Dual-use Solar in the Pacific Northwest

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Executive Summary

This report updates readers on new research in dual-use solar and explores important considerations for the implementation of dual-use solar in the Pacific Northwest region. In the last few years, new findings suggest there are many environmental and economic benefits of creating multifunctional systems that combine and prioritize multiple land uses. New research of dual-use solar facilities shows increased yields in some crops and decreased water needs; benefits to grazing animals such as decreased heat stress; improved ecosystem services such as better water quality, erosion control, carbon storage, and pollination services; and further opportunities for dual-use implementation.

This report begins by reviewing the Northwest landscape in terms of the current status of dual-use projects in the region and projected outlooks, new policy changes and available funding, and current energy needs and trends. New research, since 2019, is reviewed in six areas:

1. Crop Compatibility, Productivity, and Water Retention
2. Technology Advances
3. Livestock Grazing
4. Ecosystem Services
5. Regenerative Practices
6. Dual-Use Potential

Though there may be many benefits of dual-use solar, embarking on the construction of a dual-use system requires extensive planning and forethought. Planning a dual-use system in the region must include a local focus on engaging with communities and considerations such as changing weather patterns and microclimates. There are still data gaps where research is currently being devoted, with results a few years away.

Practical considerations and additional resources are then provided for four areas:

1. Livestock Grazing and Solar
2. Pollinators and Solar
3. Crops and Solar
4. Conservation and Solar

The Pacific Northwest is a region known for its pioneering efforts toward fighting climate change. More renewable energy resources need to be built in the region to accomplish clean energy goals. Farmland protection and responsible siting of solar energy facilities are two important areas to prioritize. Dual-use solar is becoming a legitimate tool to bring together stakeholders, invest in rural communities, minimize land-use conflict, and work toward a clean energy future.

1. Introduction

The concept of building dual-use solar projects in the Pacific Northwest is gaining momentum. Dual-use solar is the practice of co-locating photovoltaic solar with another land use such as food crops, pollinator plants, livestock/grazing animals, conservation work, and other efforts that provide ecosystem or community benefits to the land. Of these, the practices that co-locate solar with appropriate agricultural land are referred to as agrisolar.[1] Increasing pressure on land uses for farming and energy production as well as efforts to maintain natural ecosystems necessitate solutions that maximize the co-benefits of land with multiple ecosystem services.[2] Since Renewable Northwest's report on dual-use in 2019,[3] there has been new research showing exciting potential on the benefits of dual-use solar, as well as new insight for achieving successful implementation. In 2022, the National Renewable Energy Laboratory published five factors of success for agrisolar systems including climate and specific location factors, configurations and layout of solar technologies, crop selection, cultivation and management approaches, compatibility for all stakeholder goals involved, and collaboration with those involved as well as the local community. While many studies are underway with results still a few years off, there are some new insights that illuminate the possibilities dual-use has to offer. This report will provide updated information on dual-use solar that can be applied in the Pacific Northwest region of both Washington and Oregon.

1.1. Why the Pacific Northwest?

The Pacific Northwest is at the forefront of fighting for a stable climate future. Pioneering more dual-use projects is an avenue that is ready to be explored further. The region is known for its productive soils, with generations of farmers and ranchers producing important products that significantly contribute to the economy. The agriculture industry makes up more than 13% of each state's economy, generating $13.8 billion in 2017 and creating nearly 300,000 jobs.[4] In eastern Washington and Oregon, farmers face many difficulties, including an alarming trend of water shortages and

[1] Agrivoltaics is another term used to refer to co-location of solar and agriculture such as food crops and animal grazing. However, there is variation in how different groups define agrivoltaics and what can be included in the term. Here we use "dual-use" and "agrisolar," which are broader terms, as defined above.
[2] https://www.sciencedirect.com/science/article/pii/S2212041620301698
[3] https://renewablenw.org/sites/default/files/Reports-Fact%20Sheets/Dual-Use%20Solar%20Report_FINAL.pdf
[4] https://www.climatehubs.usda.gov/hubs/northwest/topic/agriculture-Northwest

drought. One of the findings of dual-use solar research is improved water retention, making the prospect of wider implementation alluring to many. There are also varying perspectives surrounding dual-use solar. Some are unsure of its practicality, as not many projects exist and there is not much information regarding the deployment of utility-scale dual-use projects. Furthermore, there are a growing number of questions about compatibility with solar projects at varying scales and configurations. This update will investigate how dual-use projects are progressing in the Pacific Northwest, review published studies, preview some important work on the horizon, focus on the wide opportunity at hand, and provide a simple guide for those who may be interested in beginning their own dual-use venture.

1.2. New Policy and Funding

There have been several advancements in policy shaping the future of clean energy in the United States. The Biden Administration recently set a goal of reaching 100% carbon-free electricity by 2035 and many states have similar goals or policies to eliminate greenhouse gas (GHG) emissions. For instance, Oregon passed House Bill (HB) 2021 which is a statewide clean energy mandate requiring emission levels from electricity to be 100% below baseline levels by 2040. Similarly, Washington state adopted the Clean Energy Transformation Act (CETA) committing the state to an electricity supply free of GHG emissions by 2045. Washington has also committed to achieving net zero statewide GHG emissions by 2050, necessitating a dramatic increase in clean electricity as the state begins to electrify various sectors like transportation and home heating and cooling.[5] An important note about Northwest clean energy mandates is that they not only require energy to be produced from clean sources, but they also promote clean energy projects with co-benefits. Oregon's HB2021 establishes that clean energy projects should create additional direct benefits, such as those pertaining to employment, equity, and resiliency. Similarly, Washington's CETA defines "public interest" as including the equitable distribution of energy benefits as well as public health, economic, and environmental benefits. Dual-use projects can provide these benefits, increasing land-use efficiency and providing other ecosystem solutions specific to the project. This makes the prospect of dual-use an attractive option to help achieve the co-benefit goals.

In Washington's 2023 budget, the state dedicated almost $40 million in grants to certain clean energy projects, with preferences for certain siting criteria and "dual-use solar projects that ensure ongoing agricultural operations, and other sites that do not displace critical habitat or productive farmland."[6] Plus, Washington dedicated another $10

[5] https://www.commerce.wa.gov/wp-content/uploads/2020/12/Washington-2021-State-Energy-Strategy-December-2020.pdf
[6] https://app.leg.wa.gov/rcw/default.aspx?cite=82.16.182

million of the climate commitment account established by the state's 2021 Climate Commitment Act for "a pilot program that will provide grants and technical assistance to support planning, predevelopment, and installation of commercial, dual-use solar power demonstration projects."[7]

Oregon is also investing in projects that could help with dual-use development. In 2016, the Community Solar Program was established as part of Oregon's "coal-to-clean" bill. Here, utility customers can pay to subscribe to a particular project and in return, receive a credit on their bills reflecting the energy generated by that project. The program does not mention dual-use specifically, but the model of creating a more intimate connection between subscribers and a specific project means that projects with co-benefits (like dual-use projects) are likely to be more attractive to potential subscribers.

Another Oregon program, the "Community Renewable Energy Project Grant Program" established by HB2021, has many provisions that prioritize rural communities for grants for renewable energy projects, storage systems, and infrastructure. Also established by HB2021, is the "Customer-Supported Renewables" program, which allows local governments to partner with a regulated utility to serve their residents with power from a specific clean energy project. Again, while this program and the Community Renewable Energy Project Grant Program do not directly refer to dual-use projects, it is expected that dual-use projects are likely to have more community support, given the co-benefits the projects can offer.

There have also been significant **federal investments** for not just renewable energy, but also dual-use projects. In 2021, the United States Department of Agriculture (USDA) announced funding for the program Sustainably Co-locating Agricultural and Photovoltaic Electricity Systems (SCAPES) and awarded $10 million to the University of Illinois to determine crops best suited to pair with solar. Other SCAPES partners include the University of Arizona, Colorado State University, Auburn University, and the University of Chicago. The research sites of this study include Illinois, Colorado, and Arizona, with results expected in 2025.[8] In December 2022, the Department of Energy (DOE) announced $8 million in funding for projects that integrate solar energy production and farming. The DOE states that the funding is intended to support agrivoltaics and maximize benefits to farmers and local communities by reducing barriers to both community and utility-scale solar energy deployment. The projects selected for the Foundational Agrivoltaic Research for Megawatt Scale funding program are not located in the Pacific Northwest region.[9] However, the studies will produce results that may be

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[7] https://fiscal.wa.gov/statebudgets/2023proposals/Documents/so/soClimateCommitmentActSummary.pdf
[8] https://news.arizona.edu/story/uarizona-partners-10m-usda-grant-expand-research-growing-crops-under-solar-panels
[9] https://www.energy.gov/articles/doe-announces-8-million-integrate-solar-energy-production-farming

incorporated into practices in the Northwest. Topics pertain to technology, socioeconomics, deployment resources, outreach strategies, sustainability, and markets in rural North America.

The federal Inflation Reduction Act changes tax laws that significantly impact the solar manufacturing industry in the U.S. and incentivizes increased installations of solar projects. With the appropriation of $11.7 billion to the Loan Programs Office at the DOE, the office now has an increase of about $100 billion in new loan authority to invest in solar (and potentially dual-use) projects.[10]

2. Update on the Northwest Energy Landscape

Dual-use implementation in the Pacific Northwest is still in its infancy. While dual-use projects have gained more attention in recent years, research on large-scale solar with crops and grazing is still considered to be in the early stages. There are successful examples of crops and grazers co-located with solar in the United States and elsewhere; however, many in the Pacific Northwest are still uneasy about the idea of combining solar and agriculture. Not every site that is suitable for solar is similarly suited for dual-use. There is uncertainty around financial viability, potential fire hazard, and general practicality. Many solar developers as well as owners/operators will be risk averse when considering a new project. Safety concerns include risk to people on site, fire risk, and farm equipment use.

Economic viability is a key factor to consider, as there is more variability with dual-use projects that have more workers and machines onsite that must be insured. Insurance to cover operations beneath panels and any fire hazard a project creates may fall within the landowner's existing insurance, or it may require additional coverage by both the landowner and solar developer. Adherence to dual-use commitments made to the community during the permitting process will need to be supported throughout the lifespan of the project and the roles and responsibilities of solar developers and landowners must be clearly defined. There is a need for additional research and funding to prove dual-use concepts and demonstrate their feasibility and success so that solar developers can become more comfortable with implementing dual-use projects.

The lack of dual-use projects is due to the aforementioned reasons, but there can be other limiting factors as well, including high up-front costs. (There is still uncertainty as to perceived or actual increases in up-front expenses associated with construction and long-term management of dual-use projects). Under most circumstances, a solar developer may not necessarily have the means to invest in the initial costs due to the fact that projects are selected on a competitive basis or designed to work with a fixed rate

[10] https://www.energy.gov/lpo/inflation-reduction-act-2022

under the Public Utility Regulatory Policies Act. Any additional upfront costs, such as those that can come with dual-use projects, have the potential to cause the project to be out-competed by traditional solar projects and fail. Finding additional funding streams and determining better mechanisms to bear any above-market costs associated with dual-use projects may ultimately make them more competitive. The funding source is important to consider as well, as federal funding may trigger a National Environmental Policy Act review, which if not already contemplated, can extend the project timelines past required deadlines. Additional research is needed to investigate the true cost of maintenance, profit-sharing opportunities, and comprehensive financial performance models for different dual-use systems.

Another factor hindering the buildout of all energy projects is limited transmission capacity. In the Northwest, many of the transmission lines carrying energy generation to demand are operating at near capacity, meaning there is often not enough room on the lines for additional power from new sources. This results in fewer energy projects coming online. If there is room on the line to interconnect, the proximity of the project to the transmission lines or substations is also important to consider, as projects proposed further away will require the building of more infrastructure, such as power lines to reach the interconnect, making the project much more costly. Energy projects located near transmission infrastructure may be more practical or preferred when it comes to transmission and the cost of interconnecting to the grid.

The cost of renewable energy and solar, in particular, has become cheaper than conventional energy generation. There is interest in mechanisms that levelize the cost of dual-use projects, so that solar can continue to be cheaper than conventional energy, and there are current efforts to explore developing dual-use projects at a competitive cost while acknowledging potential ancillary benefits. According to Lazard, an international leading financial services company, the levelized cost of solar (along with wind) is the cheapest power source available at $24/MWh on the low end. This does not account for tax subsidies. A separate Lazard analysis shows that the subsidized cost of solar is $0 on the low end.[11] Therefore, there is increasing utility interest in solar procurement in the Northwest and nationally.

Northwest utilities *are* showing interest in procuring more solar. The Washington-based utility Puget Sound Energy shows in their “2023 Electric Progress Report” that they have identified 1000 MW of solar by 2030 and over 2500 MW by 2045 in their “preferred portfolio” of “lowest reasonable cost” resources that they will need to buy or build to meet customer needs and policy obligations. The 1000 MW is nearly twice the amount of solar that was located in Washington at the end of 2022 and it must be developed in the next 6.5 years.[12] Similarly, the utility PacifiCorp, with a service territory

[11] https://www.lazard.com/media/2ozoovyg/lazards-lcoeplus-april-2023.pdf
[12] https://www.pse.com/en/IRP/Current-IRP-Process

including the Northwest, shows over 2,500 MW of solar in their preferred portfolio in Washington and Oregon to be procured by 2030.[13]

Utilities benefit from acquiring power from dual-use solar projects in a number of ways. Of course, solar is a non-emitting energy source, which many utilities are required to procure to meet GHG emissions reduction mandates. While the utility receives the electricity generated from the site, the additional uses co-located with solar have added benefits. For instance, dual-use solar projects can provide developers with a route of site selection that can reduce conflict. Improved community conversation and engagement often occur from the addition of a second land use to a planned solar project. Local communities can be more receptive and supportive of projects when a dual-use option is implemented in the project plan. As such, development timelines may be shortened.

A promising option is co-locating solar with crops. However, land use regulations in Oregon are understandably designed to protect high-value farmland, which is land that is often the most suitable for solar development and comprises a large portion of the state. This results in precluding effective dual-use options as well. Oregon's land use policies state that solar can only be permitted if it is not located on high-value farmland. High-value farmland is defined as "...land in a tract composed predominantly of soils that are: (A) Irrigated and classified prime, unique, Class I or II; or (B) Not irrigated and classified prime, unique, Class I or II."[14] This land use policy can also be challenging for farmland conservation advocates who are fending off other development of non-agricultural uses that can have a significant impact on farmland. In some cases with solar, it is possible to not only maintain agricultural use, but even to co-optimize the project for both agricultural and energy production. Furthermore, most permitting authorities require a solar developer to adhere to a decommissioning plan that requires the land to be restored to its initial condition at the end of the project's useful life.

In contrast, Washington state more or less leaves land-use decisions up to the local counties. Washington does this through the Growth Management Act (GMA) which requires some counties to create and update their own comprehensive plans following 13 land-use goals. The comprehensive plans are aimed at managing population growth and are targeted toward counties with larger or fast-growing populations. Currently, 18 of the 49 Washington counties are required to create comprehensive plans (informed by the public), and 11 more have opted in.[15] The GMA requires counties to identify agricultural resources, as farmland is considered a "natural resource industry" and stipulates that rules should preserve "rural character."[16] Non-GMA counties must still designate agricultural resources but are not guided on how to do so. "This patchwork of GMA

[13] https://www.pacificorp.com/energy/integrated-resource-plan.html
[14] https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=176032
[15] https://mrsc.org/explore-topics/planning/general-planning-and-growth-management/growth-management-act
[16] https://app.leg.wa.gov/rcw/default.aspx?cite=36.70a.070

counties and non-GMA counties, in addition to the relatively vague guidance of the GMA goals around land designated for agriculture, leaves Washington's land-use regime and its application to solar on farmland scattered and uncertain."[17] If developers want to take the permitting route through the county, it leaves them to navigate processes that may have vastly different regulations across counties and provides the counties vague guidance for how to apply agricultural resource land standards to dual-use projects.[18]

Some counties in both Washington and Oregon have implemented moratoriums that temporarily prohibit solar development in specific areas for an allotted amount of time. Solar developers in Washington have the option to get their projects permitted through the county or, alternatively, through the state Energy Facility Site Evaluation Council (EFSEC). Oregon, similarly, has the 'Energy Facility Siting Council' (EFSC). While many developers often voice their desire to go through the local county process, the siting councils have the authority to permit projects in areas with a moratorium. Counties sometimes use moratoriums as a tool to take time to establish exactly what the county would like to see in terms of solar siting. In the moratorium time frame, counties often convene solar siting commissions and draft bylaws. Recently, some counties have created bylaws different from those created for conventional solar siting by making exceptions for dual-use solar in the making of the moratorium.

3. Scalability

Most dual-use projects in the United States are small-scale or community-scale, usually taking up less than 50 acres. There are several universities currently studying the opportunities regarding upscaling to larger acreage, such as Rutgers University, University of Illinois, and Arizona State University. To date, there are few examples of utility-scale dual-use solar projects in the U.S., with the most common type of utility-scale dual-use being the co-location of sheep grazing with solar.[19] Recently, there has been a shortage of sheep in the U.S., resulting in dual-use projects being unable to obtain enough livestock to effectively manage vegetation.[20,21] The opportunity of locating sheep with solar has the potential to increase domestic sheep production if more sheep and solar projects are developed.

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[17] https://renewablenw.org/sites/default/files/Reports-Fact%20Sheets/Dual-Use%20Solar%20Report_FINAL.pdf
[18] https://renewablenw.org/sites/default/files/Reports-Fact%20Sheets/Dual-Use%20Solar%20Report_FINAL.pdf
[19] https://www.sciencedirect.com/science/article/pii/S2772783122000358
[20] https://animalagalliance.org/sheep-production-in-the-united-states/#:~:text=Two%20major%20reasons%20for%20the,consumers%20away%20from%20wool%20products.
[21] https://www.bayjournal.com/news/climate_change/sheep-and-solar-panels-using-solar-sites-for-pastureland/article_c1899a84-c4e2-11ec-b63c-7fa1a501105d.html

There may be additional factors to consider when planning a larger, utility-scale dual-use project. Implementing additional uses at the utility scale such as growing crops is still in the early stages of study and application. Substantial gaps remain in understanding the feasibility of implementing agrisolar systems at scale, but many institutions are studying the best approaches to utility-scale implementation. Depending on the dual-use plan, other factors to consider include the availability of appropriate species for revegetation, the ability to effectively co-manage the site, increased costs, insurability, safety and security, and water sourcing and fencing. There are many new utility-scale dual-use applications being considered as well.

Additional Resources on Scaling-up of Dual-use Facilities:

- Grazing Sheep on Solar Sites in New York State: Opportunities and Challenges
- The Bee and Butterfly Habitat Fund Solar Synergy Utility-Scale Solar Project Support

4. Update on the State of the Science

Since 2019, new research has provided interesting results on dual-use implementation. Many additional studies about dual-use applications will soon be available. Here we review new research on crop compatibility, productivity and water retention, technological advances, livestock grazing, ecosystem services, regenerative practices, and dual-use potential. For more information, the Agrisolar Clearinghouse provides up-to-date resources on co-located solar and sustainable agriculture.

4.1. Crop Compatibility, Productivity, and Water Retention

Although many research gaps remain, the current body of work indicates that agrisolar systems may represent a way to reduce GHG emissions while also broadly supporting the food, water, and energy security of the United States.[22] The 2019 report *Dual Use Solar in the Pacific Northwest: A Way Forward* characterizes agrisolar research at the time. Many recent studies have found further evidence solidifying the potential of dual-use systems. These studies have revealed similar or increased yields of crops, as well as decreased water use in agrisolar systems. Results show a variety of crops that are compatible with agrisolar systems, such as some expected shade-tolerant crops, but others as well. The agrisolar microclimate can extend growing seasons and provide

[22] https://www.mdpi.com/2071-1050/13/1/137#B22-sustainability-13-00137

protection against frosts. According to Gorjian et al., “PV technology has gradually become an energy-saving and cost-effective technique in the transformation from traditional to modern agriculture.”[23] Additionally, the presence of the panels creates microclimates that can extend the growing seasons of the vegetation beneath. The shade created by panels can also provide improved working conditions to those working directly with the crops.

Many studies are now investigating the co-location of crops outside of the usual “shade-tolerant” crops, including traditional row crops such as corn and soy.[24] A 2019 study in Japan found that corn grown within an agrisolar system produced 5.6% higher yields and had 4.9% more biomass than corn grown in control plots with full sun.[25] Studies from France found that lettuce crops grown in agrisolar systems yielded an average of 81-99% of the average yield in full-sun control plots, with some cultivars exceeding the average yield in control plots.[26] Studies in the same region found that the lettuce experienced a short delay in reaching plant maturity, but had a 20% reduction in water use.[27] In Tucson, Arizona, data from an experimental site showed increased fruit production in cherry tomatoes and chiltepin peppers and a small decrease in jalapeno peppers grown in agrisolar systems when compared to the control.[28]

Oregon State University (OSU) studies have found a symbiotic relationship between solar panels and the crops grown beneath them, where each performed better when combined in the same system. Many crops that are grown in a traditional field are exposed to direct sunlight and require more water because the prolonged direct sunlight causes increased rates of transpiration (water loss). Alternatively, with solar panels providing some shade to the crops, leading to cooler temperatures, the crops are not required to transpirate as much and therefore require less water from irrigation. The symbiotic benefit to the panels results from the crops contributing to maintaining a cooler local environment. The cooler temperatures allow the panels to operate about 10% more efficiently.[29] Similarly, the previously mentioned study from Tucson, Arizona, found that shading from the PV panels provided multiple synergistic and additive benefits, such as greater food production, reduced plant drought stress, and reduced PV panel heat stress.[30] However, not all technologies or configurations will necessarily yield similar results. Efficiencies of crops and electricity generation will be extremely site-specific and dependent upon the goals and requirements of the site.

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[23] https://www.sciencedirect.com/science/article/abs/pii/B9780128196106000077
[24] Bowman, Sarah, et al. “Can solar panels and row crops coexist on farmland across the skeptical Corn Belt?” Indy Star, Sept. 13, 2022
[25] https://www.mdpi.com/2076-3298/6/6/65
[26] https://www.sciencedirect.com/science/article/abs/pii/S1161030112001177
[27] https://www.sciencedirect.com/science/article/abs/pii/S0378377418309545
[28] https://www.nature.com/articles/s41893-019-0364-5.
[29] https://agsci.oregonstate.edu/newsroom/sustainable-farm-agrivoltaic#information
[30] https://www.nature.com/articles/s41893-019-0364-5

Even though co-location of crops and solar may not be practical in all locations, in some water-limited areas, co-located solar and crop systems may provide attractive economic incentives in addition to efficient land and water use. There are now more opportunities for those interested in agrisolar systems to draw from a wider body of important agricultural topics[31] such as agroforestry, intercropping, and general agronomics concerning relationships between shading and crops. While extensive progress has been made, many stakeholders are calling for further "proof-of-concept" to illustrate practical needs, such as security in investments and assurance that the financial risk will be minimized. There are many other areas of study currently being investigated with results expected in the coming years. Some of these study topics include diversifying crop compatibility, the use of transparent panels, geospatial assessment of elevated panels, microclimates below the panels (based on height and spacing), water and soil dynamics, socio-political dimensions, and more.

4.2. Technology Advances

An important consideration of dual-use applications is the type of technology that will be used at the site. For instance, there are many different photovoltaic panels available that are built with different properties. There are bifacial panels and traditional monofacial panels. Bifacial panels have the ability to absorb direct sunlight on the front side of the panel as well as reflected light from the rear side of the panel. Another factor is whether the PV system will be fixed or tracking. A tracking system has panels that move on a pivot and "track" the sunlight throughout the day, whereas a fixed system has panels fixed in place that do not move or track the sun. Most utility-scale solar systems being built today are tracking.[32] Thirdly, depending on the other uses for the land, the height of the panels, as well as the width of space between the rows of solar panels, is a major consideration. Livestock, crops, pollinator plants, and other uses may all require a certain amount of space beneath and between the panels. The height of panels is often regulated by local zoning restrictions and can be out of a developer's control, limiting the amount of achievable ground clearance below.

This report does not get into the specifics of what technology to suggest as the research is constantly evolving (especially when it comes to dual-use applications). There are many organizations tracking the best and latest technologies:

- American Clean Power
- Solar Energy Industries Association

31 https://www.mdpi.com/2071-1050/13/1/137#B23-sustainability-13-00137
32 https://emp.lbl.gov/utility-scale-solar/

- National Renewable Energy Laboratory
- Argonne National Laboratory
- Sandia National Laboratory

4.3. Livestock Grazing

4.3.1. Sheep

Grazing sheep is one of the more increasingly common activities being combined with solar. There are some well-understood benefits and there have also been some newer revelations in the last few years. Some findings from a 2022 Cal Poly study found that: sheep grazing under solar panels graze more than sheep on native rangeland, solar panels can protect sheep from climatic conditions and increase their grazing time, and solar panels increase forage digestibility and protein content through more shade and soil moisture.[33] Andrew et al. (2021) compared lamb growth and pasture production in solar pastures versus traditional pastures in Oregon over 2 years. They found that despite lower amounts of herbage offered on the solar pastures in their study, lamb liveweight production did not differ when compared to lambs grazed on traditional pastures, nor did foraging behavior differ substantially between pastures. Additionally, this study found that lambs spent most of their time under the shade of panels and postulated this as a reason for the comparable lamb growth in both systems, as the lambs were less heat stressed with the additional shade. Lastly, the sheep showed either similar or lower water intake than those grazing open pastures.[34]

4.3.2. Cattle

Cattle grazing among solar arrays is another dual-use model that has gained more attention and traction in recent years. Rangeland can hold particular promise for solar, as the partial shade has been shown to benefit forage, especially in arid conditions. In 2021, a University of Minnesota study investigated the effects of grazing dairy cattle under shade from a 30kW solar system. Some of the findings include lower body temperatures and lower respiration rates in shaded cows, and no differences in milk production between the treatment and control groups. “Agrivoltaics incorporated into pasture dairy systems may reduce the intensity of heat stress in dairy cows and increase [both the] well-being of cows and the efficiency of land use.”[35] There are some agrisolar systems in the U.S. that are already co-locating cattle and solar. Hathaway Farm in Vermont currently raises 250 head

[33] https://www.sciencedirect.com/science/article/pii/S0168159122002593
[34] https://www.frontiersin.org/articles/10.3389/fsufs.2021.659175/full#B39
[35] https://www.sciencedirect.com/science/article/pii/S0022030220310730

of beef cattle on their 650-acre farm among a 150 kW array on 5 of those acres[36] and Knowlton Family Farms in Grafton, Massachusetts recently reintroduced cattle to their 150-year-old family operation to graze beneath solar panels.[37] Work is currently being done to make cattle grazing with solar more attainable, including at a larger scale. Rute Foundation Systems is focusing on cattle-grade and cost-competitive solutions for solar components. In February of 2023, Rute was refining their high clearance solar components with vertical, single-axis trackers and cable-stayed poles with meaningful reductions in steel use, to later compare with horizontal, single-access trackers to determine optimal solutions. Rute is installing its first set of trackers in Grant County, Oregon, set to be complete in summer 2023.[38]

4.3.3. Other Animals

Additional grazing and other animal husbandry are being considered in co-location with solar such as pasture-raised rabbits, chickens, and more. California's Sacramento Municipal Utility District is currently grazing chickens on one of their dual-use plots, rather than sheep, which are grazed on their other plots.[39] A study from 2021 presented a conceptual design for a pasture-fed rabbit farm and provided technical, environmental, and economic analyses, finding that "the co-location of solar and rabbit farms is a viable form of agrivoltaics, increasing overall site revenue by 2.5%–24.0% above projected electricity revenue depending on location and rental/ownership of rabbits while providing a high-value agricultural product…"[40] An additional benefit for small animal grazing under panels is increased protection from aerial and ground predators.

There are many resources available now to provide designs and management information for grazing animals located among solar arrays. Livestock production in the Northwest, and nationally, is hindered due to the fact that there are not many animal processing facilities. Some are suggesting that one way to support the livestock industry in the Northwest is through grant funding, where perhaps developers provide matching funds to build USDA processing facilities.[41]

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[36] https://solargrazing.org/wp-content/uploads/2019/06/On-Pasture-Co-location-of-solar-agriculture.pdf
[37] https://www.agrisolarclearinghouse.org/watch-how-agrisolar-helped-the-cows-come-home-to-one-northeast-farm/
[38] https://www.agrisolarclearinghouse.org/rute-suntracker-demonstrates-cattle-grade-agrivoltaics-in-oregon/
[39] https://www.smud.org/en/Corporate/Environmental-Leadership/Power-Sources/Rancho-Seco-Solar-II-Development
[40] https://www.sciencedirect.com/science/article/abs/pii/S0959652620345200
[41] In-person conversations with farmers and others in the industry

4.4. Ecosystem Services

Outside of the previously mentioned dual-use strategies, there are further ecosystem benefits that can be achieved through dual-use systems that integrate conservation and native habitat enhancement. In these configurations, vegetation management often focuses on using pollinator-friendly seed mixes of regionally native wildflowers, grasses, forbs, and other naturalized plants. Some ecosystem services that can be achieved are carbon storage and sequestration, sediment retention, improved pollination services, and improved water quality. A 2021 article measured ecosystem services of carbon storage, pollinator supply, sediment retention, and water retention for native grassland habitat restoration at 30 solar facilities across the Midwest. They compared these ecosystem services across three land use types: agricultural land (baseline row crop and pre-solar), solar with turfgrass, and solar with native species. When compared to pre-solar agricultural land, the solar-native grassland habitat produced a 65% increase in potential carbon storage and a 3-fold increase in pollinator supply, as well as an increase in sediment and water retention at over 19% each. It should also be noted that these results were measured with panels that had 36 inches of ground clearance (the standard is between 18 and 24 inches)[42] and when compared to pre-agricultural land, turfgrass habitat also showed a small increase in the above-mentioned ecosystem services as well.[43] While this is pioneering work, early findings have been proposed using models, and there is extensive research currently devoted to further understanding ecosystem services achieved through dual-use systems with applications directly linking specific projects and ecosystem services they may provide.[44]

Because shading from panels can create a more favorable microclimate for the growth of native and naturalized vegetation, the plant communities can provide greater **carbon sequestration** and **sediment retention** compared to conventional solar vegetation management. While both traditional solar and dual-use systems are carbon-free sources of electricity, dual-use systems located with native vegetation have increased potential to sequester carbon and methane. Shading from solar panels can create more favorable microclimates for native and naturalized vegetation. A 2021 model found that by planting native vegetation, greater carbon sequestration can be achieved compared to conventional solar vegetation.[45] The deep-rooting qualities of many native plants also allow for stabilized soil and **sediment retention.** Deeper root systems can facilitate the accumulation of soil organic carbon.[46] However, it may take several years for this soil

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[42] https://eprijournal.com/can-the-sun-help-pollinators-2/
[43] https://www.sciencedirect.com/science/article/pii/S2212041620301698
[44] https://www.frontiersin.org/articles/10.3389/fsufs.2022.932018/full#B71
[45] https://www.sciencedirect.com/science/article/pii/S2212041620301698
[46] https://www.nature.com/articles/s41467-019-08636-w

organic carbon to accumulate.[47] Similar to sediment retention, a study published in 2023 found that dual-use solar facilities can act as ad hoc biocrust nurseries (crustivoltaics). Biocrust is the community of lichens, mosses, and cyanobacteria that live on the surface of soil in drylands. Biocrust - dubbed the ecosystem engineer of the earth's drylands - reduces erosion, increases the fertility of the soil, captures carbon, and retains soil moisture.[48] The study states that globally, large portions of arid lands are under severe anthropogenic stress, and intervention to restore biocrust is necessary. However, current methods of restoration are done on too small of a scale. Crustivoltaics can help break the scaling barrier, as utility-scale solar sites can significantly promote the formation of biocrust on neighboring soils.[49]

The benefits of restoring **pollinator habitat** have become well-known, as efforts to "save the bees," butterflies, and other insects have become a priority, especially in relation to agriculture and food production. Planting vegetation conducive to restoring pollinator habitat has become an increasingly common practice at solar sites. Pollinating insects are critical in maintaining balanced ecosystems, with many native bee species considered "keystone species." Pollinating insects are also critical to agriculture. A 2021 study found that the earth is losing 3-5% of fruit, nut, and vegetable production due to shrinking pollinator populations and diversity.[50] Many farmers must rely on purchasing commercial bees for pollination services. At utility-scale solar facilities, there may be opportunities to conserve insect pollinators and restore the ecosystem services they provide by maintaining sufficient pollinator habitat. If pollinator plants are grown amongst (or near) solar panels, nearby agricultural fields may benefit from the pollination services (depending on the crop type and pollinator dependency). A 2018 study investigating agricultural benefits of solar-pollinator habitat found that the crops that commonly already exist near utility-scale solar facilities and would benefit the most from the creation of pollinator habitat include: soybeans, alfalfa, cotton, almonds, and citrus.[51] Oregon is among the states with the greatest alfalfa cropland within USSE foraging zones (ranked 4th). Other pollinator-dependent crops of which Oregon has high amounts of cropland near USSE foraging zones are onions, beans, and cherries (ranked 2nd behind California). Other crops grown in the Northwest highly dependent on pollinators include apples, cherries, blueberries, cranberries, and plums. A case study by Argonne National Laboratory found that the value of pollinator habitat on U.S. lands designated as proposed

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[47] https://www.frontiersin.org/articles/10.3389/fsufs.2022.932018/full#B79
[48] https://www.nature.org/en-us/about-us/where-we-work/united-states/utah/stories-in-utah/growing-biocrust-in-utah/#:~:text=Biocrust%20Biocrust%20is%20the%20community,the%20soil%20surface%20of%20drylands.
[49] https://www.nature.com/articles/s41893-023-01106-8
[50] https://www.cell.com/one-earth/fulltext/S2590-3322(20)30651-5
[51] https://pubs.acs.org/doi/full/10.1021/acs.est.8b00020

or potential solar sites is between $1.5 billion and $3.2 billion for energy producers and farmers.[52]

Depending on the project location, by having native grasses, wildflowers, forbs, and other naturalized plants, **water quality** can be improved for local communities. If the dual-use project is located in a Drinking Water Supply Management Area, or Groundwater Management Area, the vegetation located at the project site may contribute to improving water quality. Typically, native wildflowers, grasses, and forbs have long root systems that allow rainwater to soak into the ground and end up significantly reducing the amount of rainwater runoff. The Great Plains Institute is currently studying stormwater runoff at multiple solar sites across the U.S., including a site located in Oregon (Eagle Point Solar),[53] and has developed a stormwater runoff calculator to determine how solar sites have the potential to decrease runoff and improve water quality.[54]

The ecosystem services and benefits that dual-use solar can provide require further study. There are still many questions about the realized outcomes of solar-ecosystem services that require further research and quantification. As native and naturalized plant communities and restored ecosystems can take time to mature, ecosystem services may gradually increase over time. Field-based validation is necessary to fully understand how solar sites can impact ecosystem services. The ecosystem processes of carbon storage, erosion, and runoff need further study in addition to the end-term ecosystem service value calculations noted above. Several institutions are looking into these current gaps in research, including the complete benefits to wildlife, soil health with different plantings, maintaining invasives, and more.

4.5. Regenerative Practices

It is widely recognized that renewable energy generation benefits the environment through reduced carbon emissions, but less well-known are further opportunities for realizing direct and indirect conservation benefits from the design of solar farms.[55] Regenerative agriculture encourages using principles that improve land health. Regenerative agriculture is modeled after indigenous living systems thinking and practices that increase the ecological capacity of the land. Some of the commonly applied regenerative practices include adaptive grazing, limited or no use of pesticides and synthetic fertilizer, no-till planting, and others.[56] Many growers naturally use fewer chemical inputs to prioritize soil health. Alternatives to using synthetic inputs are

52 https://www.anl.gov/partnerships/case-study-economics-of-pollinator-habitats-at-solar-facilities
53 https://fresh-energy.org/case-study-pv-smart-oregon
54 https://www.nrel.gov/solar/market-research-analysis/pv-smart.html
55 https://www.sciencedirect.com/science/article/abs/pii/S0038092X21008562
56 https://www.noble.org/regenerative-agriculture/

practices such as using beneficial insects, diversifying crops, and rotating livestock. These practices can disrupt weed cycles resulting in a more resilient agricultural ecosystem, as well as reduce human health risks and improve profitability. Some of the other ecological benefits that can come with regenerative agriculture practices include: reduced soil erosion, improvements to soil fertility, increased biodiversity, reduced water pollution, and improved soil moisture retention.[57]

For regenerative agriculture to be successful, management practices must be adapted to the needs of the unique land and operations. Recently, there has been more attention on combining solar and regenerative agriculture where appropriate. Combining the benefits of renewable energy and regenerative agriculture, where practicable, may be a win-win solution for maximizing the efficiency of the land with minimized impacts. More work still remains to understand the opportunities available to co-optimize and simultaneously achieve the best commercial and conservation outcomes through solar farm designs in regenerative agricultural landscapes.

Resources on Regenerative Agriculture:

- Natural Resources Defense Council
- Soil and Climate Alliance

4.6. Dual-Use Potential

Studies of dual-use solar systems are unveiling a wide array of opportunities for rural communities and potential solutions to work towards solving climate goals. For instance, if less than 1% of the U.S. annual budget is invested into rural infrastructure, dual-use solar systems can contribute up to 20% of the U.S.'s total electricity generation.[58] Dual-use systems also align with goals to reduce carbon dioxide emissions. Specifically, one study describes a buildout scenario of dual-use that can be equivalent to removing 71,000 cars from the road annually and creating over 100,000 jobs in rural communities. Dual-use solar provides a rare opportunity for reaching synergies amongst needs for food, energy, water, and more prosperous rural communities.[59]

Dual-use systems not only have the potential to help meet our decarbonization goals for the electricity grid but can simultaneously achieve other environmental, social, and economic objectives.[60] Agricultural areas are ideal locations for solar.[61] Therefore, investment into dual-use, agrisolar systems can be an investment in rural communities,

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[57] https://www.nrdc.org/stories/regenerative-agriculture-101#what-is
[58] https://www.mdpi.com/2071-1050/13/1/137#B22-sustainability-13-00137
[59] https://www.mdpi.com/2071-1050/13/1/137#B22-sustainability-13-00137
[60] https://www.sciencedirect.com/science/article/abs/pii/S1364032122002635
[61] https://www.nature.com/articles/s41598-019-47803-3

providing jobs in construction and supporting industries. Rural arid landscapes have the potential to benefit the most from the implementation of agrisolar systems, as many communities in these areas face urgent needs for energy production, sustainable agriculture, and water use efficiency.[62] Agrisolar systems can also benefit rural economies not only through income diversification to farmers and landowners (discussed in the following paragraphs), but also by supporting local jobs and providing tax revenue for local programs.[63] By 2050, jobs within the solar industry are expected to reach 22.2 million globally.[64]

However, there is still general concern about using land for renewable energy. Therefore, decisions regarding where to site renewable energy facilities to minimize conflict and maximize efficiencies of the land and ecosystem are important to consider. According to DOE, future scenarios of deployment of ground-based solar may require a maximum of 0.5% of land area in the contiguous U.S. in 2050.[65] While solar energy has the potential to offset a significant amount of non-renewable energy demands, there is growing concern that it will displace other land uses. In 2021, the Great Plains Institute looked at the percentage of land covered for existing and queued solar projects by total county acreage, finding that "solar development has not existed in conflict with cultivated agriculture land use at a large enough scale to risk county-level agricultural bases." For Washington and Oregon, most counties would have less than 0.1% of solar land coverage even if every project currently in a utility's interconnection queue were built -- an unlikely scenario.[66] Washington would only have one county (Adams) with more than 0.1% solar land coverage. In comparison, cultivated lands (like crop agriculture) account for much more land, with some counties using up to 75% of land for crop agriculture in Northwestern states.[67] Adeh et al. (2019) developed and validated a "model for solar panel efficiency that incorporates the influence of the panel's microclimate." They found that if less than 1% of cropland incorporated an agrisolar system, global energy demand could be significantly offset.[68] The amount of agrisolar farms needed in order to meet GHG emission reduction goals is well within reach. This is an option that invests in rural communities and keeps farmers farming when farmland is being lost to other forms of

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[62] https://pure.iiasa.ac.at/id/eprint/16494/1/The%20economic%20potential%20for%20rainfed%20agrivoltaics%20in%20groundwater%20stressed%20regions%20FINAL.pdf
[63] https://agrisolarclearinghouse.org/wp-content/uploads/info-library/agrisolar-info/system-design/utility/Developing-Utility-Scale-Solar-MI.pdf
[64] https://lutpub.lut.fi/bitstream/handle/10024/160012/ram_et_al_job_creation_aam.pdf?sequence=1&isAllowed=n
[65] 4 "Solar Futures Study Fact Sheet." U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, September 2021. Accessed March 2023
[66] https://betterenergy.org/blog/the-true-land-footprint-of-solar-energy/
[67] https://betterenergy.org/blog/the-true-land-footprint-of-solar-energy/
[68] https://www.nature.com/articles/s41598-019-47803-3

land use at an alarming rate. Between 2001 and 2016, more than 11 million acres of farmland were lost to other forms of land use.[69]

Dual-use solar can bring many benefits to the landowner as well as the environment. Within agriculture, leasing land for a solar facility can provide farmers with added income and economic security. American Farmland Trust states that "the ownership of 40% of America's agricultural land will be in transition within the next 15 years." Many potential farmers often cannot afford to enter the field, and many current farmers are operating on very slim margins.[70] According to Oregon Agricultural Trust, the average Oregon farmer is 60 years old and 81% of Oregon farmers do not have a succession plan.[71] A similar trend of concern over the loss of farmland can be observed throughout the Northwest. Dual-use is one way to protect farmland that may otherwise be converted to a more permanent type of development, keeping farmers farming.

An additional local benefit that dual-use systems could provide is the decentralization of the processing and distribution of food supply. Currently, in the Northwest, livestock processing facilities are already in short supply. High demand for processing at these facilities causes a bottleneck that inhibits the ability of locally produced livestock to be processed in a timely manner and can suppress the supply of locally produced meat products. The low number of facilities means locally produced livestock must travel farther, requiring additional resources to distribute and resulting in additional GHG emissions. If livestock production grows from an increase in dual-use projects, then this bottleneck may tighten. Therefore, depending on the model and goals of the project and the community, dual-use solar developers have the opportunity to support local food systems by contributing towards the development of additional processing facilities in order to alleviate the processing shortage. This is an opportunity that some developers can invest in, potentially cost-sharing in an alleviation measure for the livestock industry operating alongside the energy industry. Dual-use systems have the potential to improve both food and energy security by working to build system capacity.

Another finding about the potential of dual-use solar comes from a study analyzing the relationship between dual-use solar and electric vehicles (EVs). A common concern with adopting electric vehicles (EVs) is their range. Steadman and Higgins (2022) found that "agrivoltaic systems can facilitate the transition to EVs by powering EV charging stations along major rural roadways, increasing their density and mitigating range anxiety." They found that agrivoltaic-powered rural charging stations in Oregon could support nearly 674,000 EVs per year and reduce carbon emissions in Oregon from vehicle use by 21%[72].

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[69] https://farmlandinfo.org/publications/farms-under-threat-the-state-of-americas-farmland/
[70] https://farmland.org/our-work/keeping-farmers-on-the-land/?mission-area=19
[71] https://www.oregonagtrust.org/
[72] https://www.nature.com/articles/s41598-022-08673-4

5. Implementing Dual-Use in the Pacific Northwest

While there are some regional considerations and trends for the Pacific Northwest as previously mentioned, there are other practical considerations for beginning a project that do not vary too drastically from other regions but should be understood all the same. There are differences to consider for the implementation of a project in the Northwest region dependent upon project specifics and the other land use that will be combined with the solar infrastructure. Each project and the associated decision-making will be extremely site-specific. Siting a new project is largely utility-driven. Currently, transmission capacity and the ability to interconnect new projects to the grid are extremely limited in the region. Therefore, projects are also extremely limited as to where they can be sited.

In the Northwest, we have a variety of climates. Currently, most of our renewable energy is built east of the cascades, which is typically a drier, sunnier environment. There is a wide range of crops grown here with some specific crop types optimal for co-locating with solar. Crops like alfalfa, beans, and onions, ranked best for growing amongst solar, are already found growing in the Northwest. Numerous other crops are being studied, tried, and added to the list of compatibility with solar, many of which are also grown in the Northwest. For instance, in the Netherlands, construction is planned to begin soon for a project where solar will be installed above a farm's raspberry crop, dubbed "fruitovoltaics"[73] Currently, these projects are more appropriate for smaller-scale installations, however, effort is being aimed toward highlighting ways to scale-up projects such as this, to utility-scale levels.

At OSU's Agrivoltaic research site, researchers are growing multiple crops and studying how they perform when grown amongst solar and harvested with traditional farm equipment. Some of these crops include blueberries, as well as shade-tolerant crops such as "alfalfa, arugula, beets, bok choy, cabbage, carrots, chard, garlic, onions, parsley, radish, spinach, sweet potato, turnips, and yams."[74]

The Northwest is also heavily involved in raising livestock. The region has already begun grazing sheep among solar arrays and is beginning to experiment with grazing other livestock among solar arrays, such as cattle. Other opportunities are prominent as well, such as co-locating solar with pollinators and other conservation efforts.

There are other specific qualities and characteristics of the Northwest that make it a unique location for considering the implementation of a dual-use project. The region is experiencing changes in weather patterns, with some areas experiencing severe drought. This is causing some farmers in these regions to consider diversifying their crops. Another extremely important consideration for the Northwest region is community input and

[73] https://knowledge.energyinst.org/new-energy-world/article?id=137990
[74] https://oregoncleanpower.coop/solar-harvest/

involvement. While important for all regions, community engagement in the Northwest is expected to be thorough with all stakeholders and Tribes. The farmland, recreational areas, cultural spaces, and natural areas are all held with extreme importance to the folks living in the region.

5.1. Changing Weather Patterns

According to the last National Climate Assessment, the Northwest region has warmed substantially (nearly 2℉) since 1900. Warmer winters have reduced snowpack and sped up the usual slow release of water for rivers, agriculture, communities, etc. This results in drought, water scarcity, and extreme wildfires. The Northwest is projected to continue to warm throughout all seasons. These shifts in the timing of water supply can adversely impact irrigated crops, particularly where access to water storage is limited. "Irrigation demands among farmers in the Columbia River Basin are projected to increase 5% in response to climate change by the 2030s; however, actual water demands will vary depending on adaptive management decisions and crop requirements."[75] While these changes are expected to put stress on land and agriculture, dual-use offers an adaptive management opportunity to some farmers by reducing heat stress and conserving water.

Furthermore, some specialty crops, including apples and other tree fruits are already experiencing changes. Higher spring temperatures lead to earlier flowering, which then leads to a mismatch between the availability of pollinators required for the flowers to become fruit. This can affect fruit yield as well as quality. Additionally, heat stress can cause sun scald on apples and soft berry crops that may result in damage during harvest and transport.[76] Dual-use can be used as an adaptive management strategy, reducing scald and potentially providing pollinator benefits if they are incorporated in the dual-use design. Some institutions, such as OSU, are looking into co-locating overstory crops, such as apples and grapes, with raised panels. One of the hypothesized findings is that the panels will reduce heat stress and sunburn scald of these overstory crops.

5.2. Community Engagement

Community engagement is a pillar in the siting of any renewable energy facility. The Northwest contains a tremendous diversity of landscapes and is composed of communities that highly cherish their natural, cultural, and recreational resources. Changes to the landscape from renewable energy installations can impact local residents and their connection with the treasured landscape of their homes. Therefore, having a

[75] https://nca2018.globalchange.gov/chapter/24/
[76] https://nca2018.globalchange.gov/chapter/24/

thorough public process is central to the siting of new renewable energy facilities. Developers must take time to understand the local community and conditions before constructing a project. Renewable energy development can require the use of substantial plots of land, which can create conflict between project supporters and people who may prioritize other land use values. Communities and individuals throughout the region have a wide range of opinions on renewable energy and the siting of specific projects. Indigenous tribes, rural communities, environmental groups, and the military are a few of the groups that are integral to the decision-making processes for siting renewable energy facilities.

Dual-use projects enable multiple uses of the same unit of land for both power generation and agriculture, considerably increasing land-use efficiency. Oftentimes, this increase in land use efficiency mitigates land-use conflicts and can improve local acceptance. A 2022 case study found social acceptance levels are closely tied to the extent of landscape impacts. Some suggest requiring the cultivation of agricultural products below the solar modules in agrisolar systems. Some of the benefits they acknowledge are combating desertification and restoring desert areas back into cultivation. However, large solar facilities and the accumulation of many solar facilities in the same area can limit social acceptance.[77] Dual-use systems have the advantage of having a more decentralized set-up, being more integrated into local landscapes, and potentially attached to existing infrastructure (existing farms, conservation areas, etc.). Because of this, local communities and other groups may be more supportive of dual-use projects. With that, early, meaningful engagement that considers community and societal values, needs, concerns, and expectations is still necessary. These considerations can increase the responsible design of a dual-use system and therefore public acceptance.

Given the environmental and economic co-benefits of dual-use systems, increased proliferation of dual-use projects is expected. This necessitates accounting for community resistance and identifying pathways of mitigation. Localized acceptance of a project is a key determinant of a project's success and may impact community outlook on future projects as well. A 2020 survey investigating community acceptance of agrivoltaics found that about 82% of respondents "would be more likely to support solar development in their community if it integrated agricultural production." Respondents prefer projects a) will provide economic opportunity to farmers and the local community, b) are not located on public property, c) do not threaten local interests, and d) fairly distribute economic benefits.[78]

A common concern among communities located near a potential renewable energy facility is what will occur after the life of the project is over. Permits often require detailed

[77] https://www.sciencedirect.com/science/article/pii/B9780323898669000122#
[78] https://link.springer.com/article/10.1007/s44173-022-00007-x#:~:text=This%20survey%20study%20assessed%20if,if%20it%20integrated%20agricultural%20production.

explanations of how the specific project will be decommissioned. Upon completion of the economic life of a project or the permit expiration, the owner of the project can either remove the facility (decommission) or apply for a new permit and "repower" the site by upgrading the panels if the efficiency has lowered. If decommissioning, the land needs to be restored and returned to the state it was in prior to construction. Decommissioning means below and above-ground wires, inverters, transformers, fencing, and foundations are removed and either recycled, refurbished, sold as scrap, or landfilled. Additionally, access roads are excavated and replaced with soil, any compacted soil is de-compacted, and the site is revegetated. The costs of decommissioning are the responsibility of the project owner and not the community or landowners. Some third parties often estimate a negative cost of decommissioning, due to the salvage value of the solar equipment.[79]

Additional Resources:

- Behavioral Science and the Human Dimensions of Energy Systems- National Renewable Energy Laboratory
- Siting Renewable Energy in Oregon
- Least Conflict Solar Siting - WSU Energy Program
- Dual Use Solar Opportunities in Washington State
- "What Happens When a Solar Facility is Decommissioned?"
- Agrisolar Clearinghouse Social Science Research

6. Dual-Use Guide: How to Get Started

Embarking on a dual-use project can be daunting. The dual-use research field is dynamic and new findings are ongoing for understanding successful deployment and operation of dual-use projects. There are different considerations and decisions to make depending on the type of dual-use project that will be constructed. Here, we provide a quick summation of information on types of dual-use projects, and key considerations before getting started on a mid-scale dual-use project. For more information on the latest dual-use research, see section 4 "Update on State of the Science."

There are several factors to consider before constructing a dual-use facility. Below are some of the initial concerns. **1.)** Consider the land type and decide upon the corresponding goals for the land. Depending on the location, some types of dual-use may be better suited than others. Space efficiency, energy output, and cost are all important factors to review. It is not possible for every farm or location to have solar due to cost and inability to connect to the grid. It is also not possible for every solar installation to be a

[79] https://cleanpower.org/wp-content/uploads/2021/12/Final_What-happens-when-a-solar-project-is-decommissioned_Fact-Sheet.pdf

dual-use project. The local utility should be consulted about interconnection potential. **2.)** Research financing options. There are several federal and some state (including WA and OR) monetary incentives that can go towards the construction of dual-use projects.[80] **3.)** Consider the size of the project and type of ownership. For smaller projects, there are two types of panel ownership, direct ownership and third-party. With direct ownership, the panels are owned outright by the landowner, along with the energy that comes from them. With third-party ownership, a solar company is hired to acquire the panels and install them on the land. The solar company receives revenue from the electricity generated, but they pay the landowner in a solar lease. Solar leases generally last for 15-30 years with renewal options for an additional 5-10 years if the landowner and solar company developer wish to continue the operation. There are also ownership scenarios where a third party acquires a lease and then another third party maintains the facility for the leaseholder. American Farmland Trust has a Solar Leasing Guide for Agricultural Landowners in the Pacific Northwest that can be consulted to determine the best steps to take when considering a solar lease. Additionally, the American Solar Grazing Association has an evolving standard contract they recommend for solar grazers. **4.)** Convene or contract a team of experts to discuss other appropriate decisions around the dual-use project goals. Experts may be internal to the developer chosen and can include: a developer, a grazer, a seed specialist, a dual-use expert, an environmental specialist, engineers, a construction team, and legal counsel.

As the project progresses, consider having a central location and logbook check-in for the many people who may be working at the project location and any visitors. Many traditional sites operate with this practice with fewer people involved. Having a central location and check-in for owners, operators, electricians, farmers, grazers, etc., is important for human and food safety.

6.1. Types of Dual-Use and Common Considerations

6.1.1. Livestock Grazing and Solar (Sheep and Cattle)

Grazing livestock among solar panels is a popular dual-use option, as it has the benefit of controlling the growth of vegetation, taking the place of traditional mowing and offering both financial and environmental benefits. For a traditional solar farm, tall growing vegetation can shade the panels and inhibit attaining sufficient irradiation. Therefore, grazing livestock such as cattle or sheep can be an option, curbing the need for vegetation maintenance, as well as controlling erosion, and supporting the production of both food and energy.[81] Other specific benefits of employing grazers rather than mowing

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[80] https://app.leg.wa.gov/ReportsToTheLegislature/Home/GetPDF?fileName=630-Dual-Use_Solar_Opportunties-WSUEEP23-05_a1f93bbc-ff57-4f2d-ad9f-35e40cbc67ee.pdf

[81] https://www.sciencedirect.com/science/article/abs/pii/S1364032122002635?via%3Dihub

the vegetation are healthier soils and reduced emissions. If the site has historically been grazed, there could be reduced maintenance and operation costs due to existing knowledge and available resources. Alternatively, if project developers are contracting livestock farmers, the farmers can be paid to graze their animals at the site. "Solar grazing can offer local livestock owners additional pasture opportunities and the opportunity to be paid for a valuable service, increasing income to their business and adding to the economy of the rural communities…"[82] Solar grazing can provide additional income streams for farmers who graze their sheep at solar sites, which increases income and simultaneously spares the cost of buying or renting pastureland for the sheep to graze.[83]

Establishing the goal for the land and inventorying what resources are already available is the first step. Consideration needs to be given to the choice of livestock. Sheep are often favored because they are smaller and pass easier through rows of solar, not damaging equipment.[84] In the Northwest, the idea of cattle co-located with solar has received more attention recently, as Oregon has about 9 times as many cattle as sheep.

Common Considerations

- Technology
  - Height of panels
    - A mounting system will need to be designed to accommodate the height of the animals. Most sheep like to stay with their flock and may panic if they cannot see the others. Thought should be given to the costs and feasibility of raising the lower edge of the panels (noting if the system will be tracking the movement of the sun) to above the average height of sheep. Larger grazing animals such as cattle will require the mounting system to be even higher to accommodate their size.[85]
  - Durability of panels (sturdiness)
    - The lower edge of the panels should be above the animal height even with sturdy panels. In some instances, an animal may bump or dent a corner panel if the panels are flimsier. In these cases, the animal could get hurt and it can be costly to replace damaged panels. Potential snow accumulation on the panels is another factor to consider when determining which panels to use. Snow can add unwanted weight.

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[82] https://www.agrisolarclearinghouse.org/policy-approaches-for-dual-use-and-agrisolar-practices/
[83] https://apnews.com/article/climate-science-business-lifestyle-environment-and-nature-8f388056808946fbc1aa9a4d6bbc812e
[84] https://www.sciencedirect.com/science/article/abs/pii/S1364032122002635?via%3Dihub
[85] https://www.sciencedirect.com/science/article/abs/pii/S1364032122002635?via%3Dihub

- Above-ground vs. below-ground wiring
  - Current practices recommend a below-ground conduit for the wiring, as animals can barrel into them, damage the wiring, or injure themselves.
- Cover for emergency off switches
  - A current sheep-grazing solar farm reported finding emergency off switches flipped, to later discover that the sheep were bumping into the switches. Care should be taken to either ensure emergency off switches are not located at animal height or that covers are placed over the switches.

◆ Type of vegetation

- When designing a pasture plant species mix, select pasture species that are tolerant to shade and persistent under heavy traffic.
- Species found in a typical seed mix for grazing in the Northwest will vary based on the type of grazing livestock, for example: sheep, dairy cows, or beef cattle.
- It is recommended to consult a seed specialist to ensure the seed mix is appropriate for the location and design of the specific project.
- OSU is currently studying holistic seed mixes including species with medicinal properties for livestock such as sheep.

◆ Water source

- Determine the best place to locate water sources. If a well is nearby and water can already be provided, the rate of grazing may be lower.
- Site-specific solutions are often necessary to source water on-site.

- Rotations
    - "In senescent forage conditions, 4-day rotations lead to more grazing than 1-day rotations."[86]
    - Limiting the daily grazing time (e.g., on-off grazing: 3 h-grazing/d only) or rotational grazing pastures at low grazing intensities may be viable options for sustainable grazing of seasonally wet soils under solar panels."[87]
- Fencing
    - Fencing designs for agrisolar systems are an area of innovation. There are more factors to consider for solar when located with livestock or crops.
        - Gate width should accommodate all equipment and be able to pass through, turn, and move around.
        - Wildlife-friendly fencing often cannot be used because of the need to protect livestock.
    - Temporary electric fencing is an option that many sites use so livestock can be more easily moved and rotated between plots.

➔ Additional Resources on Livestock Grazing and Solar
- American Solar Grazing Association
- OSU Pasture and Grazing Management in the Pacific Northwest

6.1.2. Pollinators and Solar

In the U.S., solar-pollination projects have largely focused on establishing native and naturalized forbs and wildflowers, grassland, and other pollinator-friendly vegetation. Depending on the panel technology and configuration, perennial vegetation is typically planted throughout the project footprint. The mixture of species is carefully chosen to reflect those that are compatible with solar energy production and attract and support native insect pollinators and other beneficial insects by providing food resources and nesting habitat.[88]

Solar beekeeping involves placing beehives on or near solar sites that have native and naturalized vegetation or pollinator habitat. Solar beekeeping can offer local beekeepers new revenue streams and offer resiliency through using a diverse source of

86 https://www.sciencedirect.com/science/article/pii/S0168159122002593
87 https://www.frontiersin.org/articles/10.3389/fsufs.2021.659175/full#B39
88 https://www.sciencedirect.com/science/article/pii/S2212041620301698#bb0065

pollen for honey production.[89] Landowners typically see positive impacts on soil health, and neighboring farmers can benefit from pollination services as well.

For a solar-pollinator facility, the first step is to establish the goals for the land. Determining the type of vegetation and pollinators that are wanted on the property is an important consideration. Developers often work with seed mix specialists from vegetation management, landscaping, conservation, or consultant companies to find an appropriate seed mix for the site. Research should be done to determine what species are native to the area, which are invasive, and what naturalized species can be planted. One challenge of making pollinator-friendly solar is the increase in cost associated with seeding pollinator plants. This type of seeding is usually more expensive upfront than turf or gravel but may reduce management costs over time. Similarly, pollinator vegetation may need additional maintenance for the first few years and then require much less maintenance for the remainder of the project if planned well. Besides providing quality pollinator habitat and forage, goals and considerations for the land could be focused on helping a specific species or habitat, planting only native vegetation, or also including naturalized vegetation, and discovering the type of maintenance and care that comes with the choices made.

Common Considerations

- Selecting Seed Mix
    - Seed mixes should have qualities such as rapid establishment and tolerance of shading and full sun. Solar-shaded plants can have a delayed bloom and provide much-needed pollen resources in the later summer months for pollinators.
    - A seed mix should include plants that do not reach a peak height that could shade the low edge of the panels unless plans are to use strategic mowing or livestock grazing to avoid interfering with project efficiency.
    - Taller species can be planted in buffer areas around the perimeter of the solar array, which could provide a greater diversity of vegetation for pollinators.
    - Native Vegetation
        - Native plants can often better resist invasive species and comply with noxious weed prevention standards.
        - It can be difficult to acquire native wildflower seeds in the Northwest region. Therefore, looking into seed availability should be done early in the development process.

[89] https://www.agrisolarclearinghouse.org/policy-approaches-for-dual-use-and-agrisolar-practices/

- Naturalized Vegetation
  - Naturalized species are non-native and can live in harmony with native species causing no disruptions to biodiversity. They are another option for seeding a pollinator-solar facility and can significantly increase options that work for different stakeholders.
- Planting the right vegetation for the soil type and location is important to ensure that invasives do not overtake the area. This allows for a reduction in vegetation management and potential herbicide use.

◆ Seeding
- Many seeds require a certain time of the season to plant and establish.
- On average, pollinator plants can take 2-3 years to establish.
  - A current area of investigation is around methods of achieving quicker establishment. A common concern is the ability to meet stormwater permitting conditions that require established vegetation.

◆ Vegetation Management
- Careful mowing or livestock grazing can be done to manage vegetation. Project directors can hire someone to do so.
- A vegetation management calendar should be employed to accommodate bloom seasons, especially if bees are kept nearby.

◆ Cost
- Money can be saved if the site already has native species that are compatible with the project and can be preserved during construction. Therefore, the entire site does not need re-seeding.

◆ Good neighbor provisions and control
- It is important to implement control measures for vegetation such as creating buffers if necessary between the pollinator site and any neighbors if dispersal and establishment of the plant species is unwanted.

◆ Technology suitability/considerations
- Height of panels
  - Increased ground clearance may be necessary depending on the types of pollinator plants grown. Many pollinator plants can grow several feet tall. 18” to 24” is widely accepted as the maximum clearance between the lowest edge of the panel and

the ground before material costs substantially increase from elevating the panels.

- Beekeeping
  - Keeping managed bees at the site is an option that some solar-pollinator facilities have implemented. Keeping bees introduces another multifunctional benefit to the land, increasing land-use efficiency.
    - Usually, the developer partners with a local beekeeper, and the hives are housed near the wildflower forage/pollinator vegetation.
    - Introduction of beehives should be withheld until pollinator vegetation is fully established.
    - Locating bees outside of the solar site's fence may avoid insurance complications.[90]

- Additional Resources on Pollinators and Solar:
  - DOE "Buzzing Around Solar: Pollinator Habitat Under Solar Arrays"
  - USDA "Resources to Help Pollinators"
  - Agrisolar Clearinghouse Solar Apiaries
  - The Bee and Habitat Fund Solar Synergy Utility-Scale Project Support
  - Right of Way Pollinator Habitat Scorecard

6.1.3. Crops and Solar

Dual-use of land for both crops and solar allows for both crop-agriculture and solar power generation. It is an increasingly popular area of study. While few of these projects have been implemented at scale, researchers are finding the benefits can be wide-ranging (see section 4.1). However, while some dual-use approaches require minimal changes to PV panel architecture, crop production systems often require adjustments of a typical solar design. Changes required often include increased spacing between the rows of panels, increased height to allow the crops to grow beneath or between, and other potential changes as well. Though these dual-use systems require thoughtful design, they can provide an opportunity to balance both agricultural and renewable energy production goals. Researchers have found that a variety of crops can be grown in co-location with solar installations. Crops can be grown under the panels, between rows, or on the perimeter of the solar installation. Research is ongoing to better understand the

[90] https://www.agrisolarclearinghouse.org/fact-sheet-making-the-case-for-solar-beekeeping/

performance of different crops and the feasibility of co-locating with solar systems.[91] Some of the crops that have been deemed compatible include some that can typically be found in the Pacific Northwest.

Common Considerations

- Three main types of systems:
    - Elevated
        - Panels are located directly above crops (usually by about 6 feet). Benefits include protection of crops from extreme weather such as heavy rains, hail, and extreme heat.
            - Crops such as berries, grapes, and apples can be found in elevated systems.
    - Inter-row
        - Crops are grown between the rows of solar panels. Crops are not as protected in this system, but crops have more access to sunlight than in elevated systems.
            - Crops such as grasses, grains, kale, and broccoli are found in inter-row systems.
    - Combination of inter-row and elevated. Crops are grown directly below the panels and between rows.[92]
- Technology suitability/considerations
    - Type of Panels
        - Research has shown that agricultural yields improve under panels made of amorphous silicon (a-Si) and cadmium telluride (CdTe) compared to panels made of mc-Si (crystalline silicon)."[93]
    - Tracking and Vertical Panels
        - Most new solar installations in the region have rows of panels that move in unison to track the sun throughout the day. An option that is being studied is panels that go fully vertical to allow better movement of farm equipment throughout the rows.
    - Depending on the chosen system, further considerations include:
        - Spacing of Rows

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[91] https://www.agrisolarclearinghouse.org/policy-approaches-for-dual-use-and-agrisolar-practices/
[92] https://www.climatehubs.usda.gov/hubs/northwest/topic/agrivoltaics-pairing-solar-power-and-agriculture-northwest
[93] https://www.sciencedirect.com/science/article/abs/pii/S1364032122002635?via%3Dihub

        - Widened spacing between rows of panels is often required to increase the penetration of solar radiation. There should also be room left to operate a typical tractor.
    - Increased Height of Panels
        - The mount for the panels may need to be increased to allow crops room to grow.
- Crop types
    - Combining solar with agriculture may not work for all crop types, such as those requiring a large amount of direct sunlight. Many crop types are currently being studied for compatibility.
    - A current area of research is investigating extended growing seasons of certain crops in dual-use systems.
- Irrigation/Water source
    - "Big gun" irrigation is not compatible with solar installations. Some crop/solar farmers are experimenting with permanently installed sub-surface irrigation, spray heads, and others.
    - Irrigation decisions will be location and crop-specific.
        - Site-specific considerations will pertain to questions such as: Does the farm already have water rights? Does a well need to be installed?
        - There is potential for a reduction of necessary irrigation (see section 4.1).
- Fencing
    - Solar arrays often require surrounding fencing. For fencing installed at crop and solar farms, it is recommended to leave a wider buffer between the area used for the dual-use site and the exterior fencing to leave enough room for a typical tractor to turn and operate easily through the site.
        - A typical project can have a setback of about 16 to 20 feet. Depending upon the farmer's needs, fences may need to be set back further than this.
    - Fencing is an area of innovation that many people are focusing on improving.

- Additional Resources on Crops and Solar:
    - USDA "Agrivoltaics: Pairing Solar Power and Agriculture in the Northwest"
    - Agrisolar Clearinghouse
    - USDA "Agrivoltaics: Coming Soon to a Farm Near You?"

- DOE "Farmer's Guide to Going Solar"
- University of Massachusetts Amherst Clean Energy Extension Solar PV and Agriculture Information
- Jack's Solar Garden

6.1.4. Conservation and Solar

One conservation opportunity, often seen as a subset of pollinator-friendly dual-use, is conservation-focused solar, where the goals are to protect biodiversity and restore ecosystem services through restoration and management of native vegetation and wildlife amongst ground-mounted solar. While solar arrays are not typically considered a part of a "natural" environment, they do offer a land area with relatively little human interference. Beyond supporting pollinators, other species can benefit too, such as birds, small mammals, insects, and other native species. Benefits that can be realized from dual-use conservation and solar are better water filtration, cleaner stormwater runoff, protection of invasive species, and prevention of soil erosion. Solar sites with native plants can allow better nutrient cycling and improve soil conditions that may end up in future agricultural use after the life of the project.

Most solar developers already must consult with the county and the Department of Fish and Wildlife about mitigation for any disturbances to habitat. Depending on the species' status, developers may also need to work with the U.S. Department of Fish and Wildlife. Projects focused on conservation can have "on-site" mitigation for wildlife impacts, as natural habitat is being conserved. Leases will require language to allow for conservation uses. Traditional solar sites often require fencing for protection and liability reasons. However, conservation-focused solar can implement other wildlife-friendly provisions such as areas with no fencing or wildlife-permeable fencing. Although this form of dual-use may not be feasible everywhere, it has the potential to offer solutions that allow multi-beneficial land uses allowing for both solar development as well as land and wildlife conservation.

Common Considerations

(See Pollinator-Friendly "Common Considerations" above for similarly applied information)

- Fencing
    - Wildlife-Permeable Fencing

        - This is fencing with large holes that allow small to medium-sized wildlife to move freely through the area if they desire.
        - Wildlife-permeable fencing is a current area of innovation where research is investigating fencing modifications on wildlife movement.
    - Unfenced passageways
        - Wildlife corridors are an important consideration. An unfenced passageway may be necessary at larger facilities to allow bigger animals passage, such as deer, coyotes, and bears.
- Minimal Land Grading
    - Topsoil takes years to build and is key to having healthy, productive soil and vegetation. When possible, developers may incorporate the technology and design elements that will avoid stripping soil to grade land during construction.
        - New racking technology is currently being studied to more easily achieve this.
- Habitat Improvements
    - This may include habitat protection, preservation, and restoration.
    - There may be opportunities for artificial housing or habitat depending on the location of the site.
        - For instance, raptor perches can be built with steel pipe and wood and placed near open areas.
        - Trees and shrubs can be used for visual screening as well as foraging and habitat use
- Other opportunities include:
    - Wetland restoration and creating conservation areas after completion of the project.
    - Further research is needed on other viable opportunities for combining conservation practices and solar.

Additional Resources

- Amplifying Clean Energy with Conservation
- Making Solar Wildlife Friendly
- Artificial Perches for Raptors
- Renewable Energy Wildlife Institute

7. Conclusion

Renewable energy and dual-use solar are currently at an advantage from the abundance of new programs, funding, and interest. Washington and Oregon both have clean energy policies and goals investing in the transition to a clean energy future, with specific aims to build out renewable energy that can create additional co-benefits that can be equitably distributed. Dual-use solar presents opportunities and potential to achieve those parameters while supporting landowners, communities, developers, the land, the food system, and the climate.

The Northwest is a special and unique place with a diversity of landscapes and communities. This report shows there are a multitude of benefits dual-use solar can bring to the region. Examples include; water-saving opportunities for farmers in the east who are seeing the effects of drought on their crops; livestock grazers can attain more income and provide additional shade to their herds; ecosystems can be restored and conserved for pollinators and wildlife habitat; and clean energy goals can be achieved. Dual-use solar often has the advantage of increasing land use efficiency and can result in more community support. Dual-use solar can also provide additional income to farmers when many are facing development threats from other industries that would prohibit continued farming.

New research shows dual-use systems can provide more benefits than were previously realized, allowing renewable energy to work in tandem with agriculture, conservation, and innovation. While some research gaps remain, studies are continuing to hone in on some of the important details. Today, more studies have published results solidifying the benefits and opportunities that dual-use projects can bring to local ecosystems and communities. There are more resources available for people interested in learning about dual-use solar. Proficiency in implementation is improving, and the Pacific Northwest is a region that could capitalize on the advantages of wider dual-use solar implementation.