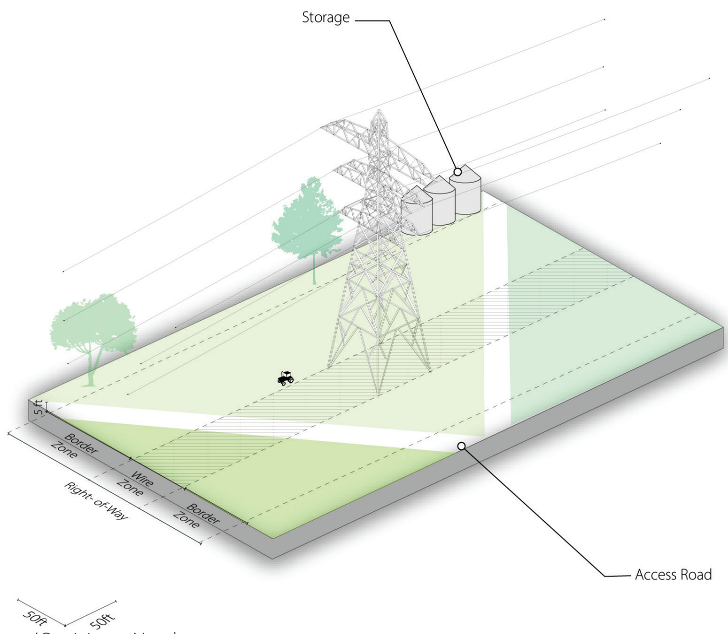
CONSIDERATIONS:

- Trees need to be harvested before reaching 12' to avoid conflicting with the wire zone.
- May require fencing to protect from grazing.
- Access can be controlled or open to public.
- Provides some degree of habitat and ecosystem services.
- Requires an access road, from where goods and people can be transported to and from the space.
- Compatible with trails and other recreational activities

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Large-Scale Agriculture



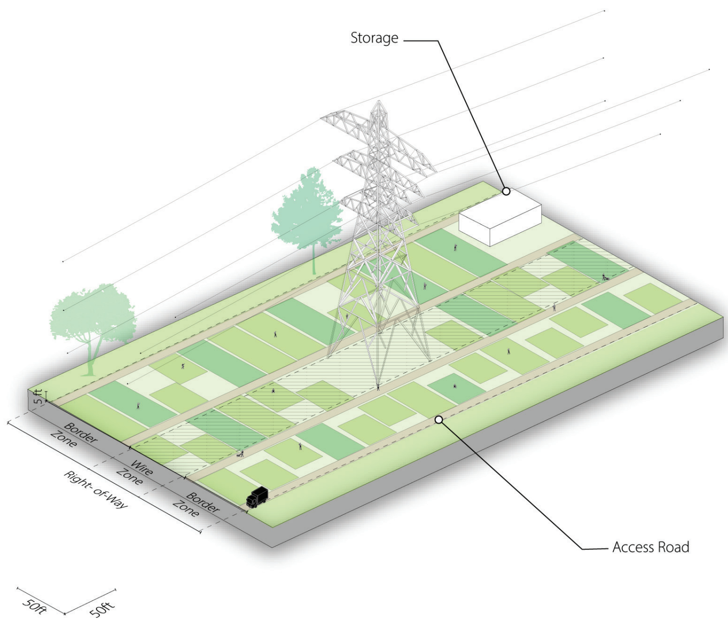
CONSIDERATIONS:

- Low clearance of row crops, vegetables and managed orchards allows flexibility of arrangment.
- Active management of land reduces need for utility vegetation management.
- Storage structures can be placed in the border zone or outside of the right of way. Special rules govern height limitations on strucutres like grain storage.
- Requires an access road, from where goods can be transported to and from the space.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Small-Scale Agriculture



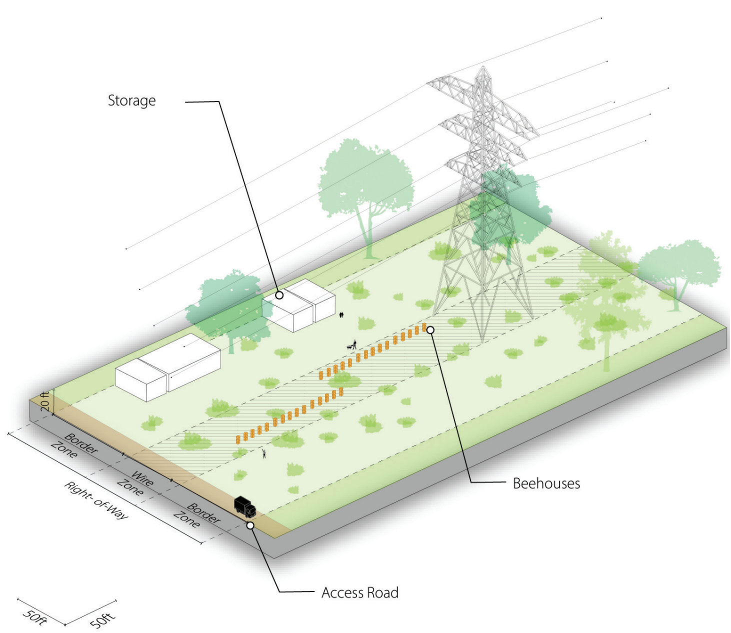
Name/ Participant Number:

CONSIDERATIONS:

- Low heights of row crops, vegetables and managed orchards allows flexibility of arrangment.
- Active management of land reduces need for utility vegetation management.
- Storage structures can be placed in the border zone or outside of the right of way. Special rules govern height limitations on strucutres like grain storage.
- Requires an access road, from where goods can be transported to and from the space.
- Flexible in scale, from community-based to commercial agriculture.

REACTIONS/NOTES (please mark up this card):

Beekeeping



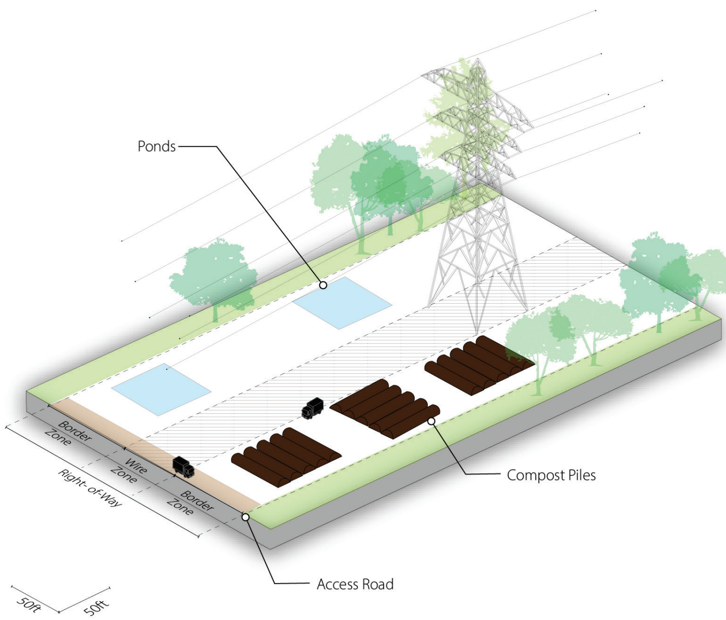
Name/ Participant Number:

CONSIDERATIONS:

- Can accommodate hives in fixed locations, or nomadic beekeeping at various sites along the transmission corridor.
- Can support habitat restoration or agriculture -- Consider position of bee-keeping areas to support pollination in nearby agricultural areas or other habitats.
- Hives should be located away from public gathering areas.
- Can be tended by property owner, or by third-parties.
- Requires an access road, to access or move beehouses.
- Opportunity for educational programming.

REACTIONS/NOTES (please mark up this card):

Industrial Composting



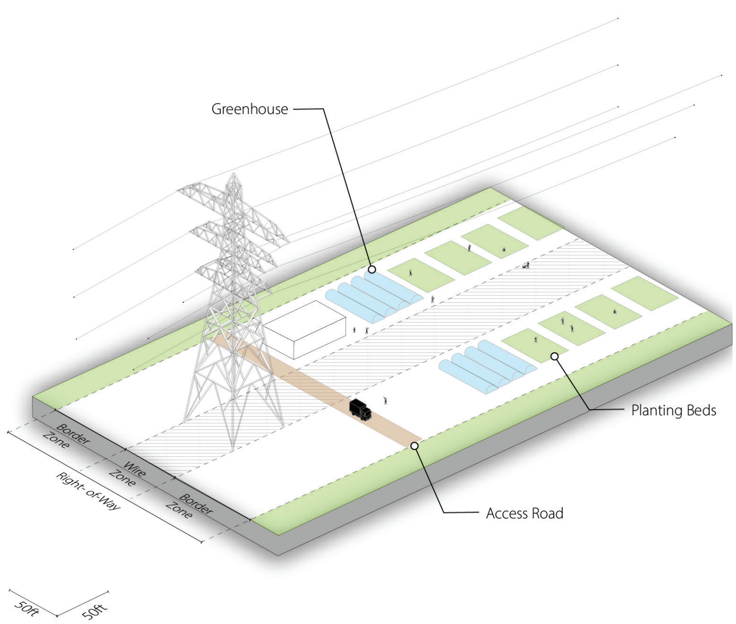
CONSIDERATIONS:

- Particularly useful in areas where the corridor goes through a private farmland.
- Provides space for processing cuttings and chipped wood from corridor vegetation management.
- Provide a structurally stable access road for large trucks for organic waste delivery and finished compost pickup.
- Large compost, earth or "spoils" piles generally prohibited in the wire zone.
- Access is controlled (fencing).

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Plant Nursery



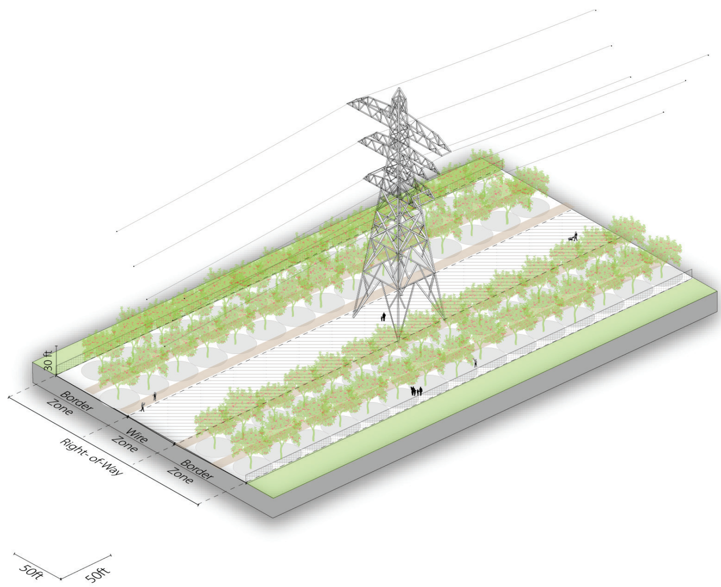
CONSIDERATIONS:

- Low clearance of high-tunnels, propogation areas, and potted plants allows flexible layout
- Can support low-cost lease for commercial operations in areas where the corridor is not suitable for agriculture.
- Parking for staff and public with separate access from truck deliveries.
- Requires areas for material stockpiling -- growing media, seeds, containers, etc.
- Irrigation required.
- Opportunity for educational programming.
- Access is usually controlled (fencing).

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Orchard



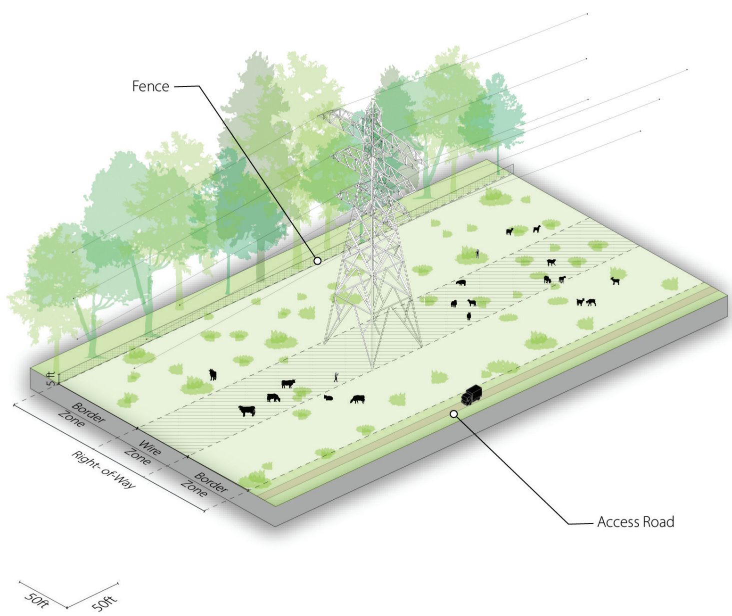
Name/ Participant Number:

CONSIDERATIONS:

- Temporary strucutres and fruit tree planings allowed in the wire zone -- Fruit trees must be low-growing to avoid conflicting with wire zone.
- Irrigation is required.
- Can function as a "u-pick" destination inviting public participation; may be paired with other public programming.
- Public access may be restricted for use of tools or application of fertilizers, herbicides, fungicidses or pesticides.
- Orchard may contribute to ecosystem functions. Benefits from pollination services (see Beekeeping module).
- Requires access road for trucks and orchard equipment.

REACTIONS/NOTES (please mark up this card):

Grazing



Name/ Participant Number:

CONSIDERATIONS:

- Grazing areas may cater to cattle, sheep, goats, or other grazing animals.
- Fencing can be used to control animal grazing within the corridor. Fencing requirements differ by species.
- Fencing does not need to occur at the corridor edge if adjacent land use is also grazing land.
- Must be separated from wildlife areas and public recreation trails.
- Animals may provide vegetation management with no cost to utility operator.

REACTIONS/NOTES (please mark up this card):

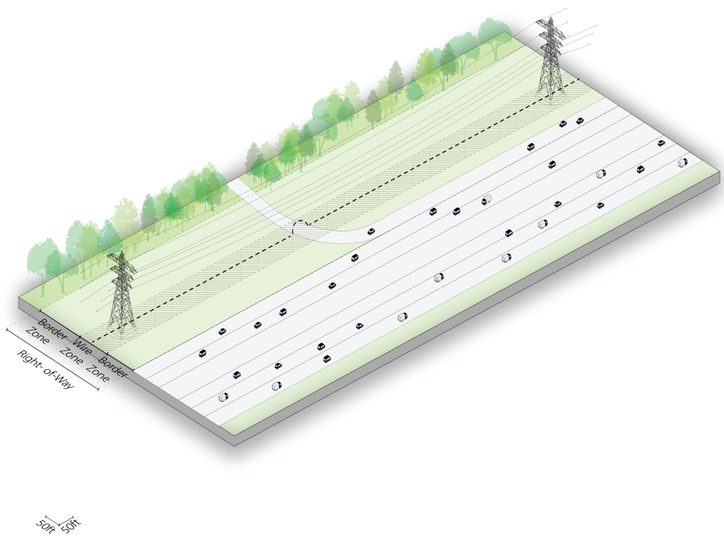
Hunting

CONSIDERATIONS:
- Safety considerations are required in order to co-locate with other recreation activities. Consider orientation of hunting blinds or platforms in relation to public access.
- Requires permission from landowner.
- Benefits from distance away from populated areas.
- Hunting permits and other activities can provide funding and public support for conservation.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Roadway Verge



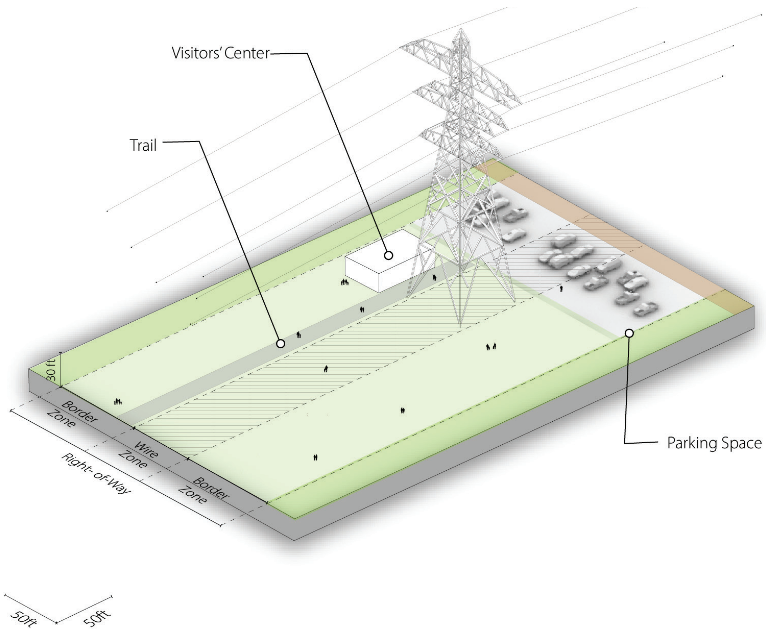
CONSIDERATIONS:
- Using existing right-of-ways reduces impacts on communities and ecosystems, and streamlines approvals by avoiding lenghty negotiations with stakeholders and landowners.
- Towers should be located as far as possible from the roadway if using the transportation right-of-way to avoid conflicts with future road expansion.
- If located adjacent to the roadway, barriers or landforms/ topography are required to prevent collisions of vehicles with the towers.
- Any co-located trails must navigate over/ under any high-speed highway offramps.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Trailhead

Entrance to a trail or trail network



CONSIDERATIONS:

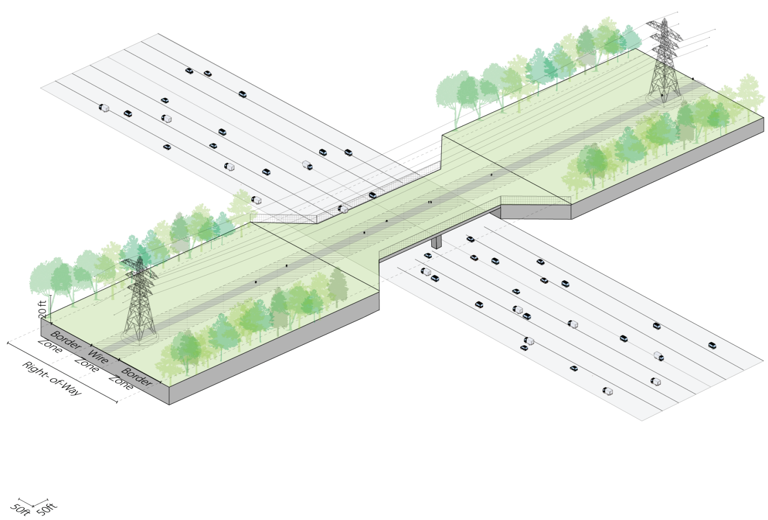
- Provides an entrance point to a trail system and to the cransmission corridor.
- Should be located strategically to provide corridor access at key locations.
- Entrance can attract people to educational programming, signage or exhibits.
- Structures such as visitors centers and information center should be located outside of wire zone.
- Needs to provide safe crossing for trail users at parking lots and road crossings.
- Can be associated with trails, with sports fields, and/or gathering spaces.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Overpass Type 2

Elevated crossingr for humans



CONSIDERATIONS:

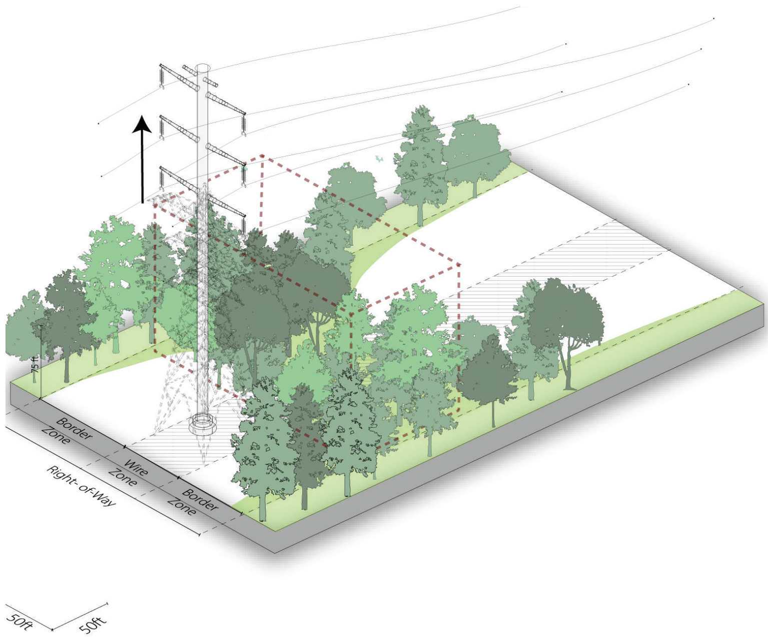
- Requires construction of a specialized crossing structure.
- Potential to connect areas fragmented by roadway infrastructure.
- Crossing structure (bridge) may be much smaller than that of a wildife overpass (See Overpass Type 1 module).
- Fencing to keep people safe from vehicle traffic.
- Compatible with any trail module.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

High Forest Crossing

Forest crossing across the corridor to reduce forest fragmentation.



CONSIDERATIONS:

- Enabled by raising the height (and thus the clearance heights) of a transmission tower at selected points along the corridor.
- Accomodates taller trees in the right of way than the Low Forest Crossing (see Low Forest Crossing module), increasing forest connectivity.
- Vegetation must still occur as close to the tower as feasible, to minimize interference with wire sag and sway within the wire zone.
- Less need to avoid tall-growing (incompatible) tree species, as clearance heights accomodate a wider range of species.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

Ravine Crossing

Forest crossing across the corridor to reduce forest fragmentation.

CONSIDERATIONS:

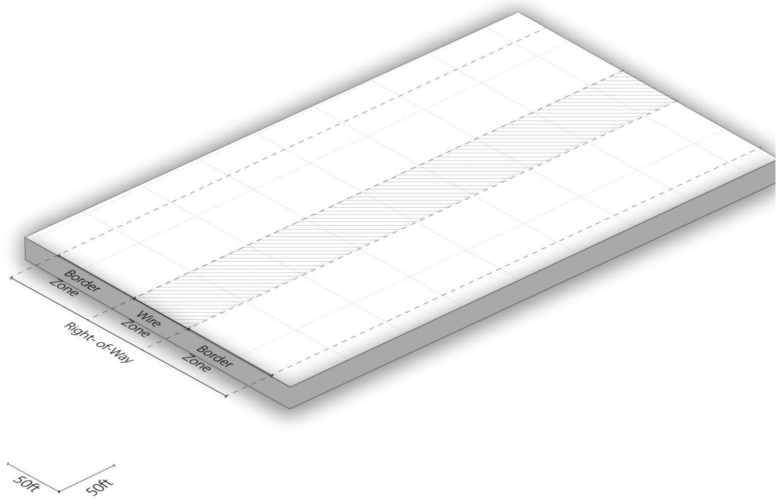
- Takes advantage of natural drops in topography to allow trees into the wire zone, avoiding forest fragemntation and increasing forest connectivity.
- Trees in the wire zone must stay in the lowest area between towers with the greatest clearance heights.
- Less need to avoid tall-growing (incompatible) tree species, as the increased clearance heights due to topography accomodate a wider range of species.

REACTIONS/NOTES (please mark up this card):

Name/ Participant Number:

(Module Name)

NOTES (please mark up this card):



Name/ Participant Number:

(Module Name)

NOTES (please mark up this card):

Name/ Participant Number:

Appendix E: Expanded Technical Considerations for Transmission Corridors

Tower Heights & Minimum Clearances: Engineering and safety requirements consider numerous variables to determine these parameters, but the voltage rating of the transmission line governs every aspect of system design. As PNNL's *An Introduction to Transmission Infrastructure* presentation document states, "Transmission towers are designed to keep high-voltage lines adequately separated from one another and their physical surroundings… The voltage on the lines determines the tower height…" (PNNL, 2025a). Tower heights are designed so as to maintain all the required vertical clearance between the ground or obstacles and the *conductors* (the technical name for transmission wires) at their lowest point, even under conditions of maximum sag. Sag occurs during high temperature and heavy electrical loading in summer (which increases thermal expansion of the conductors), as well as ice accumulation on the conductors in winter (which adds weight). Additionally, because higher voltages result in greater potential to induce current in nearby objects, transmission wires with higher voltages need to be held further from people, structures, vehicles and machinery. Table 232-1 of the National Electrical Safety Code (NESC) provides reference standards for vertical ground clearances to conductors, starting from a minimum of 14.5 feet for pedestrian-only areas, 18.5 feet for roadways and 26.5 feet for railroad crossings for lines carrying 22kV (NESC Table 232-1, 2023). These minimums increase substantially with higher line voltages, at a rate of 0.4 inches per kV over 22kV. For example, the required vertical ground clearance below a 470kV open supply conductor would increase by approximately 15 feet compared to a 22kV line, to 29.5 feet for pedestrian-only areas, 33.5 feet at roadways, and 41.5 feet above railways. Given that conductors may sag 15-20 feet for longer spans, and that these minimums apply to the lowermost conductor (with towers often carrying three conductors in a vertical arrangement along with a ground wire), tower heights can quickly add up. For 500kV high-voltage lines, typical lattice steel tower heights in the US range from 80-200 feet for single-circuit designs (usually with the three conductors arranged side by side, horizontally) and 150-215 feet for double-circuit designs where the tower carries two sets of three conductors, arranged vertically on either side of the tower (PNNL, 2025a). The large spread between the upper and lower numbers reflects a substantial degree of potential variability in the design of towers.

Corridor Width: The Electric Reliability Standard FAC-003-4 published by the North American Electric Reliability Corporation (NERC) establishes Minimum Vegetation Clearance Distances and applies to all transmission lines in the United States with voltages greater than 200kV. For example, Table 2 of the Standard provides clearances based on line voltage rating and elevation above sea level. A 500 kV transmission line requires between seven and over nine feet of clearance (North American Electric Reliability Corporation, 2016). Similarly, the Rural Utility Service and NESC publish standards for minimum clearances to nearby structures (Rural Utility Service, 2025). Clearances vary by building type; NESC standard 234F2 requires special clearances around agricultural structures such as grain bins, with higher clearances required on the loading side to account for equipment like portable augers. Given these complexities, agencies such as the Bureau of Land Management provide guidance on typical corridor width for given line voltages and tower structure types, which range from single-pole systems with 230kV or less, at 50-110 feet in width, to steel lattice towers supporting up to 765kV, at widths of 160-250 feet (Bureau of Land Management, n.d).

Vegetation Management: Because the vertical and horizontal clearances are set relative to the position of the conductor wires, the permitted height of vegetation varies across the cross-section of the corridor. Utility operators across the country have adopted a "wire zone and border zone" approach, which limits growth of vegetation to all but low-growing, stable plant communities such as grasslands and some shrubs in the area directly beneath the conductors — the wire zone (Pacific Gas and Electric Company, 2024). Meanwhile, in the border zone between the wire zone and the outer edge of the ROW, some taller vegetation may be permitted to grow, helping to establish a transition to adjacent plant communities. However, because the applicable codes and Federal and State regulations only define the minimum engineering and safety clearances, in practice transmission owners and operators maintain their own standards for vegetation management and access that reflect the need for safe, cost-effective operations and maintenance.

The rise of Integrated Vegetation Management (IVM) practices in transmission corridor ROWs shows the value of holistic strategies that can provide multiple benefits, both improving environmental quality and reducing costs for utility operators. The Environmental Protection Agency defines IVM as "the practice of promoting desirable, stable, low-growing plant communities — that will resist invasion by tall growing tree species — through the use of appropriate, environmentally-sound, and cost-effective control methods" (U.S. Environmental Protection Agency, 2008). For over twenty years, the New York Power Authority (NYPA) has used IVM to control the growth of incompatible plants, and provide extensive pollinator habitat, as well as plant and ecosystem diversity. Such techniques have since been implemented across the United States (Askins, 2019). In 2013, the Right-of-Way Stewardship Council developed an accreditation process for utility operators effectively implementing IVM, and in 2025 eleven utilities, from NYPA to the Bonneville Power Administration, have received accreditation.

Public Perception: Transmission lines are often seen as undesirable by nearby residents, who may be concerned about aesthetic impacts to the landscape such as the introduction of towers and wires or disturbances such as the cutting of trees, potential impacts to home and property values, changes to permissible land uses within the ROW, or a fear of health risks stemming from transmission lines' electromagnetic fields. While "there are no known health risks that have been conclusively demonstrated to be caused by living near high-voltage power lines" (Zeman, n.d.), for some people such health fears continue to persist. Such fears are enhanced by tangible phenomena, such as the sound that transmission lines can produce — when a strong-enough electromagnetic field around a conductor interacts with sufficiently moist air, "an electric discharge can ionize the surrounding air, which can sound like a humming or crackling noise" (PNNL, 2025a). Nuisance shocks can also occur when electric fields around transmission conductors "induce a voltage on the metal frame of a vehicle if parked on a nonconductive surface ... especially in humid weather" (PNNL, 2025a) and while not dangerous, can result in an unpleasant shock "comparable in sensation to household static electricity" (PNNL, 2025a). A goal of the multi-benefit approach is to mitigate negative views by creating more compelling public experiences under transmission lines and providing more dual-use opportunities for tangible public and ecological benefits, both of which can be enhanced through design.

Trail Co-Location: State and local governments and trail advocates have identified transmission corridors as a means of providing residents with access to nature and recreation, as well as trail links between, or extensions, of existing trails. Implementation of trails within transmission corridors typically brings together a range of stakeholders. For example, the coalition supporting the "Route of the Badger" trails project in Southeastern Wisconsin includes the Rails to Trails Conservancy, cycling advocates, the regional planning commission, numerous municipalities, nonprofits, and private citizens. This system with over 700 miles of trails seeks to link existing trails to new pathways including those within transmission corridors operated by We Energies. Here the "Powerline Trail" offered access of underserved communities in Milwaukee to the larger recreational and trail network (Rails to Trails Conservancy, 2025). Resolving liability concerns for operators can contribute to significant expansions of recreational amenities. For example, in 2013, the Texas Legislature passed HB200 2013-14 which reduced liability exposure for utilities allowing public activities on their easements. This change opened for possible trail development over 500 miles of corridor ROWs operated by CenterPoint Energy in Houston (Schmitt, 2014). A similar agreement between Oncor Electric and the City of Dallas in 2018 resulted in the utility donating 110 acres of land to the City, provided it would maintain transmission easements there. Numerous smaller examples exist across the country, resulting in successful transmission trail collaborations.

Highway Co-Location: While IVM and the incorporation of trail systems represent notable developments for the management of existing corridors, the need for new or enlarged transmission corridors has raised the question of where to find space for these new or enlarged ROWs. Co-location along roadways and other transportation ROWs has gained interest as an opportunity for enabling transmission routing in places where acquiring a standalone transmission corridor is difficult. Integration of transmission corridors with other infrastructure offers one means to streamline both ROW acquisition and implementation. For example, co-locating transmission with transportation infrastructure on state-owned land radically reduces the number of stakeholders — from landowners to regulatory authorities — involved in a project and also provides consistent conditions for tower placements. State Departments of Transportation (DOTs) have authority to prepare Utility Accommodation Policies that determine permitted co-locations. Currently 42 states allow longitudinal transmission lines with DOT discretion, nine prohibit them, and some actively promote alignment. In addition to the safety concerns and clearances mentioned above, a wide, unobstructed clear zone is required between the roadway edge and the towers to avoid potential collisions of vehicles with towers (O'Neil et al., 2025). The design of DOT ROWs also generally provides the potential to expand the number of lanes in the future. However, the high cost of relocating transmission towers can prevent DOTs from being able to easily add lanes.

Undergrounding: Most discussions of transmission infrastructure center on overhead wires and towers, but underground transmission offers potential to address some of the aesthetic and technical concerns associated with overhead structures. Underground systems, which are most common in urban areas, cost considerably more to install than overhead systems. However, in some cases these costs may be offset by long-term benefits. For example, in 2021 the California utility PG&E embarked on the undergrounding of 10,000 miles of power lines to reduce the risk of potential wildfires from equipment failures, vegetation, or down or sagging lines along its transmission corridors. In this case, perceived aesthetic, safety and risk-reduction benefits outweighed the increased cost, estimated to be ten times that of replacing overhead lines (Gawler & Pandey, 2023). From an aesthetic standpoint, underground systems eliminate all visible tower infrastructure. From an ecological perspective, while underground transmission systems require extensive trenching and ground disturbance at the time of installation, as well as large concrete access vaults every 2,000-2,500 feet (National Grid, 2015) as well as an access road. However, the narrower ROW of only 10-12 feet would enable forest canopy closure above the buried lines, significantly reducing forest fragmentation. While the option of selective undergrounding opens some additional opportunities for multi-benefit corridor design, cost remains a key concern and limitation preventing undergrounding from being considered a default option. For this reason, the workshop focused primarily on aboveground transmission arrangements, with selective consideration of undergrounding on a site-specific basis when such undergrounding could offer significant aesthetic, ecological, resilience, or multifunctionality benefits.