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Resolving Groundwater Overuse

Feasibility of Agrivoltaics Coupled with Groundwater Rights Retirement

EUREKA COUNTY | ECD Eureka Conservation District | The Nature Conservancy Nevada

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RECOMMENDED CITATION:

Saito L, Tibbitts J, Gower P, Zimmerman G, McHugh D. 2024. Resolving groundwater overuse: Feasibility of agrivoltaics coupled with groundwater rights retirement. The Nature Conservancy, Eureka Conservation District, and Eureka County. 48 pages. Available at https://www.eurekacountynv.gov/departments/natural-resources/feasibility-of-agrivoltaics-coupled-with-groundwater-rights-retirement-study/ and https://www.groundwaterresourcehub.org/where-we-work/nevada/.

Executive Summary

The Nature Conservancy (TNC), in partnership with Eureka Conservation District and Eureka County, undertook a study to explore the viability, socio-economic benefits and tradeoffs of coupling groundwater rights retirement with agrivoltaics.

The Nature Conservancy (TNC), in partnership with Eureka Conservation District and Eureka County, undertook a study to explore the viability, socio-economic benefits and tradeoffs of coupling groundwater rights retirement with agrivoltaics. The study consisted of two phases, with the first phase involving community scoping that used a third party to 1) conduct a situation assessment that elicited input from a range of potentially affected interests and 2) facilitate a community meeting to present study concepts and gather substantive input from the community on the topic of retiring groundwater rights while transitioning agricultural land to solar farms. Phase 1 was completed in November 2023 and resulted in a report found here. The current report conveys the results of the second phase of the study that addressed the technical feasibility of concurrently retiring groundwater rights while transitioning corresponding land to agrivoltaics in Diamond Valley. We note that it is possible to implement agrivoltaics without retiring groundwater rights, and groundwater rights can be retired without implementing agrivoltaics.

This study has four sections: groundwater rights retirement, solar energy development, agrivoltaics, and key considerations for Diamond Valley. A complete set of findings is in Section 4, with a summary included here.

Section 1 of this report provides a background on groundwater rights retirement and considerations for landowners in Diamond Valley considering groundwater rights retirement. The following is a summary of the key considerations for groundwater rights retirement:

- At the time of this report, over 12,000 AF of groundwater rights in Diamond Valley have had applications submitted for retirement under the Nevada Water Conservation and Infrastructure Initiative, which equates to about 3,000 acres of currently irrigated land.
- The establishment of a fair and robust system to retire groundwater rights that conserves water is essential.
- Valuation of groundwater rights will require complex analysis due to limited data on water transactions involving groundwater rights retirement; any future valuation analysis will need to incorporate multiple valuation methodologies to arrive at a defensible range of values for Diamond Valley groundwater rights.
- Provisions to address weeds, rodents, and establishment of vegetation on land with retired irrigation rights should be included in conservation programs used to retire water rights.

Agrivoltaic project in Oregon © Misha Allen/UNCE

- Programs to retire groundwater rights may be able to include compensation for capping wells or vegetating fallowed land.
- Programs should consider the use of temporary irrigation to establish dryland vegetation, or allowance of stockwater if the land is to be used for grazing.

Section 2 of the report considers solar development and grid interconnection potential in Diamond Valley. Below is a summary of key findings for landowners in Diamond Valley considering solar energy development on agricultural land:

- The average annual solar irradiance in Diamond Valley is sufficient to make utility-scale solar energy development economically and technologically feasible.
- For entering into leases with solar energy developers, landowners should consider the following:
  - Payment amounts and timing
  - Lease duration
  - Whether the lease precludes or limits other land uses such as agriculture
  - Risk of the solar developer following through on the terms of the lease (such as in the case of a developer going bankrupt)
  - Tax implications of implementing solar on agricultural land
  - Decommissioning of solar equipment after the life of the project
- If the landowner does not own or operate the solar generation system, the landowner is not a party to the power purchase agreement between the solar energy generation system and the entity purchasing the power.
- A solar company participating in Phase 1 of this study was seeking about 3,000 acres collectively to have a viable project.
- There is no requirement for a building permit or other land use approval for solar in Eureka County.
- There is uncertainty about how power generated in Diamond Valley may be connected to transmission infrastructure.

Phase 1 community meeting in September 2023, Eureka, NV

- NV Energy is proposing the Greenlink North project, which would include a new 525-kilovolt (kV) transmission line along Highway 50 and a new substation in Lander County.
- Any solar development and associated infrastructure must ensure cultural artifacts or places of cultural importance are not disturbed or destroyed during construction or maintenance of facilities.

Section 3 of this report examines agrivoltaics technology and provides information for landowners in Diamond Valley considering agrivoltaics with and without groundwater rights retirement:

- Agrivoltaics can provide diversification of income to mitigate the volatility of agricultural income.
- There could be property tax implications when farmland is converted to solar energy production. However, if the landowner maintains an agricultural use in conjunction with solar and can prove at least $5,000 gross income from the agricultural enterprise on the land, the landowner may continue to receive lower tax burden based on agricultural assessed land value.

Sheep on La Ola Solar Farm, Lanai, HI © Merrill Smith/DOE

- Most soil types under irrigation in Diamond Valley are well-suited for establishment of vegetation that can subsist and persist on precipitation alone.
- Plant yields with agrivoltaics have had mixed results, with some showing increased yields and others showing decreased yields as compared to fields with no solar panels.
- Grazing of livestock is common for agrivoltaic farms, with sheep and goats being attractive for helping with vegetation removal and erosion control, and having a small enough size to pass through solar layouts without damaging equipment.
- Solar panels may be able to improve water use efficiency by improving soil moisture beneath panels.
- Crops beneath panels may increase solar panel efficiency by lowering panel temperatures.
- Effective solar leases are important for protecting landowners from financial risks.
- Energy potential of a quarter section in Diamond Valley (160 acres) is approximately 32 megawatts (MW); on the irrigated section the potential is approximately 25 MW.
- An open-access, interactive web map tool was created as a part of this study to help with visualizing agrivoltaic potential in Diamond Valley.
- Some useful resources include:
  - University of Nevada Cooperative Extension website on agrivoltaics (https://extension.unr.edu/agrivoltaics/default.aspx)
  - AgriSolar clearinghouse (https://www.agrisolarclearinghouse.org/)
  - American Solar Grazing Association (https://solargrazing.org/)
  - Department of Energy agrivoltaics website (https://www.energy.gov/eere/solar/agrivoltaics-solar-and-agriculture-co-location)
  - Agrivoltaics index (https://solarfarmsummit.com/agrivoltaics-index)

The full set of key findings from this study is in **Section 4**.

Introduction

The goals of the GMP include stabilizing groundwater levels in Diamond Valley, reducing consumptive use to not exceed perennial yield, preserving the socio-economic structure of Diamond Valley and southern Eureka County, and maximizing viable land uses of private land.

In 2015, Diamond Valley was designated as a Critical Management Area (CMA) (Order 1264) and a groundwater management plan (GMP) was subsequently developed and approved. The goals of the GMP include stabilizing groundwater levels in Diamond Valley, reducing consumptive use to not exceed perennial yield, preserving the socio-economic structure of Diamond Valley and southern Eureka County, and maximizing viable land uses of private land. The GMP implements a schedule for reducing groundwater use in Diamond Valley over time by converting water duties to shares and will inevitably result in irrigated land coming out of production.

At the same time, the Nevada Constitution and Nevada Revised Statues (NRS) require that 50 percent of the electricity sold to retail customers by each electrical utility in the state be from renewable energy sources (e.g., solar, wind, geothermal, biomass, hydropower) by 2030 (Nevada Constitution Section 39 and NRS §704.7821), as well as commit Nevada to being a leading producer of clean and renewable energy to achieve zero-emission energy production by 2050. Such a transition to renewable energy could significantly impact biodiversity and other conservation values (Al Mamun et al. 2022). A possible strategy to achieve multiple goals in the GMP is to concurrently retire private property groundwater rights while transitioning all or portions of formerly irrigated agricultural lands to photovoltaic solar farms. The Nature Conservancy (TNC), in partnership with Eureka Conservation District and Eureka County, undertook a study to explore the viability, socio-economic benefits and tradeoffs of coupling groundwater rights retirement with agrivoltaics[1].

The study consisted of two phases, with the first phase involving community scoping that used a third party to 1) conduct a situation assessment that elicited input from a range of potentially affected interests and 2) facilitate a community meeting to present study concepts and gather substantive input from the community on the topic of retiring groundwater rights while transitioning agricultural land to solar farms. Phase 1 was completed in November 2023, with key concerns that included:

- **Groundwater rights retirement:** how a long-term, fair-priced water rights buy-back program would work; tradeoffs of transferring or reselling water rights to other parcels as opposed to selling the water rights for permanent retirement; handling of land after retirement (i.e., soil erosion, dust, use of land for dryland grazing, etc.)

[1] Agrivoltaics refers to photovoltaic solar generation infrastructure on agricultural lands that are still being used for agriculture.

Machacek Substation, Eureka, NV © Peter Gower/TNC

- **Solar development:** equipment concerns (e.g., what happens when panels become obsolete); up-front costs that might be associated with signing agreements; aesthetics (e.g., changes to the landscape); economic impacts (e.g., employment that might be temporary); and inequities that could cause community tension (i.e., some provided the opportunity to lease land whereas others will not have the opportunity)
- **Greenlink North (GLN) transmission line:** how it might connect near Diamond Valley, what upgrades might be needed, and who the new energy might be for
- **Solar with agriculture:** how this might impact assessment of land; what are incentives to solar companies to allow agriculture with solar; would solar allow enough sunlight for crops to grow, and would irrigation be allowed for cover crops or reliable crop growth?
- **Tribal concerns:** impacts of solar projects on cultural sites and natural resources of importance to the Duckwater Shoshone Tribe

This report conveys the results of the second phase of the study that addressed the technical feasibility of concurrently retiring groundwater rights while transitioning corresponding land to agrivoltaics in Diamond Valley. We note that it is not required to retire groundwater rights to implement agrivoltaics, nor is it necessary to implement agrivoltaics if groundwater rights are retired. In Section 1 we provide background on groundwater rights retirement, followed by information about solar energy development in Section 2, and discussion of combining agriculture with solar energy development in Section 3. In each section, **we provide implications for Diamond Valley in bold font**. In Section 4 we summarize key points for Diamond Valley.

We have also included Appendix A that presents responses to questions and considerations raised during Phase 1 of the project, and Appendix B that includes methods we used in preparing this report.

Diamond Valley, NV © Adriane Tibbitts

Section 1

Groundwater Rights Retirement

Diamond Valley, NV © Thomas Ott/DRI

Nevada is estimated to have about 2 million acre-feet (AF) of perennial yield (i.e., the estimated amount of groundwater available for consumptive use), but about 1.5 times that have been given out as water rights. This has led to over 50% of the 256 hydrographic areas (administrative groundwater basins) being overappropriated, and 20% of the hydrographic areas are overpumped according to 2023 basin status maps from the State Engineer. Diamond Valley (Basin 153) is overappropriated by more than 350%, and overpumped by more than 160%. A recent study by The Nature Conservancy determined that 39% of the over 6,500 wells analyzed in Nevada had significantly declining groundwater level trends (Saito et al. 2022), indicating impacts of overuse of groundwater is already occurring in many places. The largest consumer of groundwater in Nevada is irrigated agriculture (Dieter et al. 2018), and water conservation alone will not be able to return groundwater use to sustainable levels. Thus, land will have to come out of irrigated agriculture, creating a challenge for preserving the socioeconomic structure of agricultural communities and maximizing viable land uses of private land.

Diamond Valley, NV © Chip Carroon

A potential tool for reducing consumptive use of groundwater permanently in areas where the groundwater table is declining due to overuse of groundwater is groundwater rights retirement, where water right holders can voluntarily retire water rights that cannot be available for any use in the future. Several states have implemented programs to retire groundwater rights using combinations of state and federal funds.

In 2023, Senate Bill 176 was proposed to establish a Nevada Water Buy-Back Initiative in the Nevada Conservation and Recreation Program of the Department of Conservation and Natural Resources. The bill included $5 million for retiring groundwater rights and administering the program, with priority of application to overpumped groundwater basins with known conflicts with existing water rights or detriments to natural resources. Although there was broad support for the bill, it did not pass out of the legislature.

More recently, the Department of Conservation and Natural Resources is implementing the Nevada Water Conservation and Infrastructure Initiative (NWCII) using $21 million of American Rescue Plan Act (ARPA) funds to retire groundwater rights in Nevada. Southern Nevada Water Authority, Walker Basin Conservancy, Central Nevada Regional Water Authority (CNRWA), and Humboldt River Basin Water Authority (HRBWA) were selected to implement programs that would search out and work with willing water right holders for the State to "buy back" and retire groundwater rights in priority basins by September 2024. Because of the short timeline, this effort is seen as a "pilot" to test the interest and effectiveness of groundwater rights retirement in Nevada. **At the time of this report, over 12,000 AF of groundwater rights in Diamond Valley have had applications submitted for retirement under the NWCII, which equates to about 3,000 acres of irrigated land.**

The following sections describe some of theconsiderations associated with groundwater rights retirement.

1.1 Groundwater rights retirement programs

Several of the programs in other states to retire groundwater rights are associated with the United States Department of Agriculture's Conservation Reserve Enhancement Program (CREP). The general model involves paying farmers and ranchers over 10-15 years an annual rental rate per acre of land on which irrigation water rights have been retired permanently. There can be additional federal or non-federal incentives to achieve conservation outcomes. For example, in the Harney Valley Groundwater CREP in Oregon, farmers can receive an additional one-time payment of up to $10,000 for retiring groundwater rights near groundwater-dependent ecosystems (GDEs). In the Republican River Basin in Colorado, the CREP includes higher incentives for participation for groundwater rights and associated lands that are closer to the river (Monger et al. 2018). Some programs provide assistance with covering the cost of well abandonment (e.g., Harney Valley Groundwater CREP).

There have been studies to evaluate the efficacy of CREP and similar conservation programs towards achieving the goals of reducing consumptive use of groundwater that have examined:

- **Enrollment in conservation programs like CREP in Colorado and Kansas:** Enrollment tends to increase with higher incentive payments, less water availability, low soil quality and rapidly declining groundwater (Monger et al. 2018; Rosenberg 2020). Another study in the High Plains Aquifer in western Kansas indicated that farmers with larger landholdings were more likely to retire some water rights because they could compensate with other wells (Pfeiffer and Lin 2012).
- **Impact on well capacities in the Upper Arkansas River Basin in Kansas:** CREP was effective at increasing well capacities and average groundwater levels after 15 years, but the program's cost would not have had a favorable cost-benefit ratio without the federal subsidies (Manning et al. 2020).

In Kansas, there are other program types that are aimed at reducing groundwater use. The Intensive Groundwater Use Control Area (IGUCA) is an approach to address water

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conservation, and in the Walnut Creek area it has been used to restrict groundwater use to address conjunctive management issues with Walnut Creek. Earnhart and Hendricks (2022) looked at changes in water applied and acres irrigated for senior water rights (i.e., water rights with priority dates on or before October 1, 1965) versus junior water rights both within and outside of the IGUCA over 1991 to 2010 (the IGUCA was implemented in 1992). Both senior and junior water right holders reduced the depth of water they applied in the IGUCA as compared to those outside of the IGUCA, but only junior water right holders significantly reduced their irrigated areas. This could be because junior water right holders were only allocated ~44% of senior water right allocations, thus forcing them to make more severe changes to their water use (Earnhart and Hendricks 2022).

Another Kansas program is the Water Transaction Assistance Program (WTAP), which compensates water users for the retirement of their groundwater or surface water rights. In a comparison study of high priority areas (HPAs) targeted for water rights retirement, Tsvetanov and Earnhart (2020) found that there was substantial reduction in groundwater use in these areas compared to non-HPAs.

Another option for retiring groundwater that has been used in Colorado is groundwater conservation easements (see example at Peachwood Farms in Colorado). Conservation easements in general are legal tools to restrict certain land uses of property in perpetuity, often to protect the public benefit of the land and water rights from changes to historic use of the land (Warner and McCarty, no date). Landowners get payment or tax benefits for using conservation easements (Brown et al. 2023). Groundwater conservation easements involve a landowner overlying an aquifer voluntarily restricting groundwater pumping in perpetuity. Restrictions on groundwater use could be partial or complete, and the easement could be tailored to enable continued agricultural operations or other conservation values on the property (Warner and McCarty, no date). One of the constraints on applying this approach is the State's existing statutes for conservation easements, which may be unclear about the ability to apply conservation easements to groundwater use. Nevada's statute (NRS §111.390 to NRS §111.440) is unclear about the use of conservation easements for groundwater, but Colorado's statute clearly allows groundwater conservation easements (CRS §38-30.5). Further, Nevada's doctrine of beneficial use to preclude forfeiture of water (NRS §534.090) is unclear regarding non-use under a conservation easement as a beneficial use.

1.2 Fair, robust system to retire water rights that conserves water

An important aspect of successful programs that involve water transactions is a perception by the public that the water allocation process is equitable and fair, and that there is predictability in the outcome of the process (Howe et al. 1986). **It is hoped that the "pilot" groundwater rights retirement programs that are using funds provided by NWCII, lessons learned from programs in other states, and the information gained from the current study will help the State and stakeholders to design an effective and fair program for Nevada that would be useful to groundwater users in Diamond Valley.**

Also, because the intention of groundwater rights retirement is to assist with stabilizing declining groundwater levels, the groundwater rights being retired should actually be in active current use. Programs in other states have provisions to ensure that the water rights being retired are being used (e.g., the Upper Arkansas River Basin CREP requires that eligible producers have used at least 0.5 acre-feet per acre on the retired land in 2/3 of specified years, and at least half of their water right in three of the previous five years [Manning et al. 2020; Rosenberg 2020]). **Legislation or regulations enacted in Nevada to establish a Nevada water buy-back program could include language to ensure that water rights to be retired are being actively used.**

Another aspect of the perception of a fair system will be a reasonable valuation of groundwater rights to be retired. Valuation of irrigation groundwater rights is a complicated and expensive process partly due to a lack of competitive water markets (Sampson et al. 2019). **A full valuation of groundwater rights that might be retired in Diamond Valley is beyond the scope of this report. Water right valuation is highly complex and often requires specialized methodologies to account for a lack of market transactions, especially in places with few transactions of water and land such as Diamond Valley. Any future valuation analysis will need to incorporate multiple valuation methodologies to arrive at a defensible range of values for Diamond Valley groundwater rights. In lieu of providing a complete valuation, we instead describe the varying water right valuation methodologies and how they can be applied to Diamond Valley. Rough, incomplete data are also provided as an example of the valuation methodologies as well as a foundation for future valuations.**

Diamond Valley, NV © Thomas Ott/DRI

Water rights in Diamond Valley are measured through a system of shares that was introduced under the GMP. Shares were created as a function of the legal duty of the water right as well as a priority factor that ranges from 1.0 for the most senior rights to 0.8 for the most junior rights. Unlike annual allocations that are reduced periodically per the GMP, shares are a measure of the proportion of water available for pumping in Diamond Valley that is attributable to a specific water right. **Shares are independent of changes in allocation, and therefore are the best metric for determining a property's water availability relative to other agricultural properties in Diamond Valley under the GMP. Any future water right valuation should seek to provide a value denominated in shares that will be applicable through future allocation reductions.**

1.2.1 Comparable sales approach

The most straightforward method to value any asset is to utilize comparable sales of assets with very similar characteristics. This is often the main valuation methodology used in land appraisals. However, unlike the market for land where there are often a fair number of transactions with observable prices in any given area, water right transactions are much more rare (Sampson et al. 2019) and often have opaque pricing.

A search of the Eureka County Recorder's online platform for water right deeds over the past ten years included 12 transactions (Table 1). Sales to Eureka County are transfers to fulfill requirements of Eureka County Code 8.150 requiring water rights dedications to the county for

Table 2. Diamond Valley comparable water right sales. These sales have not been verified. All prices are in November 2023 dollars. Sales to Eureka County (grey) are transfers to fulfill the requirements of Eureka County Code 8.150 requiring water rights dedications to the county for the creation of new parcels and are not likely to be market values. AF = acre-feet. Source: Eureka County Assessor Water Right Deeds

Sale No.	Year	Grantor	Grantee	AF	$/AF(2023)	Water Type
1	2023	Individual	Eureka County	4	$538	Irrigation
2	2023	Individual	Eureka County	6	$538	Irrigation
3	**2023**	**Agricultural Company**	**Individual**	**6**	**$760**	**Irrigation**
4	2021	Agricultural Company	Eureka County	2	$595	Irrigation
5	2021	Agricultural Company	Eureka County	2	$595	Irrigation
6	2021	Agricultural Company	Eureka County	2	$595	Irrigation
7	2020	Individual	Eureka County	2	$636	Irrigation
8	2020	Individual	Eureka County	4	$639	Quasi-Municipal
9	**2018**	**Individual**	**Individual**	**4**	**$308**	**Irrigation**
10	**2015**	**Mining Company**	**Individual**	**387**	**$895**	**Irrigation**
11	**2014**	**Developer**	**Individual**	**10**	**$816**	**Quasi-Municipal**
12	**2013**	**Developer**	**Individual**	**18**	**$1,155**	**Quasi-Municipal**

the creation of new parcels and are not likely to be market values. Table 1 of comparable water right sales should not be considered a complete listing of water rights sales in the area, nor have they been verified. It is likely that water rights have been transferred using an instrument other than a water right deed.[2]

The sales in Table 1 provide a snapshot of some potential water right values and a baseline for a more complete valuation. The most relevant sale is Sale No. 3, wherein an individual purchased 6 AF of water rights from an agricultural company for $760/AF and subsequently transferred the water to Eureka County in Sale No. 2. However, this was a small volume of water purchased to fulfill a water right dedication requirement and thus may not be indicative of the value of larger irrigation water assets.

Sales in 2015 and earlier may also provide an important indication of value as they occurred before Diamond Valley was designated as a CMA. Further research may help to identify whether the designation of Diamond Valley as a CMA led to lower groundwater right prices, in which case, the current prices could reflect the allocation reductions planned under the GMP. In addition, further research should attempt to identify additional water rights sales and their applicability to irrigation water right values in Diamond Valley. To identify transactions, appraisers could review water right title transactions recorded with Nevada Division of Water Resources as well as interview local water officials.

1.2.2 Income capitalization approach

The income capitalization methodology estimates the value of water according to the contribution it provides to net income for a business. In a dry area such as Diamond Valley, growing cultivated crops to mechanically harvest for human or animal food is not possible without irrigation. As such, the net income of an agricultural operation can be attributed to the presence of water rights.

The income capitalization model operates by creating what is essentially a profit and loss statement for an average or "model" farm that represents farms in the target areas, commonly known as a "crop budget." Revenue and costs are determined based on available data and incorporate all parts of the farm operation from the cost of seeds and harvesting to non-operating costs such as taxes.

As part of a 2023 study for the CNRWA and HRBWA for the NWCII water buy-back funding, Hansford (2023) used Nevada alfalfa pricing and crop budgets from Idaho, Utah, and Nevada to develop an annual net farming income per acre applicable to Diamond Valley. Calculated average alfalfa prices in Nevada between 2019 and 2022 were $241/ton of alfalfa, or $1,034/acre (Hansford 2023).[3]

For expenses, Hansford (2023) used crop budgets for Diamond Valley and Eureka County as well as areas similar to Diamond Valley in Idaho and Utah to determine that an expense ratio of 80% was warranted, resulting in a net income of $207/acre. The average duty in the area is 3.86 AF/acre[4], resulting in an annual net income of $53.58/AF. Hansford (2023) applied discount rates between 2% and 8% over time periods ranging from 5 years to perpetuity, with a median value of $1,074/AF. The allocation reductions prescribed by the GMP will either decrease the yield per acre or reduce the number of acres that can be irrigated, resulting in reduced income and a reduced value per acre.

The analysis by Hansford (2023) used state-wide alfalfa prices and older crop budgets from the larger region. Future research could develop a current crop budget specific to Diamond Valley for a more robust valuation.

[2] There were no water right deeds listed between 2015 and 2018, indicating that water deeds were likely recorded as regular deeds.

[3] Hansford (2023) calculated yield per acre at 4.3 tons/acre, which is the average yield between 2014 and 2018 for all the CNWRA member counties. The average for Eureka County was 4.2 tons/acre.

[4] Per the 2017 crop inventory report from the State Engineer.

1.2.3. Land price differential approach

A land price differential approach values water rights by comparing property value with water rights to property without water rights for otherwise identical properties. The volume of water available to a property is determined by the number of shares available for irrigation using the property's water rights as prescribed by the GMP.

A total of 77 transactions were identified as potentially useful for the analysis after filtering the transactions in the Eureka County Assessor's sales data (see methods in Appendix B). Each involved a different mix of irrigated and dryland acres. The sales ranged from 50 to 800 acres, and prices ranged from $30/acre to $4,539/acre. The analysis assumes that the differences in per acre values are largely attributable to the number of GMP shares on the property. There were 68 dryland properties that did not include any shares, and 9 properties that had between 2.39 and 3.85 shares/acre. The differences in shares/acre are due to the proportion of irrigation and non-irrigated land on the property as well as the legal duty and priority date that determine the number of shares per water right.

The resulting per-share price from this analysis increases with the proportion of shares per acre (Figure 1). A regression equation applied to the data indicated a value of $279/acre for properties with no shares (dryland) and a value of $839/share[5].

This analysis contains relatively few (9) irrigated land transactions, which creates potential issues with the validity and accuracy of results. Although there were 77 total transactions, only 9 had water rights, with a wide range in value between $1,800/acre and $4,500/acre. As well, this analysis looked at land transactions over 10 years from 2013 through 2022, which includes a number of sales from before the implementation of the GMP. If the analysis is limited to just the five-year period from 2018 through 2022, then the value per share falls to $679/share, potentially indicating a reduction in the value once the GMP was implemented[6].

Future land price differential analysis could incorporate land sales from other similar areas. Comparing land transactions from other areas against the handful of Diamond Valley transactions may also help describe the impact of the GMP on Diamond Valley water right values.

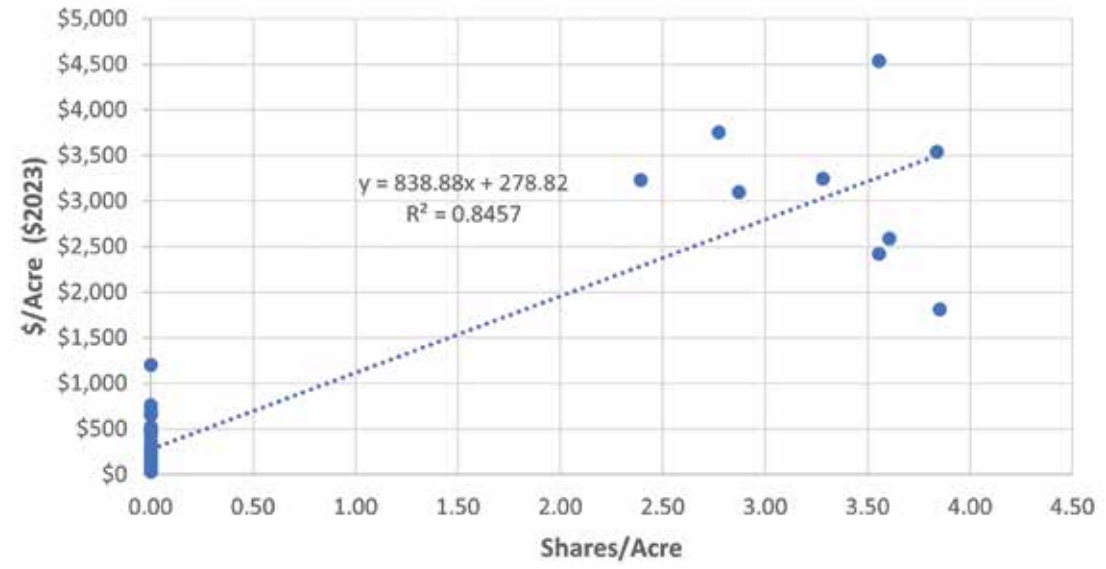


Figure 1. Per acre price in 2023 dollars in relation to the number of shares per acre in land sales transactions between 2013 and 2022 in Eureka County.

[5] From Figure 1, $839*(1 share/acre)+$279 = $1,118 (the estimated value of a property with an average of one share per acre) - $279 (estimated dryland value) = $839 (the estimated value of one share)

[6] This reduced date range only includes four irrigated land transactions, which is too few to have any statistical reliability.

1.2.4 Replacement cost approach

A fourth commonly used methodology in water right valuation is the replacement cost approach that involves using the cost to replace the water asset from a different source. Since the entire hydrologic system in Diamond Valley (both groundwater and surface water) is over-appropriated and there are no nearby alternative water sources, this method was not applied.

1.2.5 Valuing water rights under GMP curtailment

The Diamond Valley GMP uses annual allocations to set the volume of water available for each water right share, with decreasing annual allocations over time until the groundwater table stabilizes. Thus, irrigators will receive less water per share, reducing the income generating potential of irrigation water rights and thus reducing the overall value of the rights. The current value of Diamond Valley water rights is the net present value of the future income that can be generated from the water assets; in other words, future reductions in allocations must be considered to determine an accurate present value for the water assets.

The methodologies discussed in Sections 1.2.1 through 1.2.4 are backwards looking and may not have incorporated the reduced allocations prescribed by the GMP. Recent comparable water right sales and recent land sales used in the land price differential approach likely considered future GMP water allocations, but more research is needed to verify this. This section presents potential ways an appraiser or water right buyer might incorporate future GMP allocation reductions into water right prices.

1.2.5.1 Applying unit value to remaining allocations

The simplest way to value a water right under a reduced allocation is to apply the unit value from before ($/AF) to the volume of water that is still available under the reduced allocation. For example, a water right with a legal duty of 100 AF and 100 AF of allocated pumpable water that was previously worth $50,000 or $500/AF would, under a reduced allocation of 67% (i.e., 67 AF of pumpable water), have a total value of $500/AF * 67 AF = $33,500. Alternatively, one could calculate a new unit price for the full legal duty of water to be $335/AF of legal duty.

While this method is useful for determining value after a single reduction in allocation and is illustrative for showing how allocation reductions will reduce total value, it is more difficult to apply to the Diamond Valley GMP where further reductions will occur annually into the future.

1.2.5.2 Income capitalization

An income capitalization model specific to Diamond Valley could be used to estimate net income for the different annual allocation levels prescribed in the GMP. This will generate a value per AF for each year of the GMP. Each of these annual values can then be discounted back to the present to provide a present value for the water inclusive of anticipated reductions in allocations.

Hansford (2023) applied the income capitalization approach to consider future allocation reductions prescribed by the GMP. Net present value for net farm incomes of $207/acre were calculated over different time periods ranging from 5 years through perpetuity. The projected decline in irrigation consumptive use as described in Appendix I of the GMP was used to establish a weight for each time period. This resulted in an estimated land value per acre of $3,038/acre, which yields a unit value of $787/AF for an average duty of 3.86 AF/acre. This unit value is 25% less than the value indicated before the GMP-prescribed allocation reductions were incorporated.

1.2.5.3 Revealed price

As stated previously, the best way to value an asset is to utilize pricing of very similar assets. The GMP-prescribed allocation reductions have altered the value of Diamond Valley water rights – they are no longer similar to Diamond Valley water rights before the GMP nor to water rights in nearby areas that do not have prescribed allocation reductions.

Recent land and water prices in Diamond Valley likely take the allocation reductions prescribed in the GMP into account as it is well-known locally. However, relatively few recent water right and irrigated land transactions were identified for this report. If future research could identify sufficient, current (i.e., within the last several years) data on water and/or land prices and these transactions are verified with buyers and sellers, it may

be possible to utilize data from Diamond Valley alone to determine the current value of water given planned GMP allocation reductions.

However, as noted previously, it is unlikely that a sufficient number of transactions exist within Diamond Valley alone. To provide a comparison to Diamond Valley water rights, researchers may need to gather pricing information on land and water transactions outside of Diamond Valley. Incorporating pricing data from areas outside of Diamond Valley into a simple statistical model may increase the explanatory power of the model. Incorporating a local variable to control for whether the transaction was in Diamond Valley would still allow for estimation of Diamond Valley water values. In addition, incorporating data from other similar areas with a long enough time horizon may show a divergence in Diamond Valley water prices as the GMP was developed and adopted.

1.2.5.4 Non-appraisal water pricing

Methods are available to elucidate prices without a formal valuation. For example, reverse auctions have been used to value and transact water throughout the Western United States, including the System Conservation Pilot Program in the Upper Basin of the Colorado River and the much smaller Snoqualmie Valley Agricultural Water Bank in Washington State. In a reverse auction, an entity seeking to purchase water rights asks for sellers to submit bids as to the volume of water they would be willing to sell and the price they'd be willing to accept for this water. The seller would then accept the lowest bids (potentially given a reserve price) and purchase the water. Ideally this option would help buyers and sellers to efficiently arrive at an accurate market price, however in practice reverse auctions can be complex and may fail if there is not sufficient interest on the part of the sellers.

1.3 Alteration of the landscape when irrigation water is removed

Wind erosion, non-native plants, and dust storms can increase on land that is fallowed (Varzi and Grigg 2019). In a survey of landowners in Nebraska about the US Department of Agriculture's Conservation Reserve Program (CRP), among the most frequently listed negative perceptions of the program were weed problems on CRP lands that were their own or adjacent (Lute et al. 2018). Some conservation programs to retire water rights do allow the application of a limited amount of water per acre to establish a conservation practice on land where irrigation water rights are retired (Monger et al. 2018; Harney Valley Groundwater CREP) to reduce the potential for these negative effects. **Provisions to address weeds, rodents and establishment of vegetation on land with retired irrigation rights should be included in conservation programs used to retire water rights.**

1.4 Alternative uses of the land after irrigation water is removed

Dryland grazing may be possible on non-irrigated land if stockwater is available, which may be an option for a water rights retirement program. Crops requiring little or no irrigation may also be possible as discussed in Section 3.3. This report also addresses the possibility of applying solar energy development to formerly irrigated land, or integrating solar production with agriculture where groundwater rights are being retired. **See Section 2 about solar energy production and Section 3 about agrivoltaics**.

1.5 Spillover effects

An additional consideration for groundwater rights retirement is the possibility of spillover effects in which the retirement of groundwater rights by a particular landowner might affect the behavior of other water right holders. Groundwater aquifers are an example of a common pool resource because the extraction of the resource by one user can decrease stock levels of groundwater for other users (Rad et al. 2021), which could result in increased costs because of requiring more pumping lift (Ekpe and Klis 2023). When groundwater use is retired, groundwater levels at neighboring wells may increase over time, but

there also could be more water available to the same user in the future (Rad et al. 2021). Some researchers have also proposed that neighbors can be influenced by each other's behavior, which could result in complementary reductions in water use when a user retires their groundwater rights (Hrozencik et al. 2021). In examining groundwater use in the Upper Arkansas River Basin CREP in Kansas, Rad et al. (2021) found that wells within a 2-mile radius of one or more retired wells reduced their average annual water use by 5% of their previous groundwater use, potentially because of reduced competition for the resource. However, they also found the response was temporary and extraction rates increased over time (Rad et al. 2021). Another study used surveys of irrigators in Colorado and Kansas where programs are in place to reduce groundwater use to determine that the treatment group that received mailers that compared their water use against similar water users decreased their groundwater use by 4% compared to a control group, resulting in 21,000 acre-feet of lower groundwater use (Hrozencik et al. 2021).

Crested wheatgrass in Diamond Valley, NV © Jake Tibbitts

Section 2

Solar Energy Development

Solar installation near Las Vegas, NV © Chip Carroon

In 2020, the US Department of Energy (DOE) estimated that solar technologies supplied approximately 3 percent of the total US energy demand. National and state-level initiatives to increase non-fossil fuel forms of energy development, such as solar, are increasing the demand for new solar energy generation systems nation-wide. As mentioned earlier, NRS §704.7801 requires that 50 percent of the electricity sold to Nevadans by 2030 is from renewable energy or energy efficiency measures.[7] The state also has a goal of achieving 100 percent renewable energy by 2050 (Public Utilities Commission of Nevada 2021). Nationally, by 2050, the DOE predicts that 45 percent of all electric generating capacity will be from solar (United States Department of Energy 2021).

The National Renewable Energy Lab (NREL) maps solar irradiance, which is a measure of solar generation potential. The southwest US has the nation's highest irradiance (Figure 2) and is experiencing extensive solar energy development. **The average solar irradiance in the Diamond Valley is approximately 4.5 kilowatt hours (kWh) per meter squared (m2) per day, which makes utility-scale[8] solar energy development economically and technologically feasible.**

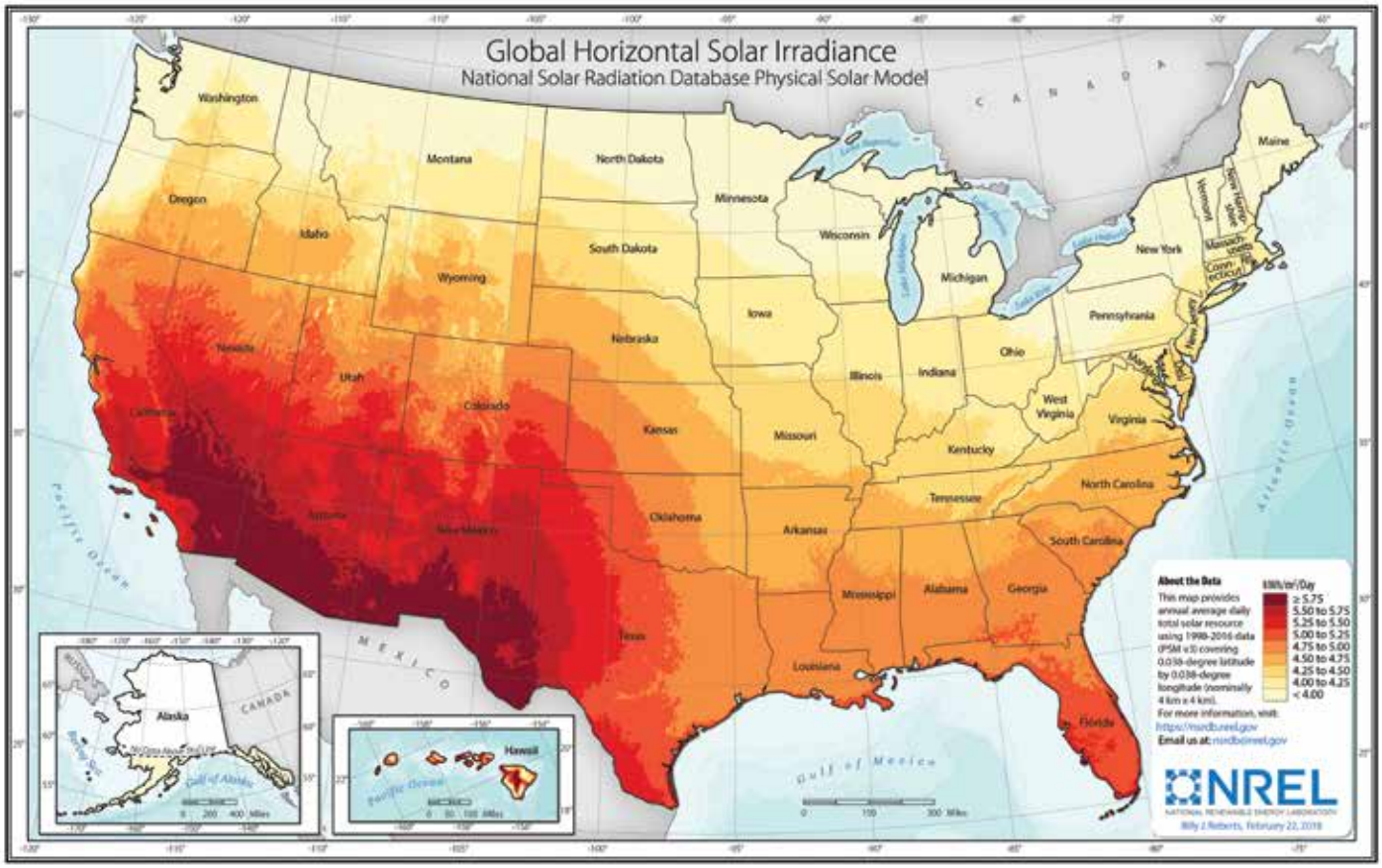


Figure 2. Solar irradiance across the US. Source: NREL (2018)

[7] Energy efficiency measures are those that reduce the demand for energy. These could include building retrofits, such as improved insulation, low-energy use appliances and lighting, and upgrades to heating and cooling systems.

[8] Utility-scale refers to energy generated, typically 20 megawatts or more, for the purpose of providing electricity to many users as part of an electrical utility's generation, transmission, and distribution system. Utility-scale systems are in-front-of-the-meter systems because they supply electricity to multiple customers. In some cases, electricity generated is used by the same entity that owns or operates the solar generation system. These are behind-the-meter systems because the purpose of the electricity is to serve the needs of the individual who generates the power and not a broader customer base. Most behind-the-meter systems are less than 1 megawatt (Gomez and Morley 2021).

This report focuses on photovoltaic (PV) technologies for utility-scale solar energy generation systems[9]. Solar PV systems use panels to capture irradiance from the sun and convert it into electricity. A collection of solar panels is a solar array, or also commonly referred to as a solar farm.

Recent advancements in solar PV technologies include tracking and bifacial panel systems (Figure 3). Tracking systems enable the PV panel surface to always be directly facing the sun. They use sensors and motors to gradually tilt the panels to track the sun (Abidin et al. 2021). Bifacial systems have PV collectors on both sides of the panel, which enables sunlight refracted from the earth's surface to be converted to electricity. Both technologies increase energy generation potential compared with fixed axis, single face solar PV systems.

Solar farms also include a series of collector wires and inverters to convert the direct current (DC) from the PV panels to alternating current (AC) so that it can enter the electrical grid, typically via a substation. More commonly, solar farms will include a battery storage component, which allows the energy producer and utility to regulate the release of electricity into the grid, so the electricity use is optimized relative to energy demand.

Other components of a solar PV system are support structures consisting of steel pilings driven into the ground that hold the panels, motors (for tracking systems), and collection circuitry. Ground mounted PV systems are typically 6 to 8 feet above the ground surface depending on underlying topography and vegetation. Panel rows are typically spaced 20 feet apart to allow access for maintenance and to avoid any panel row shading an adjacent row.

Over time, the efficiency of a solar panel's ability to convert sunlight to electricity gradually diminishes until the cost to own and operate the system becomes economically unviable. The typical lifespan for a solar farm is 25 years (Al Mamun et al. 2022). Some components, including the panels, can be recycled or reused. The remaining materials must be disposed of in landfills.

2.1 Site control, solar development leases and desirable land characteristics

Solar developers obtain legal authority (also known as site control) over a project site by purchasing the property or executing a lease with the landowner. Purchasing the land grants a solar developer the full rights of landownership.

Figure 3. Bifacial PV system in Nevada with tracking capability. Source: Peter Gower/TNC.

[9] Concentrated solar panel (CSP) systems are another type of utility-scale solar energy generation system that use mirrors to direct sunlight toward a central tower that collects the heat and converts it to energy. The Ivanpah solar plant in southern California and the Crescent Dunes solar plant near Tonopah, Nevada are two examples of CSP systems. Operational and environmental concerns with CSP, combined with recent advancements in PV technologies have led to PV systems being the preferred technology for new solar development projects.

However, the up-front cost to purchase the land may preclude that option. A lease with the landowner grants the solar developer limited rights to install and operate the solar project in exchange for payment to the landowner. A lease negotiated with the landowner stipulates the amount a solar developer will pay the landowner in exchange for the use of the property. The typical lease term is 30 years. Lease payment amounts vary site to site. In general, a property that is closer to an interconnection location (see Section 2.2) will have a higher lease value. Similarly, a project developer needs to account for civil engineering, insurance and other project design and operation costs, which influence the lease rate. Properties without topographic challenges, such as water features, slopes, or being situated in floodplains, will have higher lease rates. **Landowners should consider the following when considering signing a lease to allow solar development on their property:**

- **Payment amounts and timing**
- **Lease duration**
- **Whether the lease precludes or limits other land uses such as agriculture**
- **Risk of the solar developer following through on the terms of the lease (such as in the case of a developer going bankrupt)**
- **Tax implications of implementing solar on their land (see Section 3.2)**
- **Decommissioning, including land reclamation and disposal of solar equipment after the life of the project**

Acres per megawatt (MW) of generation capacity is the common metric used to describe land surface requirements for solar PV systems. With recent advancements in solar PV technology that increase the energy generation capacity of each panel, there is a decreasing amount of land needed to generate 1 MW of electricity. Land requirements also depend on row spacing, topography, and underlying ecological conditions; flatter sites with no ecological constraints provide the maximum

Solar project in Nevada © Peter Gower/TNC

generating potential per acre. The current industry standard for a site without topographic or ecological constraints is approximately 5-10 acres per 1 MW of solar PV generating capacity (Solar Energy Industries Association 2024a).

Currently in Eureka County, property owners can install solar PV systems on their property at any time. There is no requirement for a building permit or other land use approval from the county. Depending on the size and location of the system, state permits and approvals may be required. For example, projects greater than 70 MW would be subject to review by the Public Utilities Commission of Nevada. Unlike adjacent public lands administered by the Bureau of Land Management (BLM), solar development on private property is not subject to environmental review under the National Environmental Policy Act (NEPA). In Nevada, where federal agencies manage over 80 percent of the state's land area, utility-scale solar energy development on private property is a rare opportunity (but see Section 2.2 for additional considerations regarding NEPA nexus with federal lands).

The most efficient land use pattern for a solar farm is a large contiguous block of land. For this reason, solar developers work to secure leases for multiple contiguous properties. Once the leases are in place, the developer's goal is to present a development proposal to a builder, which could include a utility. **Balanced Rock Power, a solar developer that is actively negotiating leases with Diamond Valley property owners, stated during Phase 1 of this project that the company's goal is to secure leases for 3,000 acres in the Diamond Valley, ideally for contiguous properties. Balanced Rock Power would then present the development proposal to NV Energy. The utility would then negotiate with the development company to potentially purchase the electricity generated from the solar farm.**

2.2 Grid interconnection and transmission

A power purchase agreement (PPA) is an agreement between the solar energy generation system operator and the entity purchasing the power. The PPA dictates the amount, cost, and duration of the power generated from a solar farm. **Once a solar developer secures sufficient site control either through purchasing property or securing enough leases with landowners to develop a profitable solar project and coordinates the design and permitting of the project, the company would identify a power purchaser and negotiate the terms of the PPA.** If the landowner does not own or operate the solar generation system, then the landowner is not a party to the PPA. In some cases, a solar developer may sell the project with entitlements, including leases and PPAs,

Eureka, Nevada © Peter Gower/TNC

Figure 4. Machacek Substation. Source: Peter Gower/TNC.

to another company that will construct and operate the project. In other cases, the same company will secure the entitlements and build and operate the project. The company that owns and operates the solar farm is responsible for fulfilling the terms of the PPA for the life of the agreement, which is typically 10-25 years. A PPA can be renewed (Solar Energy Industries Association 2024b). The transmission system operator may be the power purchaser or may only provide infrastructure to move the power through the transmission system to the power purchaser.

Electricity generated at a solar PV facility enters the grid via a substation. Connecting to an existing substation is the easiest and cheapest option for a solar project developer to interconnect with the transmission system. A solar project that is further away from a substation is more costly and technologically challenging than a project closer to a substation. This is because a solar project developer would need to construct a generation-tie power line to connect the generation facility with the nearest substation. According to input from NV Energy during Phase 1 of this project, transmission lines cost up to $3 million per mile to construct. Interconnecting a new power generation source with the transmission system can also be achieved by a line tap, which requires adding a small substation to an existing transmission line.

The nearest substation to Diamond Valley is the Machacek Substation (Figure 4), which is adjacent to the Eureka County fairgrounds. NV Energy, Nevada's largest electric utility, owns and operates the substation in partnership with Mt. Wheeler Power, a rural electric co-operative that supplies electricity to rural eastern Nevada, including customers in Eureka County. **NV Energy and Mt. Wheeler Power representatives indicated during the scoping phase of this project that the Machacek substation is at capacity and could not accept any new interconnections, such as from new electricity generation sources in Diamond Valley, without undergoing substantial infrastructure upgrades.**

There are two 230-kilovolt (kV) transmission lines in the vicinity of Diamond Valley, both owned and operated by NV Energy. The Falcon to Gondor line generally travels northwest to southeast along the west side of Diamond Valley. The other line roughly parallels Highway 50 east

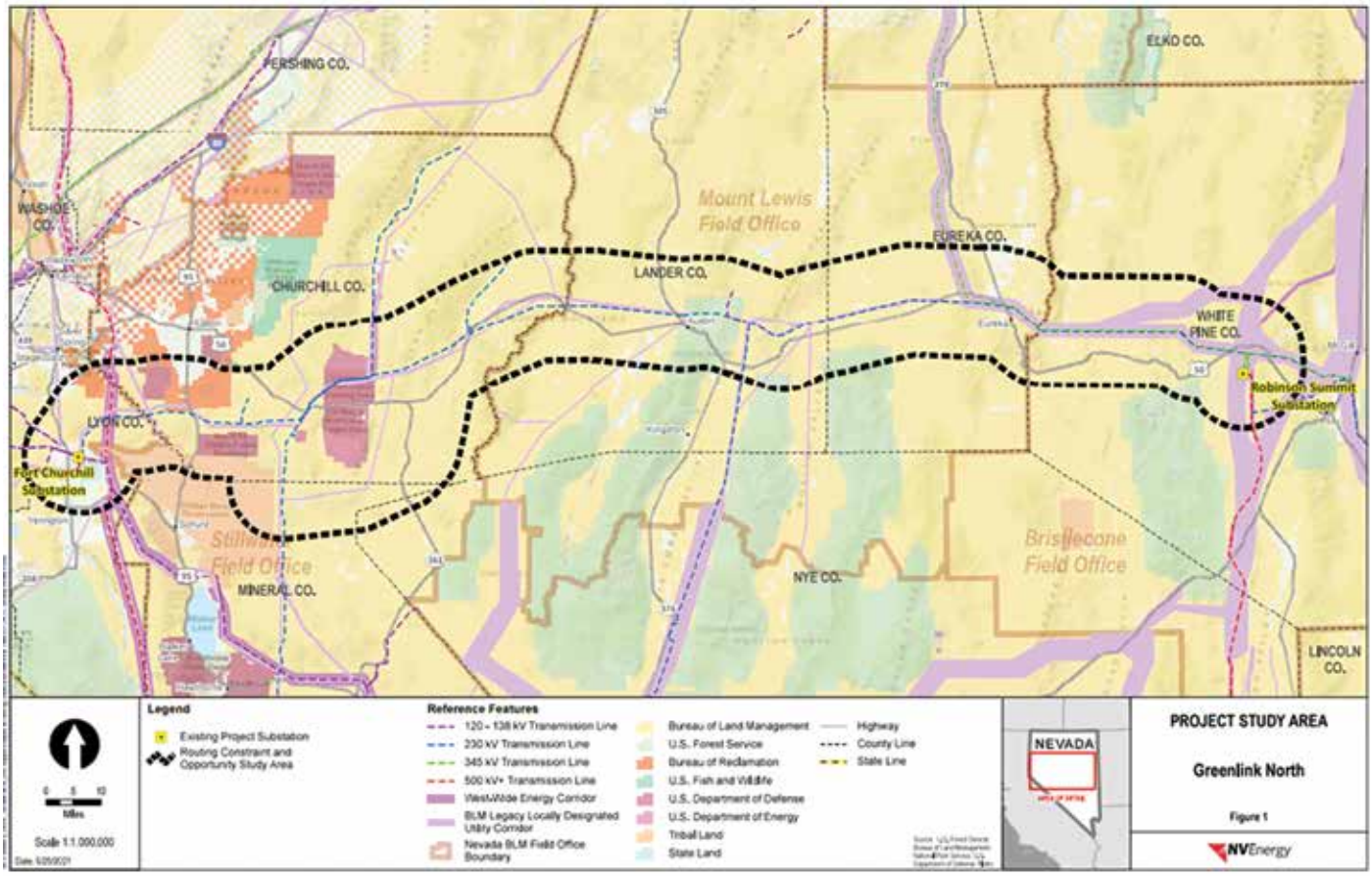


Figure 5. Proposed Greenlink North transmission line. Source: NV Energy (2024).

to west and crosses south of Diamond Valley. A line tap on one of these lines would enable new solar energy generation projects in Diamond Valley to interconnect with the transmission system.

NV Energy is proposing the Greenlink North project, which would include a new 525-kV transmission line paralleling the existing line along Highway 50 (Figure 5). NV Energy's purpose for developing the Greenlink project is to help meet the state's renewable energy goals while providing a reliable and resilient source of power to NV Energy customers. NV Energy anticipates the project coming online in 2028 (NV Energy 2024). NV Energy's Plan of Development (POD) for the Greenlink North project **includes upgrades to the Machacek Substation; however, these upgrades would not increase the substation's interconnection capacity. The POD also includes a new substation in Lander County. While this could be a possible interconnection location for new solar energy development in Diamond Valley, a new generation-tie line would be needed to connect Diamond Valley solar farms with the new substation. NV Energy's POD includes several siting scenarios for the Lander Substation, the nearest of which would be approximately 40 miles away from Diamond Valley (NV Energy 2024). The added costs of constructing a $120 million[10] generation-tie line could make it economically infeasible to connect solar PV facilities in Diamond Valley with the proposed Lander Substation. A generation-tie line from Diamond Valley to the proposed Lander Substation would also cross public land administered by the BLM and would be subject to environmental review under NEPA. Given that most land surrounding Diamond Valley is public land administered by the BLM, any interconnection scenario would likely cross federal lands and require NEPA compliance.** The NEPA process

[10] Assuming a 40-mile line at $3 million per mile.

often takes a year or longer to complete, which would further disincentivize an interconnection scenario via a generation-tie line to the proposed Lander Substation.

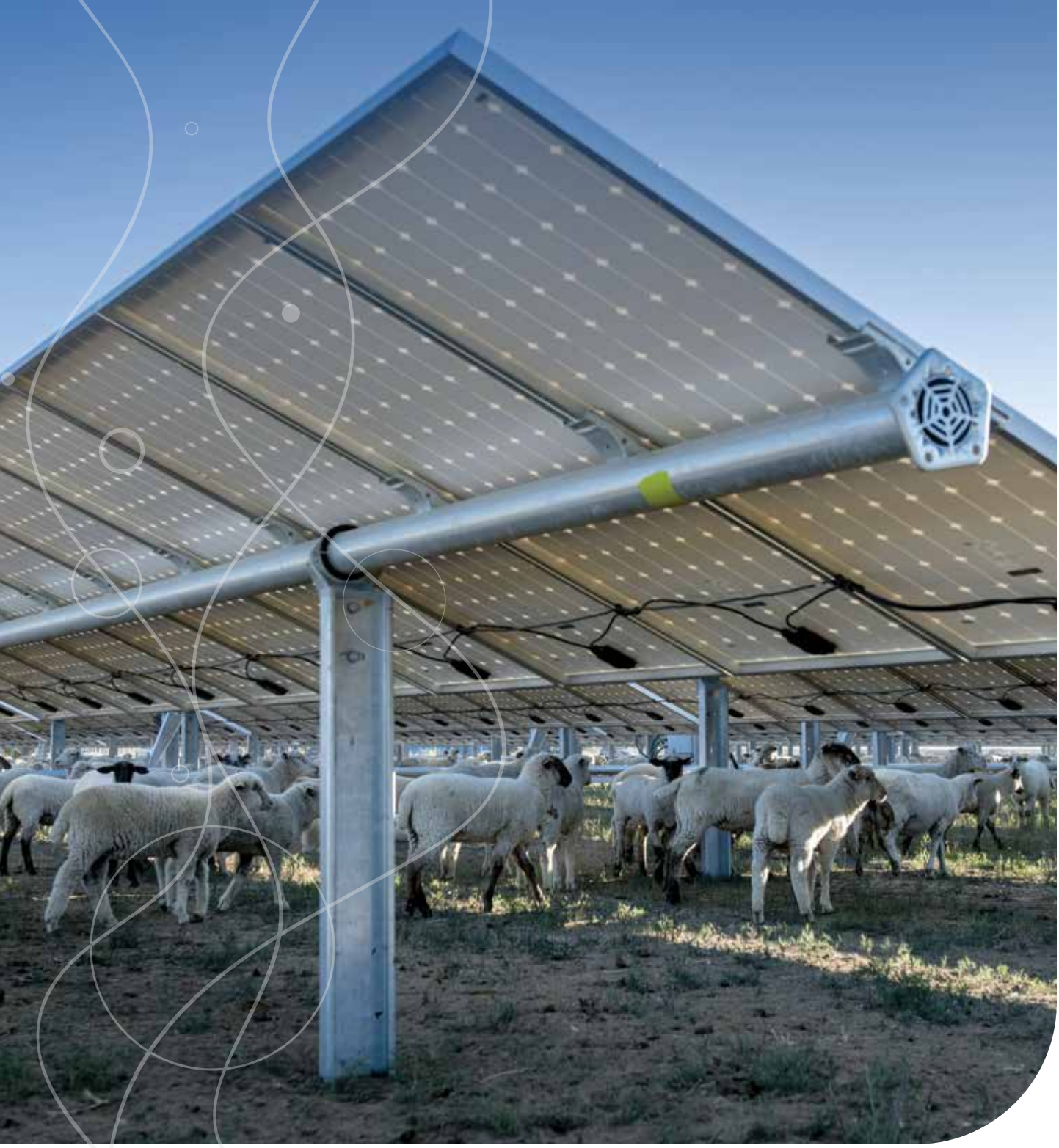
Another interconnection option is to construct a new substation (i.e., line tap) on one of the existing 230-kV lines. According to NV Energy, the existing transmission lines are at capacity. Even with a new substation, the existing lines could not accommodate more electricity entering the system. The proposed Greenlink North transmission line would provide additional transmission system capacity; however, NV Energy would need to conduct additional studies to determine the feasibility of new interconnections in Diamond Valley (personal communication with NV Energy in November and December 2023).

Regardless of the interconnection scenario, any solar energy developer would be required to submit an interconnection request to NV Energy before moving forward with an interconnection agreement. Upon receiving the request, NV Energy would conduct an interconnection feasibility study to determine the capacity of the transmission system to handle additional inputs. The results of the study would determine whether transmission infrastructure upgrades would be needed, and if so, the nature and types of those upgrades. **According to NV Energy, a solar energy developer can only enter into a new interconnection agreement with NV Energy once the feasibility study is completed and there is a plan to address any necessary system upgrades. In communication received from Balanced Rock Power (February 2024), the company was negotiating a Large Generation Interconnection Agreement with NV Energy in December 2023.** The terms of this agreement were not available at the time of publication.

Other operating and proposed energy generation facilities influence grid capacity. There are 14 pending renewable energy generation projects in Eureka, Lander, and White Pine Counties with a total proposed generation capacity of 11,400 MW. Proposed projects include the 400 MW Stagecoach Wind and 1,800 MW Tromso Solar projects in White Pine County, and 1,200 MW Lander Solar and 2,500 MW Wildcat Solar projects in Lander County (Public Utilities Commission of Nevada 2024). These projects are proposing to interconnect with the NV Energy transmission system at either the proposed Lander Substation or the existing Robinson Summit Substation. According to NV Energy's Greenlink North POD, the current import limit of NV Energy's transmission system in northern Nevada is 1,275 MW. The Greenlink North project will incrementally increase the import limit (NV Energy 2024), **but additional transmission infrastructure would be needed to accommodate the generation capacity of all the proposed renewable energy projects in northeastern Nevada (personal communication with NV Energy in November and December 2023).**

In January 2024, the BLM released a draft programmatic environmental impact statement for its Western Solar Plan. The plan seeks to direct future utility-scale solar PV energy generation projects to low-conflict locations on BLM-administered lands throughout the West. The draft plan's alternatives identify several areas throughout Eureka County where the BLM would consider future solar development.

Solar installation near Las Vegas, NV © Chip Carroon



Section 3
Agrivoltaics

Weed and grass management grazing in California © Dave Lauridsen

The term "agrivoltaics" refers to the integration of solar photovoltaic (PV) systems with agricultural production. Several studies have noted that targets for reducing greenhouse gas emissions will require transitioning some agricultural land to renewable energy production (Biggs et al. 2022; Gomez-Casanovas et al. 2023), so agrivoltaics can be an option for addressing the need for food production while converting land for renewable energy growth (Barron-Gafford et al. 2019).

There are different approaches for combining agriculture and solar systems. Abidin et al. (2021) describe systems according to the targeted output:

- Energy-centric systems minimize changes to conventional solar energy practices to optimize solar energy production while allowing agricultural production under and around the solar installation
- Agricultural-centric systems optimize agricultural production activities and maintain most existing plant management activities while integrating solar energy production
- Integrated agricultural-energy-centric approaches combine both energy performance and agricultural production targets which may provide effective diversified revenue streams

Abidin et al. (2021) suggest that energy-centric systems are best for large amounts of land earmarked for solar energy development, or places where solar development has already taken place, whereas agricultural-centric operations may be best where there is limited land or already-established agricultural areas. Agricultural-energy-centric systems may be suited for existing solar installations, farmland, or underdeveloped land (Abidin et al. 2021). Aside from utility-scale solar, Steadman and Higgins (2022) suggest that agrivoltaics may be able to be used to provide energy for electric vehicles to improve charging capacity in rural areas by shifting energy production to the point of use.

Another classification of agrivoltaic systems can be according to how the solar facilities are managed. Biggs et al. (2022) describe 1) customer-owned solar facilities where landowners who prefer operational autonomy buy and install solar panels themselves; 2) complete sale of land to the solar developer; and 3) third-party owned facilities where developers lease land from landowners. In this latter type of arrangement, developers usually install and maintain the panels and take responsibility for site cleanup. Developers in California reported average annual solar lease payments of $1,000 per acre with 20 to 30-year leases (Biggs et al. 2022). Another advantage of the lease option is that landowners can usually retain the water rights to their land.

There are several ways that solar installations can be integrated with agriculture. Figure 6 illustrates how panel

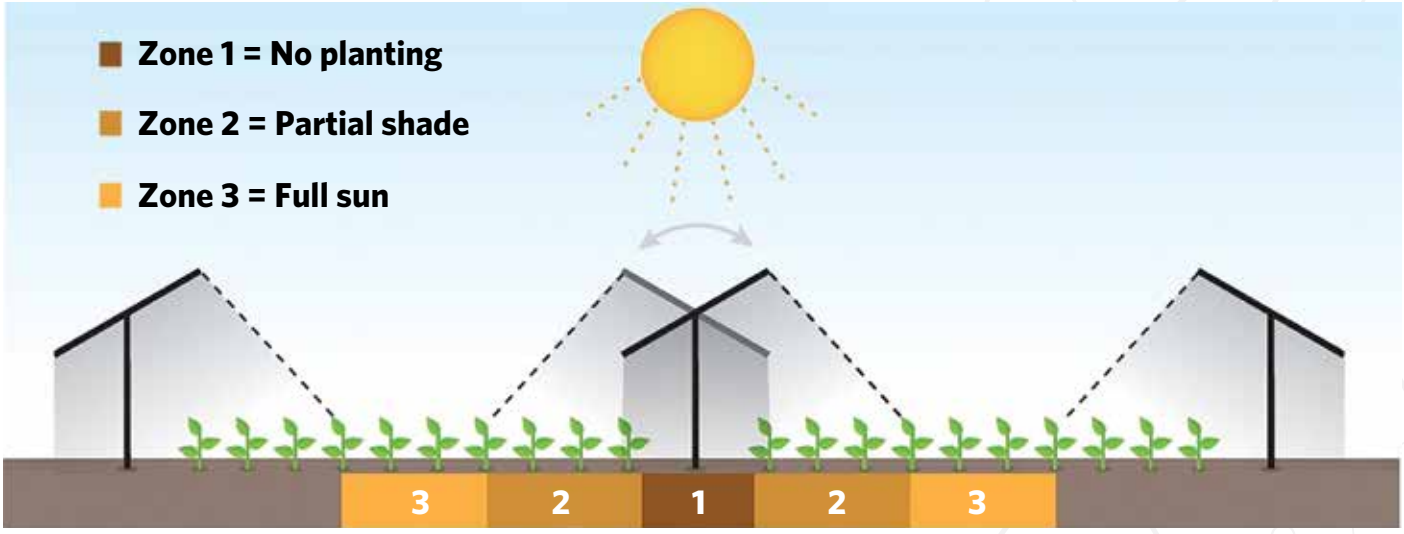


Figure 6. Shading zones in agrivoltaic systems. Zone 1 is an area that cannot be reasonably farmed due to proximity to panel structures. Zone 3 receives full sun most of the day, whereas Zone 2 receives morning or afternoon shade. Source: Gomez-Casanovas et al. (2022)

design can be used to provide desired shading or solar radiation for crops. Full-density (FD) structures are designed to optimize solar energy production and are therefore closer together. If the panels are raised, light can penetrate underneath the panels from the sides, enabling crop growth below the panels (Abidin et al. 2021). Half-density (HD) structures have wider spacing between panel rows to allow up to 70% of solar radiation to reach crop level (Abidin et al. 2021). Panels can be fixed or use tracking systems that move panels for optimal use of sunlight. Solar tracking algorithms can be developed to consider light penetration beneath the solar structure to suit selected crops while balancing energy production (Abidin et al. 2021; Gomez-Casanovas et al. 2023). There have also been installations with vertical bifacial structures that require less land, may be easier to clean, and have less interference with agricultural machinery (Abidin et al. 2021). Semi-transparent photovoltaic modules are also being studied for their utility for agrivoltaics (Abidin et al. 2021; Gomez-Casanovas et al. 2023).

The following sections describe some of the considerations associated with agrivoltaics.

3.1 Diversification of income

Surveys of landowners who have incorporated agrivoltaics (e.g., San Joaquin Valley farmers in California [Biggs et al. 2022], farmers and ranchers across the US [Pascaris et al. 2019]) indicate that **diversification of income is an important consideration.** Some landowners have felt that income from solar energy developments can mitigate the volatility of agricultural income (Biggs et al. 2022). If landowners are allowed to use the energy generated, there can be some synergy with agricultural use of power during the growing season when it overlaps with months of higher solar radiation (Al Mamun et al. 2022), thus reducing energy costs. However, this sort of arrangement may not be possible with third-party solar developers.

3.2 Land assessment changes

There may be property tax implications when farmland is converted to solar energy use. In NRS Chapter 361A (Taxes on Agricultural Real Property and Open Space), the Nevada Legislature "declares that is in the best interest of the State to maintain, preserve, conserve and otherwise continue in existence adequate agricultural and open-space lands and the vegetation thereon to assure continued public health and the use and enjoyment of natural resources and scenic beauty for the economic and social well-being of the State and its citizens" (NRS §361A.090(2)). In doing so the NRS outlines a "separate plan" for "appraisal and valuation of such property for assessment purposes" and "partial deferred taxation of such property with tax recapture" (NRS §361A.090(1)(b)). Agricultural use is defined in §NRS 361A.030 and requires the real property to be used as "a business venture for profit" with "minimum gross income of $5,000 from agricultural pursuits during the immediately preceding calendar year." Property found to be agricultural under these criteria is assessed by the county assessor to determine "its value for agricultural use and assess its taxes to be collected…at 35 percent of that value" (NRS §361A.130).

The value of land under agricultural use is substantially lower than actual market value of land because it is based on agricultural practices and rates set by the Nevada Department of Taxation and not on market value analysis. This reduced property tax rate is referred to as "partial deferred taxation" of agricultural property.

When any property (or portion thereof) assessed as agriculture and receiving partial deferred taxation converts to "higher use[11]," the county assessor is required to assess the land's "new" taxable value and then compare that taxable value against the preceding 6 fiscal years prior as follows (see NRS §361A.277 and NRS §361A.208):

1. The new land value based on the higher use is calculated for the acreage converted
2. The prior year assessed value under agricultural use is subtracted from the new assessed value resulting in the deferred assessed value
3. Property taxes are calculated by applying the local tax rate to the deferred assessed value
4. Deferred taxes are totaled for the 7-year period (current year and 6 preceding years) and billed to the landowner

[11] Higher use is defined in NRS §361A.031 and would include conversion to a solar energy installation

As an example, a random farm in Diamond Valley was used as an example to calculate the property tax should this farm convert to a solar energy project. Figure 7 is from the county assessor tax worksheet on this specific parcel of land.

As seen in Figure 7, the farm had a mix of crop cultivation types and uses with the highest taxable value for 1st Class Cultivated Farmland previously at $872.86 per acre to a low taxable value previously of $6.03 per acre for 4th Class Grazing. The assessed value jumps to $1,407 per

Office of Eureka County Assessor

AGRICULTURAL DEFFERRED TAXES DUE

ASSESSED OWNER:

CONVERSION DATE:

APN:

Fiscal Tax Year	Size (Acres)	(X)	Value Per Acre	(=)	Taxable Value	(X35%)	Assessed Value	(-)	Total Agricultural Assessed Value	(=)	Deferred Assessed Value	(X)	Tax Rate Per $100	(=)	Deferred Taxes Due
2017-2018	326.98		$1,407.00		$460,061		$161,021		$47,517		$113,504		1.8743		$2,127.41
2018-2019	326.98		$1,407.00		$460,061		$161,021		$47,517		$113,504		1.8743		$2,127.41
2019-2020	326.98		$1,407.00		$460,061		$161,021		$47,199		$113,822		1.8743		$2,133.37
2020-2021	326.98		$1,407.00		$460,061		$161,021		$46,926		$114,095		1.8743		$2,138.49
2021-2022	326.98		$1,407.00		$460,061		$161,021		$48,579		$112,442		1.8743		$2,107.51
2022-2023	326.98		$1,407.00		$460,061		$161,021		$54,059		$106,962		1.8743		$2,004.79
2023-2024	326.98		$1,407.00		$460,061		$161,021		$54,059		$106,962		1.8743		$2,004.79
														TOTAL DEFERRED TAXES DUE:	**$14,643.78**

1	A	CULTI1 - CULTIVATED 1st CLASS	134	134 CULT1	100	0	100	$872.86	$872.86	$0	$116,963
2	A	CULTI3 - CULTIVATED 3rd CLASS	134	134 CULT3	100	0	100	$485.00	$485.00	$0	$64,990
3	A	GRAZ1 - GRAZING 1st CLASS	15.26	15.26 GRAZ1	100	0	100	$33.63	$33.63	$0	$513
4	Å	GRAZ4 - GRAZING 4th CLASS	43.72	43.72 GRAZ4	100	0	100	$6.03	$6.03	$0	$264
			326.98							**$0**	**$182,730**

Figure 7. Illustration of calculation of deferred taxes for a farm converted to solar energy. Source: Reproduced from County Assessor tax worksheet.

acre with a solar energy installation, which results in a relatively large amount of deferred taxes of $14,643.78 due when converted to this higher use. The assumption is the solar improvements themselves (which are personal property, not real property) would be assessed to the solar company leasing the ground. However, as previously stated, **the landowner could continue to receive some agricultural assessed value and partial agricultural tax deferment on some of the land if they do some kind of crop under agrivoltaics and also prove at least $5,000 of gross income from the agricultural enterprise on this land.** The county assessor would have to evaluate the detailed specifics of the land use for each and every acre to make this determination.

If a property in agricultural use is sold, the county assessor sends a new agricultural deferred tax application to the new owner that they must fill out if they want to continue to qualify the property for the agricultural use assessment. If the property does not meet the requirements or there is a change to higher use, Nevada law states that prior year agricultural deferred taxes would become due. In this case, the new owner assumes the deferred tax liability from the previous owner. **Considerations for increased taxes due to conversion of the land to solar can be negotiated as part of solar leases with landowners.**

3.3 Application of agrivoltaics with little or no irrigation

Many options are available for landowners to consider when establishing vegetation to replace irrigated crops for inclusion within a solar energy installation for agrivoltaics, or otherwise. This includes, without limitation, **dryland grazing forage for sheep and/or cattle, growing of native grasses and beneficial non-native grasses (e.g., crested wheatgrass) to harvest seeds for land restoration or wildfire rehabilitation, establishing sagebrush-grassland habitat to receive sellable credits to benefit sage grouse under the Nevada Conservation Credit System, implementing habitat under a conservation plan to receive payment through a USDA Natural Resources Conservation Service program, and other similar opportunities. The Nevada Department of Agriculture (NDA) is also encouraging cultivating seed for native plants through a Foundation Seed Program to help transition and diversify crops in Nevada through the production of native seeds that can be used for restoration of disturbed sites** (see also https://www.partnersinthesage.com/nevada-native-seed-partnership for more information). Some studies have indicated that sheep are preferred when grazing livestock because they are small enough to pass between solar modules without damaging equipment (Al Mamun et al. 2022). A resource for considering grazing with solar is https://solargrazing.org/.

As noted earlier, undesirable soil erosion (including dust), noxious weed infestation, rodents, and fine vegetative fuel buildup can occur once land is no longer irrigated (Varzi and Grigg 2019). **Enforcement and abatement under NRS §555 for control of insects, pests, and noxious weeds may be possible through the already existing Diamond Valley Weed Control District and Diamond Valley**

Gold Tree Farm in California © Misha Allen/UNCE

Agrivoltaic project in Oregon © Misha Allen/UNCE

Rodent District. If sheep or other livestock grazing is implemented, there could also be the potential for disease transmission. Many of these concerns may be able to be addressed in PPAs with solar companies. For example, some PPAs include measures to address pests, such as having the solar facilities engage groundskeepers or pay for rodent removal (Biggs et al. 2022).

Most soil types under irrigation in Diamond Valley are well suited for establishment of vegetation that can subsist and persist on precipitation alone thereby ameliorating these natural resource effects of land conversion. Most of the corners of fields irrigated by center-pivot sprinkler irrigation systems (i.e., the areas not receiving sprinkler irrigation) in Diamond Valley have well established vegetation of seeded desirable, perennial grasses such as crested wheatgrass varieties and Siberian wheatgrass. Many of these seeded field corners that have been in place for many years and are adjacent to brush species seed sources have sagebrush and rabbitbrush naturally reestablishing on their own. Further, BLM has completed various vegetation fuel breaks throughout Diamond Valley among and adjacent to irrigated farmlands and the Wildland Urban Interface (WUI) in the same or similar soils as the farmlands. These fuel breaks consist of mowed sagebrush and seeding of herbaceous plants including many beneficial grasses, forbs, and subshrubs (i.e., forage kochia) that do not require irrigation to subsist. While reseeding has been required in a few locations where timing of precipitation was too low to allow germination and growth after seeding, generally these fuel breaks provide another example of the positive expectation that beneficial vegetation can be established on farmlands no longer being irrigated. Ideally, some irrigation water could be used to establish vegetation before the water right and irrigation infrastructure are completed removed, as allowed in some groundwater right retirement programs (see Section 1.3). Temporary use of water to establish vegetation is allowed under NRS §533.436 to prevent or reduce wildfire risk.

Studies of plant yields with agrivoltaics have had mixed results (Abidin et al. 2021). Barron-Gifford et al. (2019) reported increased fruit production of chiltepin (*Capsicum annuum var. glabriusculum*) and tomato (*Solanaceae lycopersicum var. cerasiforme*) under photovoltaic panels in Tucson, Arizona, but fruit production was not significantly different for jalapeño (*Capsicum annum var. annuum*) between a control site with no panels and the treatment site. Alfalfa biomass was increased by 10% over two years with movable photovoltaic panels as compared to a control plot with no panels in France, but photovoltaic production was reduced by 15% due to optimized tracking

(Edouard et al. 2023). Depending on the choice of crop, there can also be issues with accessibility for machinery during harvest in the presence of solar panels (Biggs et al. 2022).

There are many scientists and professionals able to assist in the planning and implementation of reseeding efforts on previously irrigated farmland. This includes, without limitation, the University of Nevada Extension, University of Nevada Agricultural Experiment Station, the USDA Natural Resources Conservation Service, the Eureka Conservation District, The Nature Conservancy and other non-governmental entities, and many private agronomy and natural resources consulting firms.

3.4 Attractiveness of agrivoltaics to solar companies

Biggs et al. (2022) note that utility companies and solar developers are primarily interested in transmission capacity, energy storage capacity, and land use regulations and zoning. While the application of agrivoltaics may involve increased capital costs to implement, agricultural areas are often also large flat areas with good sun exposure and access to electricity, which can make them attractive from a land use efficiency perspective (Al Mamun et al. 2022). Operating expenses for agrivoltaics tend to be similar to traditional photovoltaic systems (Al Mamun et al. 2022). Grazing of livestock on agrivoltaic farms is common; sheep and goats can help with vegetation removal and control erosion, and are also small enough to pass through solar layouts without damaging equipment (Al Mamun et al. 2022).

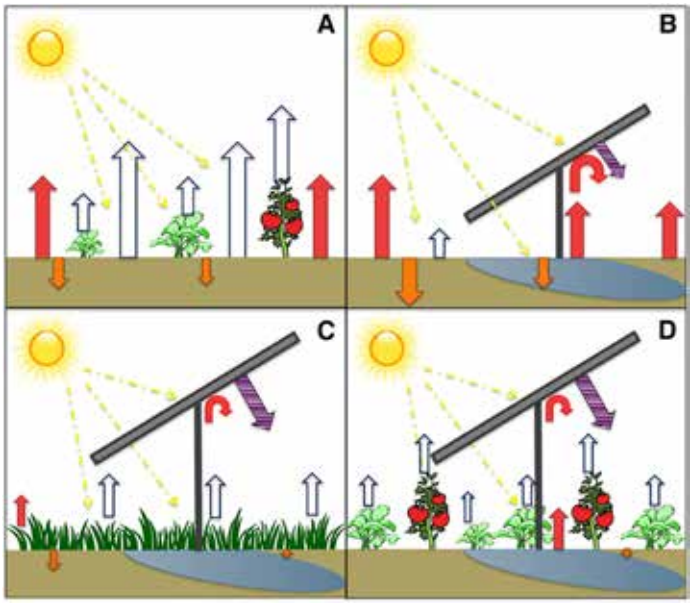


Figure 8. Illustration of midday energy exchanges for a) natural systems, b) solar PV arrays, and c) agrivoltaic system. Sizes of arrows indicate relative magnitudes of each flux. Source: Barron-Gafford et al. (2019).

3.5 Aesthetics of solar panels on agricultural land

Landowners interviewed in the San Joaquin Valley in California indicated that landscape values that involved visual aspects of solar energy developments and the viewshed were factors that could reduce landowner interest in hosting utility scale solar energy developments (Biggs et al. 2022). However, agri-tourism could also be a possibility for environmentally-oriented visitors (Al Mamun et al. 2022).

3.6 Water use efficiency, energy generation, and shade

Several studies have indicated that **agrivoltaics may increase water use efficiency because changes in evapotranspiration and soil moisture beneath panels can create a more favorable microclimate** (Figure 8; Abidin et al. 2021; Al Mamun et al. 2022; Barron-Gafford et al. 2019; Edouard et al. 2023; Walston et al. 2021), although Abidin et al. (2021) also caution that excess water and leaching can affect the structure of the photovoltaic system. Panels could also be designed for rainwater harvesting with water used for panel cleaning or to supplement irrigation (Al Mamun et al. 2022).

Traditional photovoltaic systems often have bare ground beneath the panels, but agrivoltaic facilities can lower CO2 emissions of agricultural lands (Gomez-Casanovas et al. 2023), and lower air temperatures beneath the panels which increases energy generation (Abidin et al. 2021; Barron-Gafford et al. 2019). Shading from the panels can benefit plants that prefer indirect sunlight (Abidin et al. 2021), animals (especially in areas lacking tree cover; Biggs et al. 2022), and also humans working in agricultural fields (Barron-Gafford et al. 2019).

3.7 Financial risks

The payback period for agrivoltaics can be 4 to 10 years (depending on crops) which can be longer than traditional photovoltaic systems (~5 years or less; Al Mamun et al. 2022). Revenue factors will depend on the density of the array (Al Mamun et al. 2022). To mitigate for such risk and uncertainty, financing, grants, and tax credits can be helpful (Biggs et al. 2022), as well as effective PPAs that secure electricity sales for long-term economic gain (Al Mamun et al. 2022).

3.8 Potential for agrivoltaics in Diamond Valley

In Diamond Valley, land is mostly divided into quarter sections that are 160 acres each. For quarter sections that are irrigated using a central pivot system, the irrigated portion is approximately 125 acres. Assuming a solar PV system requires a minimum of 5 acres per 1 MW of electricity generated, the maximum solar energy generation potential of each quarter section is 32 MW. Table 3 summarizes the solar energy generation potential for private properties with irrigated agricultural use in Diamond Valley that are within 1, 5, and 10 miles of existing transmission lines (see map tool to visualize these areas).

Table 3. Solar energy generation potential in Diamond Valley on irrigated agricultural land.

Distance from Transmission Line (Miles)	Private Property with Irrigated Agricultural Use (Acres)	Solar Energy Generation Potential (MW)
1	1,266	253
5	4,781	956
10	27,194	5439

Jack's Solar Garden, CO © Misha Allen/UNCE

Section 4

Key Considerations for Diamond Valley

Diamond Valley, NV © Chip Carroon

For landowners in Diamond Valley considering groundwater rights retirement:

- At the time of this report, over 12,000 AF of groundwater rights in Diamond Valley have had applications submitted for retirement under the NWCII, which equates to about 3,000 acres of currently irrigated land.
- The establishment of a fair and robust system to retire groundwater rights that conserves water is essential.
  - A groundwater buy-back program should include assurances that water rights being retired currently are being actively used.
- Valuation of groundwater rights will require complex analysis due to limited data on water transactions involving groundwater rights retirement; any future valuation analysis will need to incorporate multiple valuation methodologies to arrive at a defensible range of values for Diamond Valley groundwater rights.
  - Diamond Valley GMP shares are independent of changes in allocation and are the best metric for determining a property's water availability relative to other properties in the valley. Any future water right valuation should seek to provide a value denominated in shares that will be applicable through future allocation reductions.
- Provisions to address weeds, rodents, and establishment of vegetation on land with retired irrigation rights should be included in conservation programs used to retire water rights.
  - Options for establishing vegetation to replace irrigated crops includes, without limitation, dryland grazing forage for sheep and/or cattle, growing of native grasses and beneficial non-native grasses (e.g., crested wheatgrass) to harvest seeds for land restoration or wildfire rehabilitation (see Nevada Department of Agriculture Foundation Seed Program), establishing sagebrush-grassland habitat to receive sellable credits to benefit sage grouse under the Nevada Conservation Credit System, implementing habitat under a conservation plan to receive payment through a USDA Natural Resources Conservation Service program, and other similar opportunities.
  - Enforcement and abatement under NRS §555 for control of insects, pests, and noxious weeds may be possible through the already existing Diamond Valley Weed Control District and Diamond Valley Rodent District.
- Programs to retire groundwater rights may be able to include compensation for capping wells or vegetating fallowed land.
- Programs should consider the use of temporary irrigation to establish dryland vegetation, or allowance of stockwater if the land is to be used for grazing.

For landowners in Diamond Valley considering solar energy development on agricultural land:

- The average annual solar irradiance in Diamond Valley is sufficient to make utility-scale solar energy development economically and technologically feasible.

Diamond Valley, NV © Chip Carroon

KEY CONSIDERATIONS FOR DIAMOND VALLEY

- For entering into leases with solar energy developers, landowners should consider the following:
  - Payment amounts and timing
  - Lease duration
  - Whether the lease precludes or limits other land uses such as agriculture
  - Risk of the solar developer following through on the terms of the lease (such as in the case of a developer going bankrupt)
  - Tax implications of implementing solar on agricultural land
  - Decommissioning of solar equipment after the life of the project
- If the landowner does not own or operate the solar generation system, the landowner is not a party to the power purchase agreement between the solar energy generation system and the entity purchasing the power.
- A solar company participating in Phase 1 of this study was seeking about 3,000 acres collectively to have a viable project.
- There is no requirement for a building permit or other land use approval for solar in Eureka County.
  - Depending on the size and location of the system, state permits and approvals may be required. For example, projects greater than 70 MW would be subject to review by the Public Utilities Commission of Nevada.
- There is uncertainty about how power generated in Diamond Valley may be connected to transmission infrastructure.
  - NV Energy and Mt. Wheeler Power representatives indicated during the scoping phase of this project that the Machacek substation is at capacity and could not accept any new interconnections, such as from new electricity generation sources in Diamond Valley, without undergoing substantial infrastructure upgrades.
  - Given that most land surrounding the Diamond Valley is public land administered by the BLM, any interconnection scenario would likely cross federal lands and require NEPA compliance.
- NV Energy is proposing the Greenlink North project, which would include a new 525-kV transmission line along Highway 50 and a new substation in Lander County.
  - The Lander Substation would be approximately 40 miles from Diamond Valley. While this could be a possible interconnection location for new solar energy developing in Diamond Valley, a new generation-tie line would be needed to connect Diamond Valley solar farms with the new substation.
  - Upgrades to the Machacek Substation near Diamond Valley as part of the Greenlink North project would not increase the substation's interconnection capacity.
  - Additional transmission infrastructure would be needed to accommodate the generation capacity of all the proposed renewable energy projects in northeastern Nevada.
- Any solar development and associated infrastructure must ensure cultural artifacts or places of cultural importance are not disturbed or destroyed during construction or maintenance of facilities.

For landowners in Diamond Valley considering agrivoltaics with and without groundwater rights retirement

- Agrivoltaics can provide diversification of income to mitigate the volatility of agricultural income.
- There could be property tax implications when farmland is converted to solar energy production. However, if the landowner maintains an agricultural use in conjunction with solar and can prove at least $5,000 gross income from the agricultural enterprise on the land, the landowner may continue to receive lower tax burden based on agricultural assessed land value.
  - Considerations for increased taxes due to conversion of the land to solar can be negotiated as part of solar leases with landowners.
- Most soil types under irrigation in Diamond Valley are well-suited for establishment of vegetation that can subsist and persist on precipitation alone.

- Plant yields with agrivoltaics have had mixed results, with some showing increased yields and others showing decreased yields as compared to fields with no solar panels.
- Grazing of livestock is common for agrivoltaic farms, with sheep and goats being attractive for helping with vegetation removal and erosion control, and having a small enough size to pass through solar layouts without damaging equipment.
- Solar panels may be able to improve water use efficiency by improving soil moisture beneath panels.
- Crops beneath panels may increase solar panel efficiency by lowering panel temperatures.
- Effective solar leases are important for protecting landowners from financial risks.
- Energy potential of a quarter section in Diamond Valley (160 acres) is approximately 32 MW; on the irrigated section the potential is approximately 25 MW.
- An open-access, interactive web map tool was created as a part of this study to help with visualizing agrivoltaic potential in Diamond Valley.
- Some useful resources include:
  - University of Nevada Cooperative Extension website on agrivoltaics (https://extension.unr.edu/agrivoltaics/default.aspx)
  - AgriSolar clearinghouse (https://www.agrisolarclearinghouse.org/)
  - American Solar Grazing Association (https://solargrazing.org/)
  - Department of Energy agrivoltaics website (https://www.energy.gov/eere/solar/agrivoltaics-solar-and-agriculture-co-location)
  - Agrivoltaics index (https://solarfarmsummit.com/agrivoltaics-index)

Acknowledgments

We thank Bryant Kuechle and his team with The Langdon Group and JUB Engineers for their work on the Phase 1 report for this project. We acknowledge Eureka County, Eureka Conservation District, The Nature Conservancy in Nevada, and The Nature Conservancy's 2030 Science Catalyst Fund for funding this project. We also thank the community of Eureka and Diamond Valley, Balanced Rock Power, NV Energy, Mt. Wheeler Power, Eureka County Assessor, and members of the Duckwater Shoshone Tribe for providing input on this project. We thank Timm Kroeger for providing helpful comments on the report and Julie Cornia for report layout.

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APPENDIX A:

Responses to comments from Phase 1 of project

A.1 Groundwater rights retirement

- **Smaller farmers may be more likely to retire their water rights because they can't transfer their water rights to other parcels in the basin:** This consideration is somewhat contrary to a study of groundwater pumping in the High Plains Aquifer in western Kansas showed that a farmer that controls multiple wells in the same area can internalize impacts caused by pumping in his own wells (Pfeiffer and Lin 2012), which makes such farmers more resilient to using less water. Thus, it would appear that larger farmers may be more likely to retire some water rights because they can compensate with other wells.
- **Concerns about a fair, robust system to retire water rights that conserves water:** Some individuals expressed skepticism that the State of Nevada would produce a long-term, fair priced, water rights retirement program, or that water rights would ultimately get transferred to mining or other regions like Las Vegas. Such concerns are part of the six criteria identified by Howe et al. (1986) in regards to effective methods for water transfer that include a perception by the public that the water allocation process is equitable and fair, and that there is predictability in the outcome of the process. It is hoped that the "pilot" groundwater rights retirement programs that are using funds provided by NWCII, lessons learned from programs in other states, and the information gained from the current study will help the State and stakeholders to design an effective and fair program. The valuation of water rights is an important aspect for a fair and effective system and is addressed in this report in Section 1.2.

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- **Alteration of the landscape to unproductive land with weeds and rodent infestations:** Wind erosion, non-native plants, and dust storms can increase on land that is fallowed (Varzi and Grigg 2019). In a survey of landowners in Nebraska about the US Department of Agriculture's Conservation Reserve Program (CRP), among the most frequently listed negative perceptions of the program were weed problems on CRP lands that were their own or adjacent (Lute et al. 2018). Some conservation programs to retire water rights do allow the application of a limited amount of water per acre to establish a conservation practice on land where irrigation water rights are retired (Monger et al. 2018) to reduce the potential for these negative effects.
- **Costs for well abandonment:** Some programs do provide assistance with covering the cost of well abandonment (e.g., Harney Valley Groundwater Conservation Reserve Enhancement Program).
- **Retaining some water to maintain land for stockwater:** Under the NWCII program, complete water rights must be retired, but this type of provision may be something to consider for a Nevada water buy-back program.
- **Retiring water rights that are not being used:** Because the intention of groundwater rights retirement is to assist with stabilizing declining groundwater levels, it is important that the groundwater rights being retired are actually being used. Programs in other states have provisions to ensure that the water rights being retired are being used (e.g., the Upper Arkansas River Basin Conservation Reserve Enhancement Program requires that eligible producers have used at least 0.5 acre-feet per acre on the retired land in 2/3 of specified years, and at least half of their water right in three of the previous five years [Manning et al. 2020; Rosenberg 2020]). Legislation or regulations enacted in Nevada to establish a Nevada water buy-back program could also include language to ensure that water rights to be retired are being actively used.
- **How will retiring groundwater rights work with the Diamond Valley GMP where water rights have been converted to shares?** Section 21 (Relinquishment of Groundwater Rights or Allocations) of the Diamond Valley GMP is clear that any groundwater right under the GMP that is relinquished or retired is not available for future use and "shall not be re-issued." The GMP requires the State Engineer to update the GMP allocations to reflect the change. The GMP is flexible regarding addressing how a specific funding program to retire groundwater rights would pair with the GMP, so the requirements or restrictions of any specific water right retirement funding program could be built into the GMP case-by-case. To apply the NWCII funding for retiring groundwater rights in Diamond Valley, consultation with the State Engineer has determined that the shares and allocation for retired groundwater rights (including any banked water balance in an account at the time of the underlying water right retirement) would be placed into a special GMP water account noted as "retired." The retired right's shares would still receive annual groundwater allocations as outlined in the GMP but would be "frozen" and not able to ever be used. This approach assists DWR and GMP participants in tracking with clear documentation and memorialization of these water rights transactions and their contribution to meeting the goals of the GMP. See also Section 1.2 of this report.

A.2 Solar energy

A.2.1 Solar development

- **Many requested a "heat map" or "Diamond Valley Solar Plan" that could indicate which land is most desirable for solar development:** See Section 3.8 and the map tool for more information on solar development potential in Diamond Valley. In general, lands closer to existing or proposed transmission infrastructure are more desirable for solar development.
- **Assurances of no up-front costs before signing agreements:** The terms of a solar lease are subject to negotiation and agreement between the lessor and lessee. There are no costs or obligations to the lessee before signing an agreement.
- **Release of information about potential solar leases that can affect buyer negotiations:** Information about signed solar leases can be obtained from the Eureka County Assessor. Information about potential leases is confidential and only subject to release by participating parties.

- **Are there federal dollars or tax breaks to support solar development?** Through federal funding from the Inflation Reduction Act, Nevada property owners installing a non-utility scale solar energy system (such as rooftop solar panels) can receive a tax credit equal to 30 percent of the total cost of the installed panels. The Inflation Reduction Act also provides utility-scale solar project developers with tax credits, which reduce the overall costs of project development . The Solar Energy Industries Association predicts the Inflation Reduction Act will lead to over $565 billion in new solar energy investments over the next 10 years, which will support expanded production and installation (Solar Energy Industries Association 2024c).
- **Why doesn't the federal government provide locations or space for renewable development?** There will be solar energy development on federal lands, and those projects will require going through the process of National Environmental Policy Act review. The study described in this report only focuses on the private lands in Diamond Valley that may lose irrigated agriculture and the possibility of transitioning some of those lands to solar energy development.
- **Does solar require another form of energy production when it is not producing since solar radiation is inconsistent?** Solar is intermittent energy source. Energy production is variable depending on weather and time of day. Battery storage systems can store energy and release it over time, typically up to four hours. The terms of a power purchase agreement account for the intermittent nature of solar power. Solar is typically part of a power purchaser's portfolio of energy resources.
- **When installed equipment becomes obsolete, are landowners left with unusable equipment?** The life of the project, disposal of equipment, and land reclamation should be part of the lease agreement between the landowner and the solar energy developer.
- **Aesthetically, solar panels are not as attractive as the existing farms without solar panels:** Landowners interviewed in the San Joaquin Valley in California indicated that landscape values that involved visual aspects of solar energy developments and the viewshed were factors that could reduce landowner interest in hosting utility scale solar energy developments (Biggs et al. 2022). However, agri-tourism could also be a possibility for environmentally-oriented visitors (Al Mamun et al. 2022).
- **How will solar farms benefit the local economy and will it attract a transient workforce during installation?** Solar farms result in primarily temporary, near-term benefits to the local economy during project construction with more limited longer-term benefits. For comparison, the developers of the Libra Solar Project proposed near Yerington, Nevada anticipate 400 construction workers and 14 long-term full time jobs during operation (Libra Solar LLC 2024). Solar energy generated from projects in Diamond Valley will not contribute to the energy needs or influence the cost of electricity for Eureka County residents. This is because Mt. Wheeler Power is the electricity provider for Eureka County residents and Mt. Wheeler Power representatives indicated during Phase 1 of this project that the electric cooperative does not intend to purchase power from Diamond Valley solar energy producers.
- **Solar could create inequities because some will have income from solar development but others may not because their land was not desirable, or one neighbor will be forced to look at their neighbor's solar development:** In general, solar developers will pursue leases with properties closest to existing or proposed transmission because interconnection costs for those properties is lower than for properties further away from transmission. Desirability of a property is also subject to topography, access, and other site-specific conditions. Installing solar panels on lands previously used solely for agriculture will alter the visual landscape. The magnitude of visual impacts would vary by site based on factors such as topography, vegetation, and proximity of the panels to the primary viewing locations of adjacent properties.
- **Converting land use from agricultural to industrial or mixed use could have a negative impact to the tax base and increase a landowners' property taxes:** See Section 3.2.

- **Solar development will ensure the land is maintained (i.e., unmanaged land can produce weeds and rodent issues that impact still productive farmland):** PPAs could include measures to address rodents., as they can also be detrimental to solar infrastructure (Biggs et al. 2022).
- **If there is a potential opportunity for Mt. Wheeler Power (local electricity cooperative) to acquire the energy generated, it could reduce rates in the region:** Mt. Wheeler Power representatives indicated during Phase 1 of this project that the electricity cooperative does not intend to purchase power from Diamond Valley solar energy producers.
- **Solar could be used on non-irrigated parcel corners:** Solar developers will prefer contiguous arrays to maximize access efficiency and operation, so corners may not be the most desirable locations unless the rest of the parcel is also going to be in solar.
- **This alternative land use will help get water off the books permanently because the only water usage for solar development is during construction for dust control:** The primary water demand for solar is during construction to mitigate dust. The proposed Libra Solar Project in Lyon County, for example, would use an estimated 1,000 acre-feet of water during construction. During operation, the project would require 28 acre-feet per year for ongoing dust control (Libra Solar LLC 2024). The newest panel systems do not require washing.
- **Converting agricultural land to solar will provide a "soft landing" for those looking to retire water rights, get out of farming, and still provide a level of income.** A landowner that enters a solar lease would receive compensation subject to the negotiated terms of the lease. A landowner could use that compensation to offset the income previously received from farming following water right retirement.

A.2.2 Greenlink North (GLN) transmission line

- **Who is paying for the GLN transmission line?** NV Energy ratepayers are paying for GLN. As a public utility, NV Energy must get approval from the Public Utilities Commission of Nevada for major infrastructure investments that affect rates.
- **Will the GLN transmission line connect to existing substations or will there be a new location to potentially onboard energy in Diamond Valley?** See Section 2.2. The Greenlink North Project is proposed to the Fort Churchill and Robinson Summit Substations. A new substation is also proposed in Lander County (NV Energy 2022). Interconnection to the Greenlink North line would be subject to approval by NV Energy.
- **If GLN will connect to existing substations, what upgrades are needed?** NV Energy's POD identifies major upgrades to the Fort Churchill and Robinson Summit Substations. It also proposes minor upgrades to the Machacek Substation near Diamond Valley; however, those upgrades would not increase the interconnection capacity of that substation.
- **Will potential for solar development drive likelihood of new substation in Diamond Valley?** The potential for new solar development potential in Diamond Valley could increase the likelihood for a new substation near Diamond Valley. The location of any new substation would be subject to NV Energy's evaluation of transmission system capacity, interconnection options, and site conditions.
- **Who is the energy for? Does it stay in Nevada? Is it specifically for growth in Reno? Does it go to California?** See Section 2.2. A power purchase agreement dictates the end users of solar power. There are no power purchase agreements currently in place for potential solar energy development in the Diamond Valley.

A.3 Agrivoltaics

- **Landowners who would lease their land to solar development might retire, or would see it as an opportunity to lease the farmable land as another source of income:** Many participants perceived that most landowners who would lease their land to solar development are looking towards retirement, so they would not be interested in farming the non-irrigated land, but would see leasing as another source of income. The sentiment of diversifying income is supported by surveys of others who have incorporated agrivoltaics (e.g., San Joaquin Valley farmers in California [Biggs et al. 2022], farmers and ranchers across the US [Pascaris et al. 2019]). Some landowners have felt that income from solar energy developments can mitigate the volatility of agricultural income (Biggs et al. 2022). If landowners are allowed to use the energy generated, there can be some synergy with agricultural use of power during the growing season when it overlaps with months of higher solar radiation (Al Mamun et al. 2022), thus reducing energy costs. However, this sort of arrangement may not be possible with third-party solar developers.
- **How agrivoltaics would impact how the land is assessed:** Currently farmed land is classified as agricultural for property assessment, but having another economic use of the land could change that. See Section 3.2 for a discussion of this concern.
- **Functional application of agrivoltaics:** Participants provided some ideas of how agrivoltaics might be implemented, especially without irrigation. Vegetation would be needed to prevent weeds and rodents from impacting neighboring, productive farms. One option could be crested wheatgrass which grows well without irrigation and could be grazed and planted among solar panels that rotate with the sun. If coupled with groundwater rights retirement, participants thought some water would be needed to establish cover crops, and some thought that dryland cover crops would produce small and inconsistent yields, and therefore not be worth the cost of labor. There also was concern that using sheep for grazing would have a negative health impact due to disease transmission. To address some of these concerns, Biggs et al. (2022) note that PPAs can include measures to address pests, such as having the solar facilities engage in groundskeepers or paying for rodent removal.
- **Attractiveness of agrivoltaics to solar companies:** See Section 3.4. Participants wondered if grazing animals and rodents impacting equipment would be an unwanted risk, or if solar companies would want to invest in the extra infrastructure cost. As noted above, PPAs could include measures to address rodents (Biggs et al. 2022). Biggs et al. (2022) note that utility companies and solar developers are primarily interested in transmission capacity, energy storage capacity, and land use regulations and zoning. While the application of agrivoltaics may involve increased capital costs to implement, agricultural areas are often also large flat areas with good sun exposure and access to electricity, which can make them attractive from a land use efficiency perspective (Al Mamun et al. 2022). Operating expenses for photovoltaics tend to be similar to traditional photovoltaic systems (Al Mamun et al. 2022). Grazing of livestock on agrivoltaic farms is common; sheep and goats can help with vegetation removal and control erosion, and are also small enough to pass through solar layouts without damaging equipment (Al Mamun et al. 2022).

APPENDIX B:

Methods used for analyses in this report

B.1 Data collection and map tool

We established spatial and non-spatial data that included:

- Water rights points of diversion in Diamond Valley from the Nevada Division of Water Resources (NDWR) Permit Database
- Water rights places of use in Diamond Valley from NDWR
- Adjudications data in Diamond Valley from NDWR
- Eureka County parcel layer from Eureka County Regrid
- Eureka County roads from REST server
- Sales data between 8/2/2013 to 7/32/2023 from Eureka County Assessor's Office
- Hydrographic boundary layer from NDWR
- Sales deeds for 12 parcels
- Machacek Substation feature
- Floodplain boundary for Diamond Valley from FEMA National Flood Hazard Layer
- Energy transmission lines in Eureka County
- Groundwater-dependent ecosystems database from The Nature Conservancy

Power lines near Machacek Substation, Eureka, NV © Peter Gower/TNC

B.1.1 Senior and junior water rights in Diamond Valley

We clipped the water rights places of use layer to the Diamond Valley hydrographic boundary layer and selected only the places of use that were underground and for irrigation use. We separated the resulting layer into two layers: 1) senior water rights for those with priority dates prior to May 12, 1960; and 2) junior water rights for those with priority dates after May 12, 1960. The separation date is the data when groundwater rights allocated exceeds the perennial yield of 30,000 acre-feet as recognized by the Nevada State Engineer. This separation was done for general depiction purposes only of the geographic distribution of groundwater rights based on the perennial yield and is not intended to imply whether water rights are junior or senior if a curtailment of pumping by priority were ordered or required by the State or a court. This separation also does not account for more recent groundwater rights granted to mitigate declines in older surface water rights.

B.1.2 Additional layers

We also created a layer to represent buffering distances from transmission lines because distance to transmission facilities could be a factor for solar developers in considering project feasibility. We mapped buffers of 1, 5, and 10 miles from the transmission lines. Another layer created was a spatial join of the parcel layer with the sales records for parcels in the county.

B.2 Land assessment implications

The Eureka County Assessor provided information about how land assessment values might change if solar energy development is implemented on land that is taken out of agriculture. NRS Section 361A provides for a tax deferment for private lands considered agricultural or open space. If the land use changes to a higher use, then the county assessor must re-assess the property and issue a revised property tax assessment. Additionally, the property owner would be responsible for the deferred tax for each fiscal year the property was under agricultural or open-space assessment during the current fiscal year and the preceding 6 fiscal years (NRS §361A.277). To qualify for an agricultural deferment, a property owner must demonstrate at least $5,000 of expenditures related to an agricultural venture. Co-locating a solar farm with active agriculture (agrivoltaics) could avoid the costly tax implications of fully transitioning a property from agriculture to an industrial use such as solar.

B.3 Groundwater rights valuation

For the land price differential analysis, land sales from across Eureka County were gathered for 2013-2023 from the Eureka County Assessor. The transactions were filtered according to the following criteria:

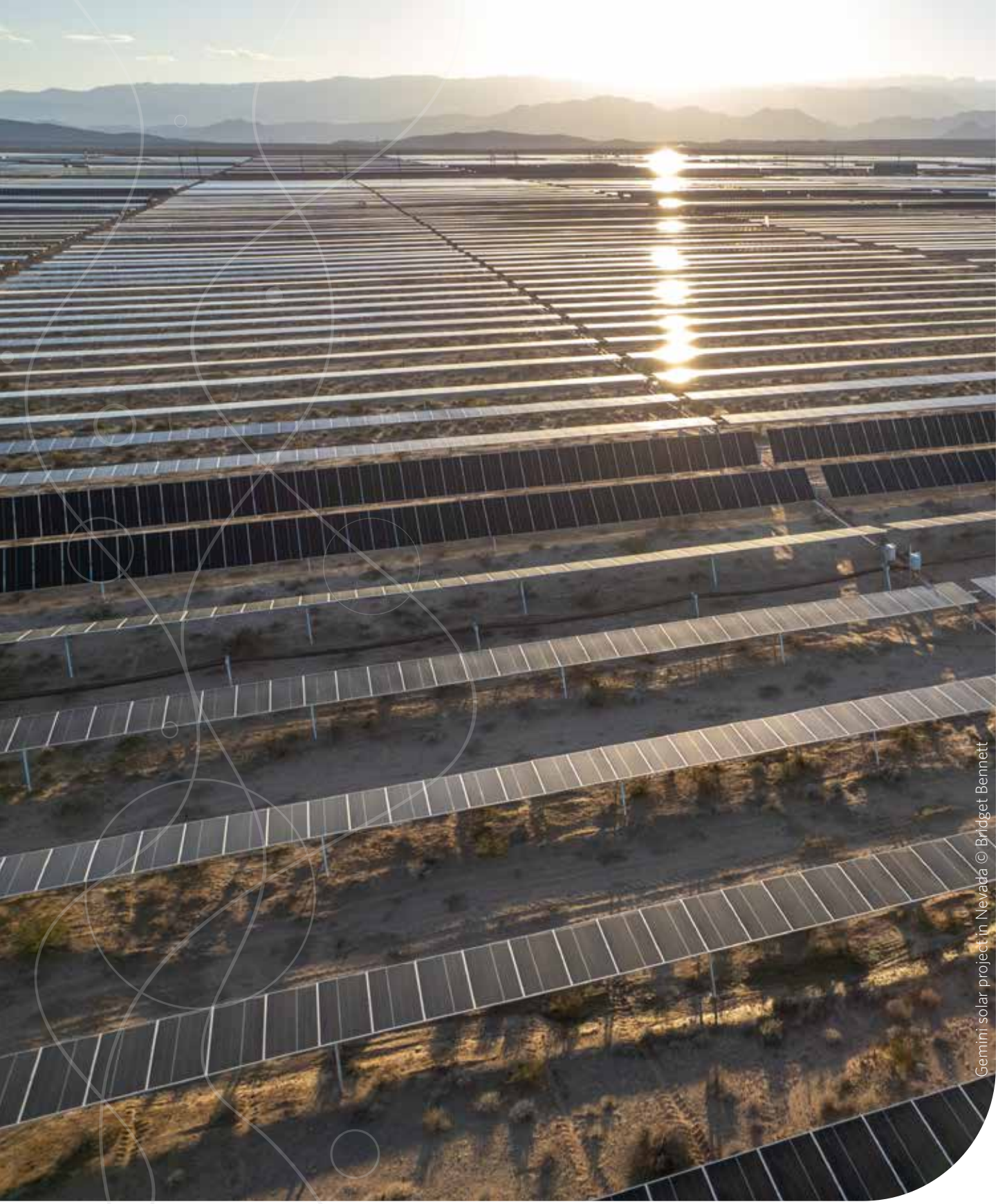
- **Transaction size:** Sales under 50 acres were excluded from the analysis because smaller acreage land sales can be associated with residential use and may not reflect the productive value that water rights contribute to the property.
- **Sale type:** The assessor notes included the type of sale, so sales involving related parties or associated businesses were excluded because these sales may not be indicative of market values. Sales where only a percentage interest of land was transacted were also excluded as it is difficult to ascertain what exactly was sold as part of these transactions.
- **Data accuracy:** Each transaction reported the number of acres sold and allocated the acres by soil class and land type. Transactions where the number of acres assigned to each land type did not equal the total number of acres within the sale were excluded from the analysis.
- **Improvements:** To ensure the analysis was not confounded by the value of improvements, sales that included assessed building values were removed.

- **Outliers:** Outliers were investigated and were removed from the analysis if justified. Reasons for removal included the following:
  - **Mining Transactions** – Transactions where mining companies were buyers were removed as the value of these transactions are not representative of the average dryland property in the area. These purchases were likely for a value significantly beyond regular dryland value, such as mining operations or the mineral estate.
  - **Old Transaction** – One transaction was a re-recording of a 2000 transaction, which was outside the scope of this analysis and was removed.
  - **Non-Diamond Valley Groundwater Irrigation** – A handful of transactions included surface water transactions and at least one groundwater transaction outside of Diamond Valley. As this analysis was focused on groundwater values within Diamond Valley other irrigated transactions were removed.

B.4 Calculation of solar energy generation potential in Diamond Valley

The places of use for water rights dataset from was subset to include only 'irrigation' manners of use and an 'underground' source to represent groundwater rights availability. Using this subset places of use layer, private property with irrigated agricultural use areas were calculated within 1, 5, and 10 miles of transmission lines. This analysis was achieved using the Summarize Nearby function in ArcGIS Pro (v 3.2.1).

Diamond Valley, NV © Chip Carroon



Gemini solar project in Nevada © Bridget Bennett

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