Solar Energy and Groundwater in the San Joaquin Valley

How Policy Alignment Can Support the Regional Economy

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Key Takeaways

The Sustainable Groundwater Management Act (SGMA) requires groundwater users to bring their basins into balance over the next two decades. In the San Joaquin Valley, this will likely mean taking more than 500,000 acres of agricultural land out of intensive irrigated production. Local and regional economies could be stressed as a result, with some regular employment opportunities in agriculture disappearing and public revenues declining if lands are not put to new uses. As landowners and newly formed groundwater agencies tackle the groundwater deficits in their areas, utility-scale solar development—already an attractive option for landowners owning property with or without water rights—could offer an opportunity to keep lands that exit irrigated production economically productive. Moreover, development could provide multiple benefits by helping to supplement habitat and mitigate dust generation on transitioning lands. However, the expansion of solar hinges on whether state-level energy system planning processes—in conjunction with local land use planning—can address the transmission challenges that threaten the region’s promise as a solar power hub.

>- **Aligning policy implementation can generate statewide and regional benefits.** Two state policies, SGMA and Senate Bill 100 (which requires that 100% of electricity sales be renewable or zero-carbon by 2045), provide a unique opportunity to help meet renewable energy goals, benefit the state’s energy consumers, and support economic stability in one of the state’s most economically challenged regions. Meeting state renewable energy goals can go hand in hand with exploring productive land uses for retired farmlands that might otherwise become a local nuisance.

>- **The San Joaquin Valley has some of the best solar development prospects in the state.** To meet SB 100 goals, electricity generation capacity in the state will need to increase at an unprecedented rate—and the high solar resource potential in the valley, combined with land availability, means it can serve as an important resource. However, to make this a reality, increasingly tight constraints in transmission capacity will need to be addressed. Project planning and financing has already become more difficult in the past few years due to uncertainty about access to scarce grid capacity.

>- **Local benefits from utility-scale solar development are not guaranteed.** Solar developments should be sited and designed to protect especially high-value conservation areas, manage local impacts like dust emissions, and deliberately provide opportunities for local employment. Local and other permitting agencies can help to smooth regulatory processes to facilitate project development where these local benefits are available.

>- **Tighter integration between state energy system planning and local land use planning will be paramount.** State-level transmission planning processes can benefit from incorporating information about where land is likely to come out of production, as retired lands can be promising for both transmission and solar development. In addition, local information can inform lower-impact solar generation planning. Groundwater agencies that have not already done so may soon be formulating and implementing demand-management actions. Knowing more about where new transmission may be built could help them work with landowners to transition formerly irrigated land into a new productive use.

Introduction: Softening Land Transitions with Solar

Widespread changes to groundwater availability are coming to the San Joaquin Valley as a result of the Sustainable Groundwater Management Act (SGMA). Between 500,000 and 1 million acres could come out of production, leading to economic stress for local and regional economies. As part of this transition, utility-scale solar development offers a promising opportunity to keep lands that exit irrigated production economically productive. However, this expansion hinges on the ability of state-level energy system planning and local land use planning to address transmission challenges and ensure that transitioning lands are used in ways that benefit the environment and the local community.
of irrigated production by 2040, according to previous PPIC analysis (Hanak et al. 2019). Improving groundwater sustainability is critical for the region, but in the near term, bringing large tracts of agricultural land out of irrigated production may impair regional economic activity and create nuisances like weeds and dust.

Utility-scale solar photovoltaic development presents an opportunity to soften some of these potential negative impacts by putting lands to use for economic and environmental benefit. Policy and economic drivers have already made solar an attractive land use, and stakeholders and planners have identified the San Joaquin Valley as a place with high potential to build more. Substantial developments are already being constructed in places like Fresno, Kings, and Kern counties. In Kings, for example, the Westland Solar Park completed its first utility-scale array earlier this year: A 250-MW solar development called Aquamarine that is just the beginning of an ambitious expansion planned over the next decade.

California’s ambitious renewable energy goals will drive increasing solar construction in the valley. The passage of SB 100 and related legislation has set the stage for an unprecedented build-out of solar in the next two decades—the same time period during which water users need to bring groundwater basins into balance under SGMA. The potential synergies are clear: much solar could be sited on transitioning agricultural lands. If executed well, this complementary shift in land use could help the state meet its renewable energy goals while providing an alternative, revenue-generating use for fallowed lands.

Despite plans for increased solar build-out, limitations on the ability of projects to interconnect to the transmission grid will constrain future development. For some time, project developers have faced increasing difficulty accessing transmission capacity in the valley, and the large-scale expansion expected over the coming decades will exacerbate that scarcity. And although solar can, if planned correctly, contribute to regional economic vitality and help manage weeds and dust, it is not guaranteed to deliver these benefits. Successfully transitioning lands from agriculture to solar in a way that generates broad benefits for the region will require coordination across local, state, and federal actors.

In this report, we take a closer look at utility-scale solar as a possible alternative use for fallowed lands in the San Joaquin Valley. This work builds upon previous PPIC analysis that estimated the scale and location of agricultural lands that will likely go fallow in the coming decades (Hanak et al. 2019). It is part of a larger ongoing PPIC effort on land transitions in the valley, which updates those falling estimates and investigates the relative benefits and costs of land use alternatives (Ayres et al. 2022; Peterson et al. 2022; Escriva-Bou et al. forthcoming). In doing so, we reviewed the scientific literature on energy planning and solar development and also incorporated input from stakeholders—including energy planners, county representatives, land managers, solar developers, and other experts from California—through four stakeholder workshops and other conversations (Ayres and Seymour 2022; Rosser and De Leon 2022).

We begin by examining the future of solar in the San Joaquin Valley, including expected solar growth and the transmission required to bring new developments online. Next, we explore the overlap between high suitability for solar and our estimates for future falling, shedding some light on how much and where agricultural land might transition to solar production. We then dive into the economic and environmental considerations necessary to provide co-benefits like job creation while minimizing potential impairments to habitat and air quality. Finally, we conclude with a set of recommendations for state agencies, county
governments and local agencies, and solar industry and workforce development stakeholders to better facilitate a smooth transition from fallowed agricultural lands to solar energy generation.

The Future of Solar in the San Joaquin Valley

Today, solar conversion is already an attractive option for some active farmland in the San Joaquin Valley. Despite transmission constraints, agricultural land conversion for solar development is ongoing, and the queue for new projects is long. This is driven in part by California’s ambitious renewable energy goals that will require a significant build-out of solar over the next two decades. Given this expected growth, solar has the potential to be an advantageous alternative land use for formerly irrigated agricultural lands.

The Current Solar Landscape

The solar industry is growing quickly in California. As of 2019, there were about 20 gigawatts (GW) of installed solar capacity (including utility-scale and distributed generation) throughout the state, with about 3 GW of that located in the San Joaquin Valley—in both cases, roughly half of this capacity was installed in the last five years. Capacity is expected to increase rapidly in the coming decades, and eventually exceed 70 GW if California reaches its 2045 renewable energy goals (California Energy Commission 2021), with potential for 100 GW or more, depending on the extent of electrification in the rest of the economy. A range of factors influence where projects are located: most importantly, access to transmission lines and interconnection costs, but also the cost of land rental or acquisition payments and resource availability (i.e., how much sunlight a site receives). With its favorable conditions, the San Joaquin Valley is a particularly attractive location for cost-effective solar development. Beyond the 3 GW already installed in the region (Figure 1; left panel), roughly 20 GW more are slated in the project queue (right panel). Although not all of these queued projects will be built, the scale of the backlog signals the industry’s interest in building in the valley and the need for further planning to fast-track cost-effective solar.

1. A gigawatt (GW) is a measure of electric power equal to one billion watts; it is a measure of generation capacity rather than generated electricity. Smaller units include megawatts (MW, one-thousandth of a GW) and kilowatts (KW, one-thousandth of a MW). A gigawatt-hour (GWh) is a measure of produced electricity—one GW sustained for an hour—and large relative to household demands. A smaller unit, the kilowatt-hour (KWh) is typically used to measure household use. In California, an individual household may consume from several hundred to several thousand KWh of electricity per year, depending on size and occupancy.
2. Typical power density per acre of utility-scale solar can range from 5–10 acres per MW (SEIA 2022). Stakeholders suggested that typical projects in California and the valley may be around 6 acres per MW, with larger installations tending to be denser. Using a representative density range of 5–8 acres per megawatt, these 3 GW of utility-scale capacity may cover approximately 15,000–25,000 acres.
Utility-scale projects have in many cases become an attractive option for landowners, relative to irrigated agricultural production. As a result, some agricultural landowners are motivated to shift to solar regardless of groundwater regulations. Stakeholders consulted for this project reported that returns to landowners from solar development often take the form of annual rental payments (perhaps $1,000–1,500/acre/year) or long-term options to buy title to or place an easement on the land (perhaps $12,000–15,000/acre) to retain it over the life of the project. These exceed comparable returns for production of annual crops (roughly $200–450/acre/year) and even more profitable orchard crops in many cases (up to a couple thousand dollars/acre/year). In addition, given the uncertainties that project developers face—including long review times for permitting and interconnection—it is also common for landowners to receive an option payment of

3. Many landowners participating in solar development reserve water rights or entitlements tied to the parcel for themselves. In cases where a landowner could not reserve waters associated with the land, interest in solar would likely be reduced.
perhaps a few hundred dollars per acre per year to hold specified lands ready for development as these processes unfold.

As solar development has proceeded in the valley, the availability of transmission capacity to support interconnection to the grid has emerged as a primary limiting factor to large-scale expansion. While there is much valley land with sufficient solar resources for development, utility-scale projects that cannot cost-effectively connect to the electric grid cannot move forward. Interconnection opportunities are already constrained, and building new infrastructure is costly. This has led to an increase in the minimum viable size of solar power developments, as only larger projects can effectively finance the significant interconnection costs needed to move forward. Over the past five years, the average size of completed projects in the valley more than doubled, from roughly 20 MW to over 40 MW, according to data from the California Energy Commission.\(^4\)

Since transmission capacity is a limiting factor in project interconnection, solar project development activity has gravitated to those areas where transmission already exists. Existing transmission is primarily located on the western side of the valley (Figure 1, right panel), resulting in a concentration of projects there. Since it is often more cost-effective to add transmission capacity along existing transmission corridors, new solar projects will likely continue to cluster on the west side in the absence of new approaches to planning and significant transmission investments in other parts of the valley.

**How Much Solar Needs to Be Built?**

Projected solar development in California is chiefly driven by the passage of SB 100 (2018), which requires 100 percent of the electricity sold to California customers to derive from renewable or zero-carbon resources by 2045 (Box 1). Decarbonizing the energy sector by the mid-2040s is a massive effort and will drive an unprecedented build-out of renewables, including solar, over the next two decades (Figure 2). To achieve this goal, developers will need to build over three times the amount of existing solar (at least an additional 70 GW, if not more). Most of this solar will be constructed with on-site, integrated short-duration battery storage, increasing the project footprint slightly. An expansion of this scale will require a significant amount of land—likely around 300,000 to 480,000 acres, assuming between 6 and 8 acres per MW of capacity.

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\(^4\) Using a range of 5–8 acres/MW, these installations may have grown from roughly 100 to 160 acres, on average, to 200 to 320 acres, on average. This excludes any on-site energy storage, although such storage would represent a relatively small addition to the project’s footprint.
Figure 2
Projected build-out of solar energy resources to achieve SB 100 goals

SOURCE: Developed by the authors using electric generation capacity data from the California Energy Commission and California Distributed Generation Statistics.

NOTES: Existing (to 2020) and projected (after 2020) solar power capacity development is shown by shaded areas and lines, respectively. Existing solar capacity is broken out into customer and utility-scale categories; a large proportion of projected capacity development will be utility-scale, including many installations in the San Joaquin Valley. Projections are based on modeled solar energy resources required to achieve SB 100 goals, but do not take into account recently adopted interim targets established by SB 1020 (2022). The new interim goals (90% by 2035 and 95% by 2040) will require a similar volume of solar energy, but over a slightly shorter time horizon than displayed here. In addition, further electrification of traditionally non-electric economic sectors (e.g., transport) may increase the total solar capacity needed to reach SB 100/SB 1020 targets.
Box 1. SB 100 and the state’s renewable energy goals

Renewable portfolio standards (RPS) in California have prompted public and private efforts to expand renewable electricity capacity since 2002. The state’s RPS has evolved over time to target higher rates of integration on more rapid timelines. SB 100 represents another increase in ambition.

SB 100 (2018) requires that by the end of 2045, 100 percent of electric retail sales to end-use customers and 100 percent of electricity procured to serve all state agencies come from renewable energy and zero-carbon resources. SB 100 is affecting how utilities, Community Choice Aggregations (CCAs), and the state plan for and purchase energy for the foreseeable future. This policy is rapidly accelerating the rate at which zero-carbon resources are being integrated onto the grid and will require state agencies to address cascading impacts on electric rates, reliability, and even other sectors—such as land use. The unprecedented build-out of some renewable energy technologies to meet this goal will require associated investments in public infrastructure and carefully thought-out approaches to deal with potential impacts on local communities and other sectors.

In March 2021, per the bill requirements, the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Air Resources Board (CARB) released the 2021 SB 100 Joint Agency Report: Achieving 100 Percent Clean Electricity in California: An Initial Assessment. This report included a preliminary economic analysis and modeling of various pathways showing how California could achieve its goals to decarbonize the electric sector. It also discussed impacts to local and system reliability and provided an initial estimate of the necessary technology portfolio mix and costs (including solar build-out estimates cited elsewhere in this report). The report encouraged additional work on identifying reliability, land use, equity, labor, and other impacts so this information can be incorporated into future planning and implementation activities. SB 100 requires the joint agencies to update this report to the legislature every four years.

In September 2022, the state enacted SB 1020, which adds additional interim targets to the SB 100 goals. It requires that 90 percent of electric retail sales to end-use customers come from renewable energy and zero-carbon resources by the end of 2035, and 95 percent by the end of 2040. It also requires that state agencies rely on 100 percent renewable energy and zero-carbon resources to serve their own facilities by 2035.

To stay on track with the SB 100 timeline, the bulk of this planned solar would need to be built in the next two decades. The San Joaquin Valley has been identified as a prime location for future development, in large part due to resource potential (i.e., solar energy available for capture). This region also presents opportunities to avoid impacts on ecologically sensitive habitat (Pearce et al. 2016; Wu et al. 2019; Wu et al. 2022). Conflicts over environmental impacts have hindered development in other areas of California with strong resource potential such as the Mojave Desert. It is conceivable that the San Joaquin Valley could become home to 30 GW of solar capacity—roughly 10 times the current amount—or even more (CAISO 2022a). Such a build-out would raise the profile of the valley as a solar hub considerably. Today, it hosts roughly 3 of 20 GW statewide, and 30 GW could make up 30–40 percent of statewide capacity by 2045, according to some scenarios.

Decisions on where to locate solar in the coming years will have lasting impacts. Large-scale solar developments have a lifespan of about 30 years, and some developers are considering longer timelines if they can deploy new panels on existing mounting and tracking systems. In many cases, future solar projects will be rebuilt in the same locations, given the hurdles project proponents need to overcome to develop
them in the first place. And since the location of transmission upgrades will largely determine the location of these new developments, state-level energy planning processes that guide public and private investments in the grid will play a major role in shaping these opportunities.

**Energy planning and transmission constraints**

According to stakeholders, expanding transmission capacity to keep pace with the projected build-out of solar energy is one of the most pressing obstacles to meeting renewable energy goals. The projected necessary build-out of solar depends on expected electricity demand, GHG reductions targets, and other factors. Recent projections call for adding up to 4,000 MW of new resources statewide annually, up from 1,000 MW in last year’s transmission plan, which incorporated lower demand forecasts and less ambitious GHG emissions reductions (CAISO 2022b). These rates of build-out will require significant increases in transmission capacity that state energy planning agencies must plan for, approve, and have permitted. Increases in expected electricity demand—for example, prompted by more extensive electrification of the economy or more ambitious GHG emissions reductions targets—could sharpen the challenges faced by planning agencies.

To identify, plan for, and ultimately build needed transmission, inputs from numerous processes at multiple different agencies are fed into the California Independent System Operator’s (CAISO) annual Transmission Planning Process (Table 1). Electricity demand forecasts—produced for the CEC’s Integrated Energy Policy Report (IEPR)—inform generation capacity acquisition plans developed as part of the California Public Utility Commission’s (CPUC) Integrated Resource Plan (IRP) process. As utilities and other load-serving entities (LSEs) make plans to contract for new generation capacity, the CAISO determines what new transmission infrastructure will be needed to meet reliability, economic need, and some public policy targets (e.g., CARB’s scoping plan to reduce GHG emissions). The permitting of generation and transmission then involves a number of additional local, state, and potentially federal agencies. Although US Department of Energy (DOE) funding sometimes supports infrastructure development, utilities or developers often finance transmission infrastructure expansion, with ratepayers ultimately paying the costs.
Numerous intersecting planning efforts will govern progress toward SB 100 implementation

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<td>SB 100</td>
<td>• RPS of 60% by 2030; zero-carbon electricity by 2045</td>
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<td></td>
<td>• Joint agency reports (every four years from CPUC, CEC, and CARB)</td>
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<td>CEC Integrated Energy Policy Report (IEPR)</td>
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<td>CAISO Transmission Planning Process (TPP)</td>
<td>• Assess transmission needs and approve new investments (annually)</td>
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**SOURCE**: Authors’ research and description.

**NOTES**: Table identifies existing energy planning and reporting processes at the state level and summarizes their goals and scope. Load-serving entities (LSEs) include investor-owned utilities, community choice aggregators, and other entities that sell or provide electricity. SB 350 (2015) required 50 percent of the electricity generated and sold to retail customers be renewable by December 31, 2030. SB 100 (2018) accelerated this goal and requires 50 percent renewables by 2025, 60 percent by 2030, and 100 percent of electric retail sales to end-use customers and 100 percent of electricity procured to serve all state agencies to come from renewable energy and zero-carbon resources by 2045. Additional interim targets were set by SB 1020 (see Box 1).

Historically, incorporating important land use considerations has not been a priority in these processes. Increasing reliance on renewable technologies like solar, with larger footprints than traditional fossil-fuel power plants, will make such considerations more important. The California Energy Commission (CEC), as the lead agency overseeing implementation of SB 100, has begun working with relevant agencies across the state to increase coordination and to incorporate important land use considerations. To plan for and build transmission in places best suited for solar, further integration between local land use and energy system planning processes will be required. This will be especially important for places that, like the San Joaquin Valley, have significant solar potential.

Several recent reforms should facilitate the better integration of various planning efforts:
In addition, one recent policy development is likely to affect how permitting accounts for land use and other considerations. In June 2022, Assembly Bill (AB) 205 was enacted. This law gives the CEC authority (in lieu of local governments) to process and approve wind, solar, and storage projects when requested by an applicant. This applies to projects over 50 MW, as well as to related manufacturing facilities, and will last through June 2029. Qualifying projects must demonstrate specific labor benefits and a net positive economic benefit to the local government that would have had authority over the project, and must enter into a community benefits agreement with at least one local organization. The CEC must decide whether to deny or approve these projects within nine months. While this new optional permitting process could expedite some solar projects, especially in areas where local opposition is strong, its practical impact on renewables development remains to be seen.

Integrating SGMA: Identifying Suitable Lands for Solar

As energy planning processes adjust to meet the challenge presented by SB 100’s ambitious goals, groundwater sustainability agencies (GSAs) formed under SGMA throughout the valley will be developing and implementing projects and actions to reduce groundwater demand and looking for ways to do so without causing excessive local economic or environmental harm. Integrating SGMA implementation into the state’s energy and transmission planning processes will set the stage for smoother transitions from irrigated agriculture to solar farms.
Synergies between SGMA and SB 100

Although conceived separately, the goals and timelines of the Sustainable Groundwater Management Act and SB 100 present important synergies. Informed, coordinated policy implementation could benefit California's energy consumers while supporting economic stability in one of the state's most economically challenged regions. Under SGMA, most valley GSAs will need to achieve sustainable management of their basins by 2040, but projects and actions to reduce groundwater demand—mostly by idling or retiring land—will need to begin before that. Likewise, to meet a 100 percent renewable and zero-carbon electricity goal by 2045 (and a 90% goal by 2035), developments in the valley will need to be planned, permitted, and installed long beforehand.

Farmlands removed from irrigated production will not provide as many employment opportunities for the valley communities that depend upon them, and local revenue from agricultural production and property taxes may decline as well. Moreover, these lands will require alternative uses to avoid becoming sources of dust and weeds. In particular, there is a risk that even managed fallow lands could end up becoming sources of dust without coordinated and effective interventions, a major concern for the valley’s rural communities (Ayres et al. 2022).

Utility-scale solar development—if designed appropriately—could help on these fronts. It could help maintain economic returns from these lands and provide employment opportunities; projects can also contribute to the coordinated, large-scale management of dust and weeds and potentially provide some habitat benefits. We discuss the specific approaches needed to deliver these outcomes later in the report. Here we focus on the specific land use planning considerations that will be necessary to ensure solar is sited in areas that minimize risks, maximize the potential for spillover benefits, and promote expedient, low-cost solar development. Coordinating the distinct processes of groundwater management and energy planning will be critical to aid a smooth transition.

Where Should Future Solar Projects Be Built?

From a developer’s perspective, the siting of a solar project is influenced by a number of factors. These include the availability and reliability of the solar resource, the necessary permitting processes, site-specific construction and labor costs, the degree of local public support, the availability of large land parcels with limited alternative uses, and—as noted earlier—especially in the San Joaquin Valley, transmission and interconnection opportunities. Smart siting approaches will also consider some additional factors, such as the likelihood of affecting unique habitat.

Previous studies have taken up the question of where to build, each focusing on different considerations. UC Berkeley’s Least Conflict Solar Analysis from 2016 identified lands within the valley that could provide solar development opportunities with “least conflict.” These lands avoid some important habitat areas as well as prime farmland that provides foundational economic and employment opportunities for valley communities (Pearce et al. 2016). That study’s goal of avoiding putting solar on farmland may no longer be

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5. Modesto, Tracy, Turlock, and White Wolf subbasins have a 2042 deadline because they are not designated as critically overdrafted.
as relevant, however, given increasing recognition of what SGMA will mean for valley agriculture. With 500,000 or more acres slated to exit irrigated production, some fallowed agricultural lands could be ideal sites for new solar projects.

Another recent study, The Nature Conservancy's (TNC) Power of Place-West, aligns solar resource potential with high-value habitat areas—alongside some restrictions related to cultural considerations—to identify promising areas for solar and wind energy technologies throughout the West (Wu et al. 2022). Across different levels of siting restrictions, the San Joaquin Valley appears to be a key area for solar development potential in California that could proceed with minimal habitat risks. Indeed, much more land fits the bill than will likely be required to meet the state's goals. The study identifies over 1.4 million acres among the valley's irrigated lands (see Figure 3 below), while state targets might need roughly 150,000 acres by 2045 at representative rates of power density per acre.

Both of these previous studies considered a number of additional potential barriers, including tribal landholdings, Department of Defense exclusions, and others. They focused on identifying suitable areas given the high solar resource potential in the valley. But linking up appropriate parcels coming out of agricultural production in the valley with development capital will require foresight as agencies and investors direct resources toward widening the key bottleneck: transmission and interconnection capacity.

Coordinating Transmission Planning and Solar Siting

The need to build more transmission to achieve SB 100 and SB 1020 goals, along with the expected role of the San Joaquin Valley in providing solar resources, highlights some potential benefits of better integrating transmission and generation investment decisions with land use planning. It is most cost-effective to build solar near existing transmission infrastructure and, given interconnection scarcity in the valley, this is the primary driver that determines where solar is built today.

Building new transmission lines where farmland is most likely to come out of production can help to support an attractive, promising land use alternative and stabilize local economies. For this reason, decisions about which lands are fallowed to achieve groundwater sustainability can and should feed into transmission planning processes, where possible.

At the same time, decisions about where transmission is expanded can influence which lands come out of production, given the degree to which landowner returns from solar outstrip agricultural returns even today—and this is before water scarcity ratchets up in the coming decades. A framework that integrates high-level land use considerations into transmission planning processes could deliver improved regional outcomes. Based on comprehensive stakeholder involvement, it could help steer development away from ecologically sensitive habitat or areas where solar construction may negatively impact local communities (for example, by exacerbating dust issues).

To produce the best outcomes, transmission siting and land use planning efforts could share information and aim to jointly satisfy multiple objectives. Market processes related to water scarcity and land productivity largely will drive farmland transitions. Still, GSAs and county planners can identify marginal

6. This work updates a previous study, The Nature Conservancy’s Power of Place, which focused on California (Wu et al. 2019).
lands exiting production and work with other environmental permitting agencies to avoid areas demonstrated to have uniquely important conservation values. With this information in hand, statewide transmission planning can prioritize expansion in suitable areas. Planners can also identify where exceptional resource potential or other factors justify transmission expansion—and communicate these plans to inform land use managers and GSAs seeking to support water-saving land transitions.

Overlaps between Suitable Solar Lands and Projected Farm Fallowing

We present in this section a preliminary assessment of where synergy may exist in the location of suitable solar development areas and lands exiting agricultural production. We also discuss some additional policy and regulatory barriers to solar development.

Although GSAs have submitted the first round of valley groundwater sustainability plans (GSPs) with sets of projects and actions to address overdraft, they focus heavily on groundwater recharge to avoid fallowing; relatively few provide detailed plans for demand management (Hanak et al. 2020). There is still significant uncertainty about where and how GSA actions may drive land falling, and what agricultural water users will do in response (for example, by trading surface water supplies). Accordingly, it is difficult to forecast precisely which lands will be fallowed under SGMA. Companion PPIC work is producing new hydro-economic estimates of likely fallowing under a number of different water supply and water trading scenarios (Escriva-Bou et al. forthcoming); we consider here a modeled scenario with no new water supplies and no trading among water users as an illustrative example of how fallowed lands may align with solar suitability.

We couple these preliminary estimates with spatially explicit information on solar development suitability from Wu et al. (2022). Figure 3 (left panel) presents the results: there is more total area potentially suitable for solar development in the valley than projected fallowed acreage. This is also true in most subbasins, with exceptions including Modesto, where solar development potential is very low, and Tule and Kern, where expected fallowing exceeds substantial solar potential. Nonetheless, the solar suitability acreages exceed what likely would be needed to build enough solar in the valley to reach SB 100 goals (roughly 150,000 acres), and not all fallowed lands under this scenario would be suitable for solar. What is clear is that areas with extensive solar suitability, especially on the western side of the valley near existing transmission, likely will be able to take advantage of the synergies described in this report. This would include especially areas in the Kern and Tulare Lake subbasins as well as the western portions of Kings subbasin. The Westside subbasin also potentially could transition additional idled lands to solar development, although these lands primarily would not be those idled due to SGMA. The Westlands Irrigation District has already seen large tracts of land retired from production for other reasons, including over 100,000 acres of drainage-impaired lands (Hiltzik 2015).
Irrigated lands suitable for solar often exceed expected fallowing; Williamson Act contracts are common in these areas

Additional constraints to solar development in the valley

Beyond transmission constraints, several potential barriers could impede solar development in the valley at the scale that might be called for under SB 100. This includes farmland preservation provisions under the Williamson Act, small parcel sizes relative to typical solar projects, and the permitting process to avoid endangered species impacts.

Williamson Act

The Williamson Act created a state program to maintain agricultural landscapes by enabling county governments to enter into contracts with agricultural landowners (Rosser 2022). Williamson Act lands are common in the valley. Figure 3 (right-hand panel) displays the share of solar-suitable lands that are currently

**Figure 3**
**Irrigated lands suitable for solar often exceed expected fallowing; Williamson Act contracts are common in these areas**

**SOURCE:** Developed by the authors using data from The Nature Conservancy, the California Department of Conservation, and the Lincoln Institute of Land Policy's Center for Geospatial Solutions.

**NOTES:** Solar-suitable acreage reflects the total area of irrigated parcels that satisfy the suitability criteria defined in Wu et al. (2022) for “Siting Level 3.” These include resource availability requirements and exclusions for cultural and environmental land protections. Left panel: Estimates of fallow acreage reflect preliminary results from PPIC hydro-economic modeling, assuming no new surface water and no water trading. Right panel: Williamson Act-contracted land includes irrigated lands under standard Williamson Act (10-year) or Farmland Security Zone (20-year) contracts.
under Williamson Act contract: in all basins the proportion is substantial, and it exceeds 50 percent in most of them.

These contracts exchange reduced property tax rates for a 10-year guarantee that the land remains in agricultural production. Specialized Farmland Security Zone (FSZ) contracts can last for 20 years. If a landowner wishes to develop the land in a manner inconsistent with the contract and remove it from the program, he or she may either file for nonrenewal, which can take up to nine years (or 19 for FSZ lands), or he or she may request a cancellation and pay an immediate fee that offsets the tax abatements received under the current contract. Box 2 provides additional information on the Act.

**Box 2. Barriers to Solar – Building around the Williamson Act**

Since 1965, California’s chief agricultural conservation policy, the Williamson Act, has provided about half of the state’s 30 million acres of farm and ranchland with a 20–75 percent reduction in their property tax assessments (California Department of Conservation 2022). Although the state ceased providing annual subvention payments to mitigate county revenue losses over a decade ago, all San Joaquin Valley counties continue to support the program. As California farmland begins to transition to solar, there has been some debate over the compatibility of solar projects and Williamson Act contracts. As it stands, there are three ways a landowner can develop solar on their property if it is under a Williamson Act contract:

1. Cancellation: If approved by their county’s board of supervisors, landowners can cancel their contracts. A considerable fee, typically equal to 12.5 percent of the unrestricted fair market value of the property, is paid to the Department of Conservation.
2. Non-renewal: Alternatively, owners can enter non-renewal, a nine-year process that is not subject to additional fees (a 19-year process for FSZ contracts).
3. Compatible use permits: While some counties (Kern, Fresno) typically do not consider solar to be compatible with the Williamson Act, others (Tulare, Kings) do under some circumstances. In these cases, landowners maintain their existing Williamson Act contracts and associated tax benefits alongside the development of a solar project.

Some counties have designated solar development, with some caveats, as a land use compatible with the Williamson Act (and thus eligible to maintain a contract), and others have not. In Tulare County, for example, solar developments may be registered as a compatible use so long as they are located near an electrical grid and would not result in the loss of future agricultural production, among other conditions.

In areas where solar is not a compatible use, the property tax benefit that accrues to landowners under the Williamson Act would likely not dissuade them from transitioning lands to solar because the increased returns from solar production would likely exceed the tax increase. This is especially the case given changes under AB 1265 in 2011 that allowed counties to reduce the level of the Williamson Act tax reduction offered to landowners. On the other hand, in cases where the contract is cancelled—as opposed to simply not renewed—the cancellation fee may complicate project planning. Some cancellation fee payments have exceeded several hundred thousand or millions of dollars for large-scale projects, which can threaten profitability or at least make developers less inclined to build on Williamson Act lands.
In addition, it is important to note that cancellation of a Williamson Act contract is considered a project under the California Environmental Quality Act (CEQA), and thus triggers a CEQA review process led by the county. In Kern, for instance, this process requires an Environmental Impact Report (EIR). This increases uncertainty for developers because the county could find that removing the land from agricultural use has significant environmental impacts.

In sum, in counties that have declared solar a conditional compatible use, like Tulare, an existing Williamson Act contract should present limited problems. But in others, like Kern and Fresno (which both have large amounts of solar-suitable land), developers may encounter more complications.

**Fragmented land parcels and ownership**

Solar developers often need to aggregate parcels to amass the land area needed for solar projects, regardless of whether they lease or buy the land from existing owners. Especially when transmission capacity is constrained and projects must be larger to effectively finance interconnection costs, the aggregation of parcels can become an onerous—and expensive—task. Projects may range into the hundreds of acres, and in areas with grid access there is no guarantee that individual parcels with a single owner could accommodate them. The bunching of existing projects on the western side of the valley was driven in large part by available transmission capacity, but also eased by the larger average size of parcels there relative to the valley’s east side. Moving forward, areas with relatively larger parcels or consolidated ownership may present advantages for developers. Efforts to adopt solar as an alternative land use in overdrafted areas with fragmented land ownership may require other favorable conditions, such as available interconnection capacity or fewer permitting hurdles.

**Permitting for endangered species impacts**

A final barrier is the potentially onerous permitting process concerning potential habitat and endangered species impacts. Although some areas are identified as unique for ecological reasons, or are valuable because they are adjacent to existing conserved areas, a much larger share of valley lands would be suitable as habitat for one or more endangered species. (San Joaquin kit fox is one example that could be common on lands identified for solar development in the valley.) Permitting processes at multiple levels can slow the development process and squeeze project margins. Programmatic approvals for solar development could expedite the process to meet state SB 100 goals—and help avoid conflict between state agency priorities. The California Department of Fish and Wildlife could lead such efforts and make approvals contingent on a set of pre-defined on-site activities to lower risks for targeted species. Furthermore, offering “safe harbor” provisions—which allow developers, owners, and operators to provide ecological benefits on their land without fear of subsequent regulation should an endangered species occupy it—could further help to reduce project risks and encourage environmental benefits.

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7. Among the valley’s agricultural parcels, those on the west side (Delta-Mendota, Westside, and Tulare Lake subbasins) are on average approximately 60 acres, while those on the east side (Tule, Kaweah, King, Madera, Chowchilla, Merced, Turlock, and Modesto subbasins) are on average roughly 20 acres (based on 2016 Statewide Crop Mapping data).
Considerations for Ensuring Positive Local Outcomes

Building solar on fallowed lands can generate multiple benefits beyond an alternative revenue source. For instance, it can help preserve habitat, control dust, and support regional employment. Over the past decade, the solar industry has learned a lot about how to create these benefits while minimizing potential impacts.

Employment and Socioeconomic Impacts

As implementation of SGMA proceeds and some farmland is fallowed, some local agricultural jobs will be lost. Under some conditions, developing solar on these lands can generate new jobs for community members. While it is unlikely that new solar jobs can entirely replace lost agricultural employment, the potential for the industry to fill part of this gap while providing a pipeline to adjacent trades is high. In our workshops and discussions with stakeholders, we heard substantial optimism in this regard (Rosser and De Leon 2022). But to realize the employment and other economic opportunities that come with solar, a number of factors will have to align.

In the past there have been concerns about whether solar installers would hire locally. In the San Joaquin, it appears that some are. For example, the Westlands Solar Park’s first utility-scale solar project—Aquamarine—consistently employed about 350 workers on-site, the majority of whom were local to the valley. Many project installers were also first-time workers in renewables, a testament to effective coordination between project developers and workforce training efforts. Local hiring is reinforced by county permitting conditions and union contract requirements. Kern County, for instance, conditions project permits on 50 percent local hire alongside outreach and connection to local job training programs. In addition, stakeholders and developers reported local hiring requirements of up to 70–80 percent in union contracts.

Some local economic leaders have also expressed concern that the solar industry may provide short-term opportunities but not steady, long-term employment options for valley residents, limiting its direct benefit to affected rural communities. Once solar projects are built, they typically require relatively little maintenance or management (IREC 2022). Consequently, nearly all the jobs generated by solar are limited to the construction and installation period, and installers tend to move from new project to new project.

Maintaining a consistent pipeline of solar projects will be key to ensuring ongoing benefits to local workers and communities. Here, California’s ambitious renewable energy goals—which have already generated a substantial project queue throughout the valley and promise significant further development—may help create continuity of workforce demand. In addition, ongoing transmission construction and maintenance work can help support regular employment. A steady stream of construction work is extremely likely in the coming decades. Considering the average lifespan of utility solar farms is about 30 years, it is also likely that the sizable solar build-out the state has planned for the next few decades will eventually need to be replaced, prolonging these employment opportunities.

Finally, solar jobs can provide a springboard into adjacent construction trades, providing an access point to more stable and lucrative careers for valley workers. According to workforce development stakeholders, since panel installer positions are good entry-level jobs, they can help trades connect a new generation of construction and electrical workers to the necessary apprenticeship pathways and training programs.
Stakeholders also emphasized the importance of coordinating solar workforce development programs and job opportunities, so newcomers are able to hit the ground running after completing the necessary training.

However, some challenges associated with attending training programs limit the ability of new local workers to “tool up.” These include language barriers, lost wages, family and childcare obligations, and transportation constraints, among others. Transportation access in particular, both to solar jobs training programs and to construction sites, is an especially persistent barrier to linking low-income communities to these jobs. One promising way to fill these gaps is to repurpose agricultural transportation networks. Agricultural workers transitioning to the solar industry also likely will need additional, tailored training and support to develop the competencies needed to make the switch, as the two industries often require different skill sets.

Filling Fiscal Gaps

In addition to the workforce transitions described above, counties face another major risk: that large-scale retirement of agricultural lands will devalue the tax base, leading to a reduction of local county revenue. This could make it challenging to maintain current levels of county services. Solar developments present an opportunity keep land working—enhancing its value and potentially helping to fill this gap.

The extent to which solar can bolster county tax revenue hinges on the interplay between the state’s solar tax exclusion and pre-existing agricultural policies like the Williamson Act. Under California’s solar property tax exclusion, solar projects are not taxed for the value of improvements to the land that come with the solar investments. As a result, these projects currently may not generate much local tax revenue for the communities where they are built. With the recent enactment of SB 1340, this tax credit now extends to January 2027. Simultaneously, about three-fourths of all irrigated croplands in the San Joaquin Valley are receiving a 20–75 percent reduction in their property tax assessment due to Williamson Act contracts. Consequently, building solar on lands that remain under Williamson Act contracts would result in little net change in their property tax assessment, and transitioning these lands out of their contracts to develop solar would likely result in only a small increase in their property taxes. Considering this, the property tax revenue tradeoffs are not as stark as they otherwise might be on conversions from non-Williamson Act farmland to solar. It is important to note, though, that the solar property tax exclusion does not apply to battery storage, an increasingly important component of solar projects, and this could bolster county revenues.

Beyond the impacts to property tax revenue, solar developments can generate significant local sales taxes. If the procurement of project components—particularly the high-cost ones—occurs within the county where the project is being built, the sales taxes will accrue locally. To this end, counties like Inyo and Kern have been working to ensure the sales tax on equipment is paid locally rather than at the port of arrival.

8. The value of the land itself, however, may be reassessed for tax purposes when a solar developer acquires title to it, consistent with California’s Proposition 13.
Finally, there are the potential multiplier effects of maintaining some economic activity on these lands and workforce opportunities in these communities.9

**Spillovers: Air Quality and Aesthetics**

The San Joaquin Valley has some of the worst air quality in the nation, and local communities understandably are concerned about the potential impacts of nearby solar construction. However, the industry has learned a lot from the first generation of utility-scale solar, and it has matured substantially when it comes to dust management. In the past, some projects razed their sites entirely, creating significant dust. Today, best practices like maintaining groundcover and placing barriers around construction sites have become more commonplace. (In some cases, small volumes of water are also applied to contain dust.) When these techniques are implemented, solar projects can even reduce dust when compared to the land uses they are replacing (e.g., fallow and productive agriculture). Still, dust concerns may require project developers to think carefully about activities like integrating livestock grazing into their vegetation management planning, as associated land disturbances during dry periods can lead to adverse dust impacts.

While developers know how to mitigate dust, regulatory oversight appears to vary across counties, particularly in the post-construction period. Currently, dust management planning in the construction process is monitored by the local air district, but post-construction management expectations vary by county. Re-evaluating the scope of these requirements across the region could help reduce risk. The San Joaquin Valley Air Pollution Control District, for instance, might consider following the Eastern Kern Air Pollution Control District’s (APCD) post-construction air quality monitoring and dust management practices, which are required in its large-scale commercial solar permits (Eastern Kern APCD 2022).

Alongside community concerns about dust are also questions about the visual impacts of agricultural lands transitioning to an industrial use like renewable energy. Building large transmission facilities and adjacent solar fields can change the local landscape aesthetically, and this could be a growing concern in the valley as solar deployment progresses, especially if located close to communities. Some stakeholders suggested that vegetation or project barriers built to help mitigate dust might simultaneously provide visual barriers, although any such barriers will likely need to be designed not to cast shadows on the array themselves.

**Spillovers: Habitat and Soil Health**

Solar has not always been seen as compatible with habitat, but if sited to avoid high-value conservation areas and managed well, land use transitions to solar can generate some environmental benefits. Protected habitats are generally not a smart place for solar development, and the more project siting can be integrated with regional conservation goals, the better. In addition, existing agricultural landscapes sometimes provide a suite of important ecological benefits that may not be present on solar sites.

In recent years, siting efforts like TNC’s Power of Place study and UC Berkeley’s Least Conflict Solar

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9. Solar development may generate knock-on economic activity in some sectors related to maintenance and operations. At the same time, when economic activity in agriculture declines, a number of related industries—such as the processing of agricultural products and contracted on-farm services—can suffer as well. The impact on county revenues from indirect sources will depend on the relative magnitude of multipliers in these industries.
Analysis, described earlier, have helped identify some areas to avoid. Generally, siting solar on formerly irrigated croplands can pose less risk to species and habitat than on other, less disturbed lands. As agricultural lands begin to transition away from irrigated crops due to SGMA, regional planning will be critical to inform which lands are most suitable for solar versus other potential uses like conservation. Specifically, coordinating transmission investment and conservation considerations can help ensure that solar developments do not block habitat corridors that currently enable species to persist.

Tailored planning processes and coordination between regional land use planners and developers can help to avoid siting on important conservation areas. However, it is possible that some solar development will occur near or adjacent to important habitat lands. In these cases, implementing habitat management practices on lands where solar is sited can further mitigate harm.

Design elements such as planting certain types of ground cover can restore local soil health, and this is becoming a standard best practice. On-site design elements can also support local wildlife. For example, the California Valley Solar Ranch (CVSR)—a 250-MW solar project in the Carrizo Plain—converted about 4,700 acres of formerly farmed land into a solar project. Because it was developed on habitat for endangered species like the San Joaquin kit fox and giant kangaroo rat, project developers were required to purchase surrounding lands for conservation as well as integrate design elements to protect species; some evidence suggests that these on-site measures were effective in mitigating impacts to sensitive species (Cypher et al. 2021). However, these measures have costs for developers and may not be undertaken unless required by regulatory agencies or supported with public funding. Avoiding critical habitat areas from the outset is one way to reduce conflict and the need for expensive measures. In addition, workshop participants proposed incentivizing these types of practices by encouraging regulators to include wildlife provisions in a streamlined permitting process.

Leveraging Benefits from Energy and Groundwater Sustainability: Opportunities for Action

Currently, planning processes for statewide energy development and local land use take place at very different scales, and coordinating their goals and analyses can help to ensure that their outcomes are complementary. Effective development of solar energy in the San Joaquin Valley will depend on linking planning processes across various levels of government and better integrating consideration of local impacts—such as dust emissions control and employment opportunities. Doing so can help soften the economic and environmental costs of these land transitions and pave the way for smoother solar development experiences. Coordinated planning will primarily require action from state and local agencies—and some efforts are already underway. Meanwhile, solar developers—alongside unions, the regional air district, and community advocates—can all play a role in making sure local areas benefit. Below we lay out some priorities for new and ongoing actions.

Integrate Energy and Land Use Planning

Currently, the California Independent System Operator (CAISO) and Public Utilities Commission (CPUC) undertake energy planning to ensure electricity reliability and meet state goals, in coordination with the
California Energy Commission (CEC). Utility-scale solar energy requires significant amounts of land, but deliberate land use considerations have not featured prominently in past energy planning efforts. This is due in part to the workload and cost required to source reliable on-the-ground information. Efforts to coordinate these processes better with local land use plans and authorities can yield smoother development experiences for solar firms, reduce uncertainty for state energy planners, and take into account opportunities and tradeoffs across a broader suite of potential project benefits.

- **Further support linkages between state energy and local land use planning.** The CEC has begun formal efforts to collect relevant environmental and land use information from regions expecting renewable energy development, including the San Joaquin Valley. Integrating this information in joint planning processes with the CAISO and CPUC will likely prove valuable, as will new CEC funding to improve the coordination of state energy planning with local land use planning regarding energy storage, energy generation, and transmission projects. In addition, solar developers and industry associations should promote research and planning processes to advance the integration of energy and land resource planning at the state and local levels.

- **Identify promising lands for low-impact solar development.** Which lands come out of irrigated production will depend in large part on market adjustments to the policies adopted by GSAs and other local agencies on groundwater extraction and water trading. At the same time, counties and GSAs can take the lead in identifying promising solar development areas within their jurisdictions, based on how best to avoid loss of meaningful habitat and disruption to local communities.

- **Coordinate to leverage the CEC’s new project approval authority.** The CEC and local land use planning entities can coordinate how best to leverage the CEC’s new authority under AB 205 to grant approval, upon request by applicants, for larger renewable energy projects. Up-front work by local land use entities to identify lands that are most and least suitable for development within their jurisdictions could help to facilitate this process.

- **Clarify rules around solar on Williamson Act lands.** County governments should clarify rules around Williamson Act compatibility where they have not already. In some areas, solar developments may not be deemed eligible for standard contracts under the act, but county boards of supervisors can permit “open-space” contracts with similar provisions. In some cases, counties also should consider waiving cancellation fees when a parcel loses water access for reasons outside the owner’s control. This could include clarifying whether GSA projects and actions that reduce groundwater access would satisfy the relevant criteria developed by the county.

### Develop a Workforce Pipeline

Solar developers and trade union representatives have already crafted acceptable local labor requirements for some projects in the valley. Continued efforts here can help to ensure that the looming expansion of solar development provides employment opportunities that are sustained and can support economic vitality over the longer term—and that solar developers have access to a ready and experienced local workforce.

- **Design suitable training and outreach.** Solar developers, unions, community colleges, community-based organizations, state agencies, counties, and other local leaders can aim to design comprehensive training and outreach programs across the valley to help prepare the workforce.

- **Improve access for low-income residents.** Improving access to both training and worksites for low-income residents can bolster awareness, retention, and effectiveness. Over the long term, establishing pathways for former agricultural workers to enter the industry should be a priority, where possible.
Support Integration of Spillover Benefits

It should be a top priority to ensure that solar development to meet state renewable electricity goals does not produce undue environmental burdens in the region. This is especially important because some valley communities already experience notable environmental quality problems.

- **Seek multiple benefits on solar lands.** Solar developers should continue to experiment with new ways to provide multiple benefits on transitioning lands (water savings, habitat, air quality mitigation) as part of new projects. They should extensively document their successes and challenges. Local and regional entities, such as the San Joaquin Valley Air Pollution Control District, can support monitoring and improved management for these sorts of spillovers.

- **Consider state support for spillover benefits of solar projects.** State agencies especially should evaluate the scope for funding support to advance multiple benefits on solar developments for SGMA. The Department of Conservation’s Multi-benefit Land Repurposing program is one place to start.

- **Simplify permitting for solar projects.** In addition, state agencies can simplify solar development permitting. This will facilitate the state’s transition to a renewable energy system by developing programmatic approvals for utility-scale solar projects in the valley. In particular, areas with existing transmission capacity and areas where transmission capacity is likely to be expanded should receive attention. Such an effort may require dedicated funding to ensure new programs are adopted in a timely fashion, given the need to permit and develop transmission and generation infrastructure quickly to meet state energy targets.

**Conclusion**

Meeting the requirements of SGMA will bring many changes to the San Joaquin Valley. Reduced groundwater availability will cause landowners to search for new uses for formerly irrigated lands and prompt communities to consider alternative development trajectories. At the same time, California has set ambitious zero-carbon electricity generation targets for itself under SB 100, and the valley is likely to play an important role in providing clean solar energy in the future. The pace of the necessary transmission and generation build-out to meet these targets is daunting, in part because it will require identifying, acquiring, and permitting the right lands very soon. Coordinating the relevant water, land, and energy policies presents major challenges, but successfully addressing them together can support a vital agricultural region in transition while also providing efficiency and cost benefits for energy consumers statewide.

To make this work, greater planning integration between levels and sectors of government—with input from solar developers and local communities—is needed. State energy planning processes can become less reactive and more proactive, in particular when it comes to understanding local land use constraints and opportunities. Likewise, counties and other permitting agencies can undertake efforts to identify promising areas for solar, permit them programatically, and communicate this to other levels of government. Solar developers can continue supporting local training programs, which will help local communities adapt to reduced agricultural activity. Finally, affirmation from state leaders that the valley is an attractive place for solar development, and important for state energy goals, will help keep things on track.
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